AN ABSTRACT OF THE THESIS OF

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Title: Determining Options for Agroforestry Systems for the Rehabilitation of Degraded Watersheds in Alemaya Basin, Hararghe Highlands, Ethiopia.

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Deforestation, accelerated soil erosion, and land degradation are serious problems in Ethiopia. The uncontrolled removal of natural forests, demographic pressures and cyclical drought has aggravated the situation, resulting in massive environmental degradation and a serious threat to sustainable agriculture and forestry. To overcome these problems efforts have been made to launch an afforestation and conservation program; however, success to date has been limited.

Thus, the main objective of this study is to find the reasons for lack of success in tree planting in the Alemaya Basin both from biophysical and socio-economic perspectives. And, based on this analysis, to propose an alternative strategy for agroforestry for the Basin.

The study has identified and characterized major land uses, socio-economic constraints and agricultural and forestry practices which have limited forestry development in the Alemaya Basin. To gather the necessary information for the study, existing information sources were reviewed. Two stage sampling was used for a land-use survey, and stratified random sampling for the socio-economic study.

Decrease in farm size due to population increases, soil erosion, shortage of fuelwood and fodder for livestock and lack of appropriate extension service were found to be the major problems that affect sustainable production in the Alemaya Basin.

Agroforestry is one of the appropriate technologies to overcome some of the problems faced by the farmers in the Alemaya Basin. The study proposed a desired state of sustainable agriculture and forestry for the Basin based on population projections, agriculture and forest products needs, and stable or improved living standards for a 20 year planning period. Alley cropping with and without fertilizers was identified as a promising agroforestry technology. Its economic feasibility was assessed by estimating costs and returns both for traditional farming and alley cropping.

Determining Options for Agroforestry Systems for the Rehabilitation of Degraded Watersheds in Alemaya Basin, Hararghe Highlands, Ethiopia

by

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TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

DETERMINING OPTIONS FOR AGROFORESTRY SYSTEMS FOR THE REHABILITATION OF DEGRADED WATERSHEDS IN ALEMAYA BASIN, HARARGHE HIGHLANDS, ETHIOPIA

1. INTRODUCTION

Ethiopia is facing rapid deforestation and degradation of land resources. Extensive forest clearing for agriculture, overgrazing, and exploitation of forests for fuelwood and construction poles has reduced the forest area of the country from 40 percent a century ago to an estimated 3 percent today. The current rate of deforestation is estimated to be 200,000 hectares per year. It is estimated that fertile top soil is lost at a rate of one billion cubic meters per year (FAO, 1981), resulting in a massive environmental degradation and serious threat to sustainable agriculture and forestry.

Although the government, through the Ministry of Agriculture and with the help from the external donors, has made efforts to overcome these problems by launching an afforestation and conservation program, success in this work has been limited. This problem is one of the major obstacles for the development of forestry programs in Ethiopia. The current practice in tree planting is also characterized by low rates of tree survival, estimated to be less than 20 percent (Uibrig, 1989; Gamachu, 1990).

Agroforestry which integrates trees into the farming system with less competition for land between crops and trees has been found a promising land-use system to alleviate problems of soil erosion and land degradation. It also provides fuelwood and fodder for the farm household. This has been well documented in the literature by the International Center for Research in Agroforestry (ICRAF), International Institute of Tropical Agriculture (IITA) and others.

The main objective of this study is to find the reasons for lack of success in the tree planting program in the Alemaya Basin, Hararghe highlands, Ethiopia both from biophysical and socio-economic perspectives. And, based on the analysis of the study, to propose an alternative strategy for agroforestry for the Basin.

The study identifies and characterizes major land uses, agriculture and forestry practices, and socio-economic constraints which have limited forestry development in the Alemaya Basin. The study also analysizes the economic feasibility of the proposed technologies, including projecting population and living standards for the Basin through time.

This research is based on a survey of (1) land-use, (2) agriculture and forestry practices,and (3) socio-economic activities in the Alemaya Basin. The land-use and agriculture and forestry surveys assessed or sampled the traditional farming and tree planting practices in order to understand how people of the Basin function, and also assessed opportunities to alleviate the problems thus identified. The socio-economic survey was undertaken to determine farmers attitudes toward tree planting, also with a view toward identifying alternative solutions to the deforestation problems.

Among the socio-economic factors and variables considered, which could affect farmers decisions towards tree planting, were the following: household food security, household income, family size, farm size, forestry extension, forestry policy, and land and tree tenure, in the study area.

Despite these problems and their severity in some parts of the country, it is probable that Ethiopia as a whole has an adequate resource base to support its present population provided appropriate natural resource management practices are developed. Appropriate implementation of agroforestry practices may reverse the degradation trend and enhance living standards.

Moreover, this study also attempts to develop a hypothetical desired state of sustainable agriculture and forestry for the Basin. This has been done based on the projections of the population, living standards, agriculture, livestock and forest production. The projections are developed from the existing data bases in the country, with due consideration for emerging government policies and new technical opportunities available through research.

In conclusion, based on the identified land-use types, land use and tree planting constraints, and also from the projections above, the study has explored in depth the contributions that agroforestry can make in achieving those ends. Thus, the study has identified appropriate agroforestry technologies, and recommended tree species and their management practices. It has also made recommendations for implementation by estimating: the number of seedlings required, the investment requirements, number of trees to be planted, the cost incurred for planting and maintenance of trees and training and extension requirement.

Finally, the study addresses the technical constraints and opportunities, institutional and social problems, and uncertainties that can hinder the practical implementation of the recommendations. Also, suggestions are made for areas of future research.

It is important to consider the present socio-political conditions of Ethiopia when trying to use the results of this study. At present, the country is in a state of political transition from a socialist-oriented government to a democratic government. During this process, a number of policy changes were made and a free market economic policy was chosen to guide the country's future development. Thus, caution is needed in using the results of this study, which is based on survey results and information prior to the government change. However, the methodological approach to the problem and analytical tools used in this study are still valid.

2. BIOPHYSICAL CHARACTERISTICS OF ETHIOPIA AND THE ALEMAYA BASIN

2.1. LOCATION

Ethiopia is situated in the horn of Africa. It has an area of 1,223,000 square kilometers, extending from latitudes 3^0 N to 18^0 N and from longitudes 33^0 E to 48^0 E. Ethiopia is bordered on the west by the Sudan, to the south by Kenya and to the east and south-east by the Republic of Djibouti and Somalia, respectively (Fig. 1).

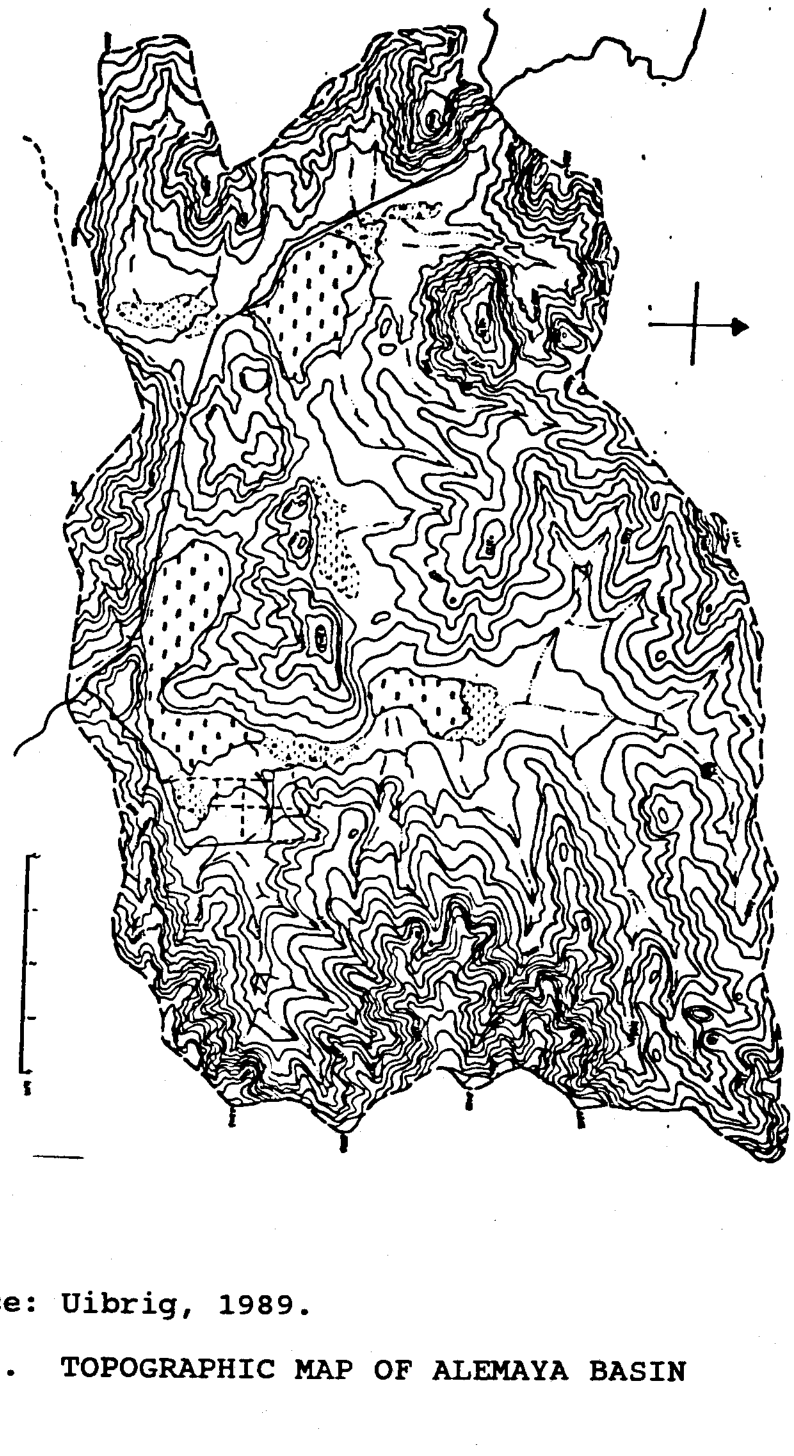
The Alemaya Basin is found in the Hararghe Highlands, at latitude 9^0 26′ North and longitude 42^0 03′ East. and has a total land area of approximately 20,000 ha, which is about 0.5 percent of the Hararghe region (Uibrig, 1989). It represents one of the most severely eroded and densely populated land areas in the region. It also typically represents the Hararghe highlands with all its physical, ecological and social characteristics (Fig. 2).

2.2. TOPOGRAPHY

Ethiopia is a country of great geographical diversity with high and rugged mountains, flat-topped plateaus, deep gorges, river valleys and rolling plains. Altitudes range from the highest peak at Ras Dejen, 4,620 meters above sea level, to the depression of the Kobra Sink, about 110 meters

Source: Gamachu, 1990.

Fig 1. ADMINISTRATIVE REGIONS OF ETHIOPIA



Source: Uibrig, 1989.

Fig 2. TOPOGRAPHIC MAP OF ALEMAYA BASIN

below sea level. Over the ages, erosion, volcanic eruptions, tectonic movements and subsidence have continued to accentuate the unevenness of the surface. Numerous streams which are the tributaries of the major rivers, such as the Abay (Blue Nile), Tekeze, Awash, Omo, Wabe Shebele, and Baro-Akobo have dissected the valleys. The great Rift Valley separates the western highlands from the south-eastern highlands, and on each side these highlands give way to vast semi-arid lowland areas in the east and west, and, especially, in the south of the country (EMA, 1988).

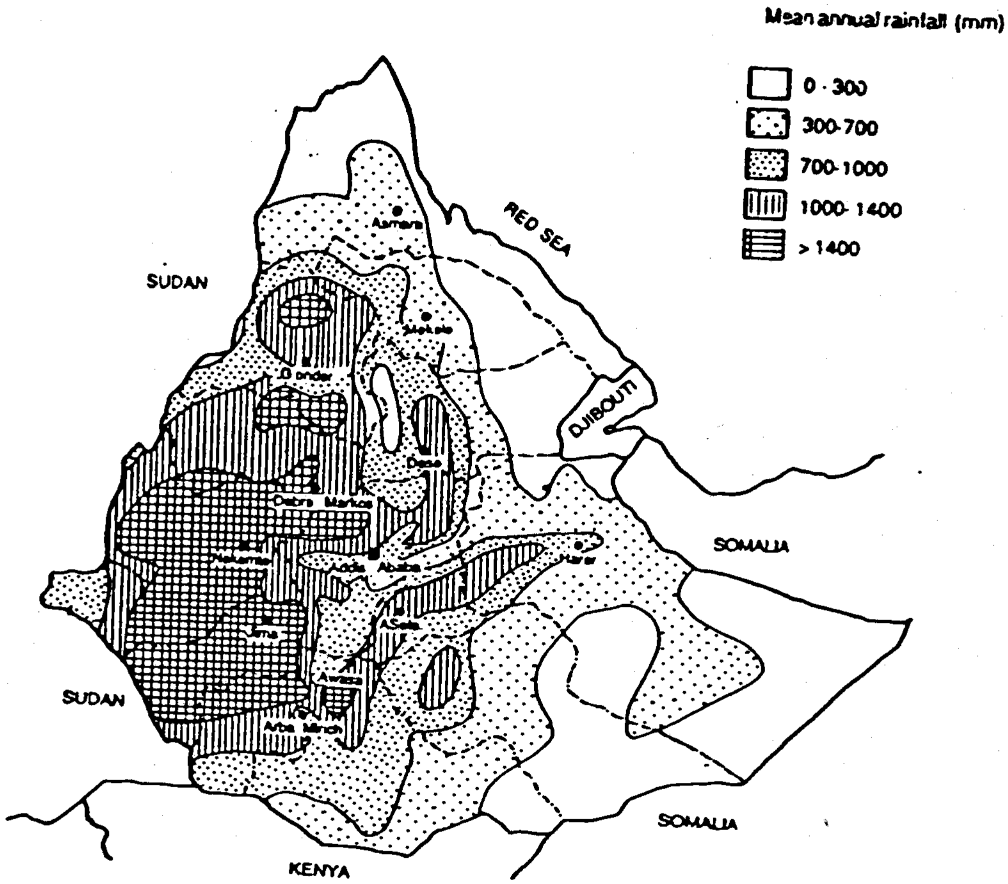
Alemaya Basin topography has been characterized as flat to undulating, where approximately 54 percent of the land area is on flat to gentle slopes (0-7 percent), 36 percent on moderate to gentle slope (8-30 percent) and the remaining 10 percent on steeply sloping area (31+ percent). The Basin has an altitude range of 1800-2200 meters above sea level.

2.3. CLIMATE

Ethiopia has a variety of climates which contributes to highly diversified forest plant and wildlife communities. The high plateau has a temperate climate with an annual average temperature between 16 and 20 degrees celsius. The lowlands have a hot climate with arid tropical conditions. The lowland plains in the north and the east have a mean annual temperature between 20 and 29 degrees celsius.

There are generally two rainy seasons in Ethiopia. The main rainy season, "KIREMET" (Ethiopian winter), extends from June to the end of September. Humidity during this period ranges from 20 percent in the north to 89 percent in the southwest. Generally, rainfall increases from 200 mm in the north and eastern plains to 1600 mm in the southwest. (Fig. 3). The "BELG"(little rains) occurs from February to April and last about six weeks, generally localized and very variable in intensity and duration. Forests thrive better in the south and southwest where heavier and better distribution of rainfall are combined with deep loamy soils.

In contrast to most of Ethiopia, the Hararghe highlands experience a single rainy season from March to September (inclusive) with two peaks, one in April and one in August. The "little rains", from March to June, are often unreliable, especially at elevations below 2,000 m. asl. Two crops are grown in the higher elevations before the onset of the long dry season from October to March each year (Poschen, 1987, Bishaw et. al., 1988).



Source: Hoekstra et.al., 1990.

Fig 3. MEAN ANNUAL RAINFALL ETHIOPIAN HIGHLANDS

The Alemaya Basin is characterized as dry sub-humid tropics, with an average rainfall of 870 mm per year and annual mean temperature of 15.8 ^{0}c, with an extreme minimum of -4 ^{0}c and extreme maximum of 29 ^{0}c (Hawando, 1982).

2.4. GEOLOGY AND SOILS

Geologically, Ethiopia is based on the Precambrian (more than 600 million years old) crystalline basement system underlying most of Africa. This basement is dominated by various schists, gneisses and granites which are exposed in areas where erosion has been intense, particularly along plateau fringes in the northern, western and southern parts of the country. Sedimentary limestones and sandstones several meters thick were deposited over this basement foundation when the sea engulfed the country from the southeast some 100-200 million years ago. Over nearly half of the country, these sediments were capped by successive flows of lava, composed mainly of basalts, which accumulated to a thickness of several thousand meters in some areas. The period of intense volcanic activity coincided with the formation of the Rift system. Evidence of volcanic activity is still to be found in the form of a few live volcanoes and numerous hot springs (Constable, 1985).

The geology of Alamaya Basin consists of Precambrian granite and, in many places the more recently formed sandstones and limestones overlie this material. According to Uibrig (1989) granite under lies about 60 percent of the surface parent material of the Basin. The area covered by sandstone is estimated to be 28 percent while limestone accounts for 9.7 percent and diorite only 1.4 percent. The alluvial material of several meter thick layers is attributed to the long period of intensive soil erosion.

The soil resources of Ethiopia have been studied in some detail in recent years and a draft provisional soil association map became available in 1984 (FAO, 1984a). Some studies on the fertility status of the soils of Ethiopia have also been complied by Murphy (1968).

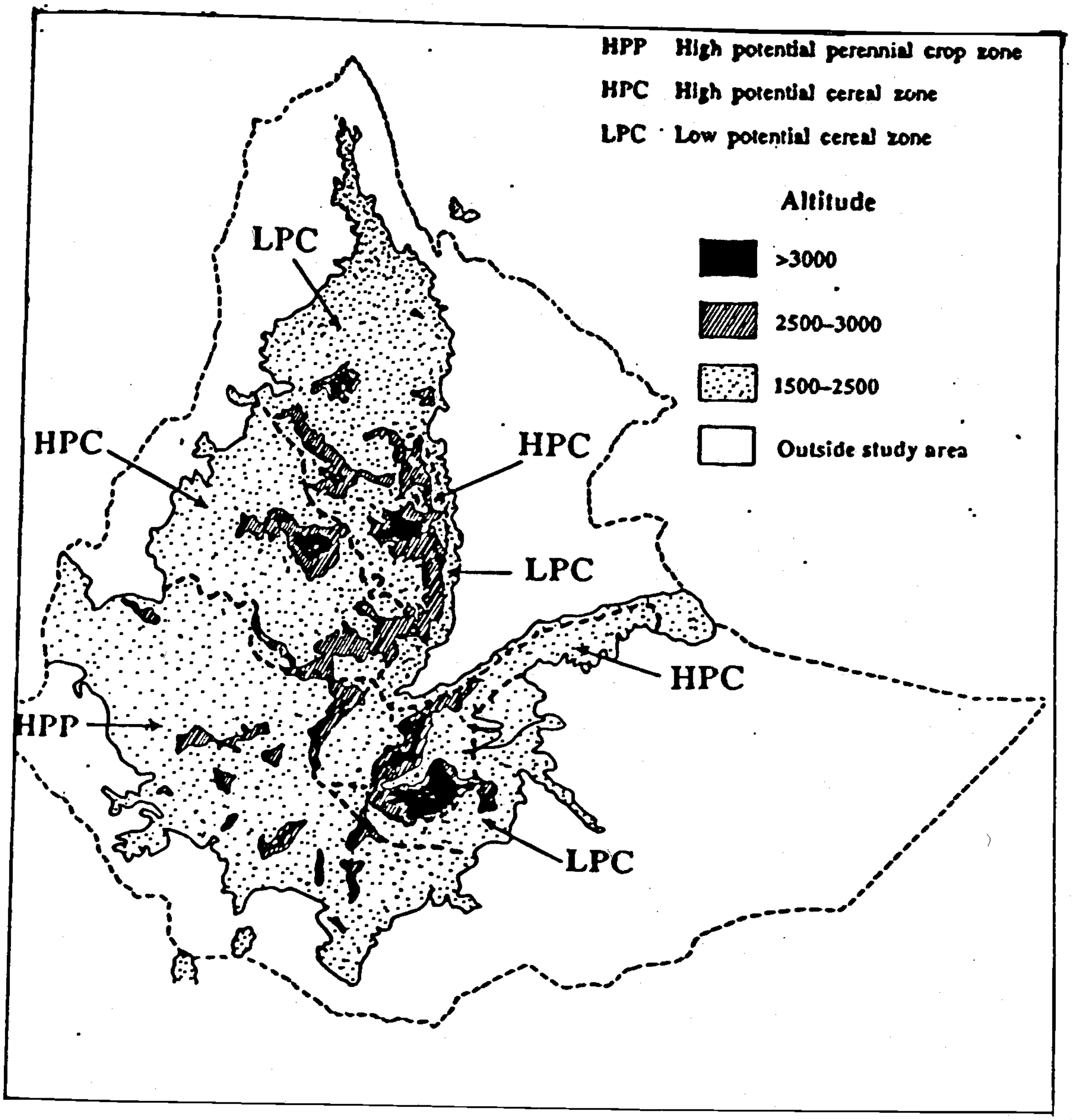
The wide range in climate, topography, parent material and land use have resulted in widely varying soils in different parts of the country. Soils are very shallow and infertile in some parts of the Hararghe highlands due to water and wind erosion. In many places, truncated sub-soils are exposed on steeper slopes. In general, there are six major soil types in the Alamaya Basin (Hawando, 1982). These are : lithosols (entisols); regosols (entisols); nitosols (alfisols); cambisols (inceptisols); fluvisols (entisols and inceptisols); and vertisols (Grumisols).

According to Uibrig (1989), lithosols and regosols cover more than 50 percent of the Basin and show the advanced stage of soil weathering through erosion. Cambisols are good quality agricultural soils, and cover about 25 percent of the Basin. Fluvisols account for about 17 percent of the study area and are preferable for agricultural use. Vertisols, which are difficult to manage, prevail in a small area only (1 percent). Rendzina over limestone is considered a very productive soil and accounts for about 6.5 percent of the Basin. The soil reaction is about neutral with the exception of limestone areas where alkaline reaction occurs.

2.5. ECOLOGICAL ZONES AND LAND USE SYSTEMS

The country has a wide range of agro-ecological zones reflecting the wide variation in rainfall (both quantity and distribution) temperature, altitude, topography and soils.

According to the study made by Getahun (1978) and Constable (1985), three broad major agro-ecological zones are identified on the highland zones of Ethiopia (Fig. 4 and Table 1). These are the High Potential Perennial Crop Zone (HPP-Zone); High Potential Cereal Zone (HPC Zone); and the Low Potential Cereal Zone (LPC Zone). Agroecologically, the Alemaya Basin is situated within the High Potential Cereal Zone (HPC Zone).



Source: Hoekstra et.al., 1990.

Fig 4. MAJOR AGROECOLOGICAL ZONES ETHIOPIAN HIGHLANDS

Table 1. Major agro-ecological zones of the Ethiopian highlands

Zone	Climate	Growing period (No. of days)
High potential Perennial zone (HPP)	Warmer and more Humid	Mainly > 240
High potential cereal zone (HPC)	Intermediate rainfall	Usually > 180
Low Potential cereal zone (LPC)	High variability Occasional drought	Mainly 90-150

Source: Hoekstra et.al., 1990.

The FAO's concept of growing periods was used to classify the land-use systems into distinctly different agricultural potentials. This growing period concept takes into account the influences on plant growth not only of precipitation and evapotranspiration, but also temperature and stored soil moisture. However, it is broadly defined here as the number of days in a year in which plants can grow without irrigation.

According to the land-use classification for the Ethiopian highlands by the Technical Committee for Agroforestry in Ethiopia, (Hoekstra et. al., 1990) the Alemaya Basin is characterized as intensive mixed cereal-livestock farming, with flat-undulating terrain, where most of the Agriculture is practiced on moderate to gentle slopes.

3. THE ETHIOPIAN SETTING: A LITERATURE REVIEW

The review in this chapter is to give an overview of the present status of land-use, forestry and agricultural practices in Ethiopia. It also provides information on the demographic, socio-economic and political conditions of the country. This background gives a general understanding to the physical and socio-political environment of the country at present. Furthermore, relevant agroforestry practices and experiments are reviewed to set the stage for the study in the subsequent chapters.

3.1. LAND-USE AND NATURAL VEGETATION

3.1.1. LAND-USE

Information on land-use types and their distribution in Ethiopia was very scant until very recently. A land use and land cover map was produced for the whole country at a scale of 1:1 million using LANDSAT imagery under the FAO "Assistance to Land Use Planning", project. Prior to this there was no systematic basis for the estimation of land use areas. The FAO study identified 5 major classes of land use and 12 vegetation cover types (FAO, 1984). The distribution of land under different kinds of uses are shown in table 2.

Table 2. Land-use and vegetation in Ethiopia

Land-Use	Area (ha)		% of the country	
1. Cropped land	18,487,190		14.8	
1.1. Annual crops		16,413,140		13.1
1.2. Perennial		2,074,050		1.7
2. Grazing and browsing land	63,725,700		51.0	
3. Forest, woodland, Bushland, Shrubland	14,608,990		11.7	
3.1. Forests		4,473,520		3.6
3.2. Others		10,135,470		8.1
4. Currently unproductive land	4,719,740		3.8	
5. Currently unutilizable land	23,292,380		18.7	
Total	124,834,000		100.0	

Source: FAO, 1984.

The diversity of the rural economics is reflected in the land-use patterns. The most recent figures, which are based on Landsat data obtained during the 1970s, show that at that time over half of the country was grazing and browsing land with only 15 percent under cultivation. The limited area of forest, 3.6 percent, reflects the considerable deforestation which has occurred over the centuries (Table 2).

Of Ethiopia's 124 million hectares, some 44 percent is classified as highlands above 1500 m where approximately 88 percent of the population is found. The highlands also contain over 95 percent of the regularly cropped areas and around two-thirds of the livestock. It is estimated that 90 percent of the country's economic activity and gross domestic product are generated from these highlands (Constable, 1985).

In contrast, the lowlands cover 56 percent of the nation's land area but include only 12 percent of the population at a density of less than 10 persons per square kilometer and contributes only 10 percent towards the country's economy.

The natural resources of the country remain very important today given the predominance of agriculture as the livelihood of 85 percent of the population. To improve the standards of living in the rural area, increased production from natural resources is required. This is necessary both to improve living standards and also to permit capital accumulation.

However, in many parts of Ethiopia, the natural resource base is currently being degraded. This is leading to lower levels of production and a deterioration in standards of living which threaten the survival of millions of rural dwellers (Wood 1990 ; Gamachu, 1990).

3.1.2. FORESTS AND FORESTRY PRACTICE

3.1.2.1. Forest Resources of Ethiopia

High forests, either coniferous or broadleafed, were the climax vegetation of 35 - 40 percent of Ethiopia before human settlement took place. With the inclusion of savanna woodlands some 66 percent of the country was covered with forest or woodlands at that time. Over the last 5000 years, there has been progressive deforestation which has accelerated tremendously during the last century as the country's population has grown (Wood, 1990).

Different sources indicate that about 35 - 40 percent of the country's land area was covered with high forests at the turn of the 19th century (Britenbach, 1961). However, rapid population growth (3 percent per year), extensive forest clearing for cultivation and over-grazing, movement of political centers, and exploitation of forests for fuelwood and construction materials without replanting has reduced the forest area of the country to 16 percent in the 1950's and 3.1 percent in 1982 (UNEP, 1983). Further estimates of the distribution of forest and woodland areas made on the basis of information from LANDSAT imagery (1979) revealed that 2.8 percent of the land surface is under forest and woodland (Kuru, 1990; MOA, 1991; Table 3).

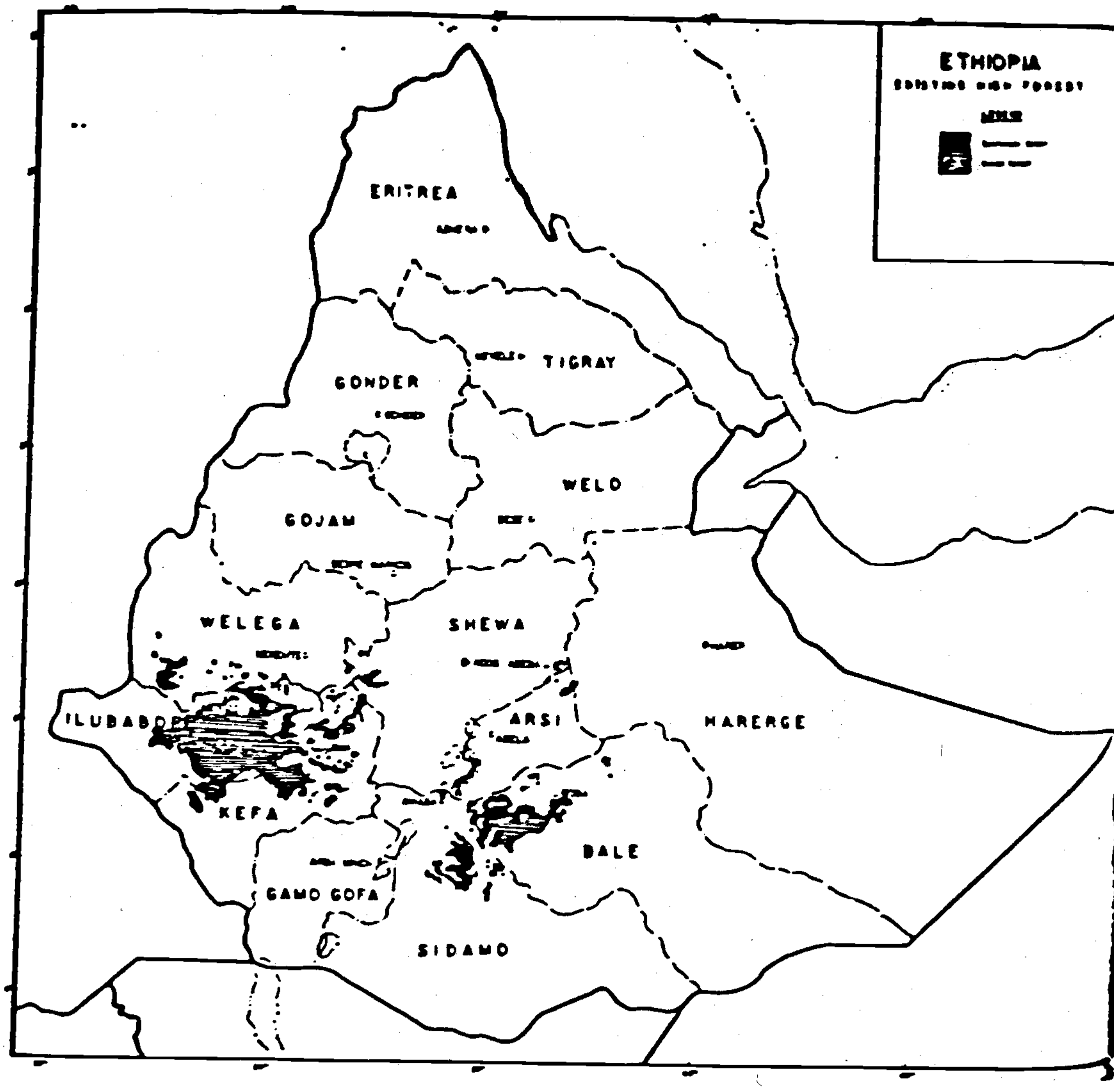
Table 3. Present (1990) Natural Forest Vegetation Coverage of Ethiopia

Vegetation Type	Area in million Ha	Coverage in percent
High forest	3.44	2.8
Riverain and mangrove forests	1.30	1.1
Bamboo woodlands	0.45	0.4
Mixed Deciduous	2.50	2.0
<u>Acacia</u>-<u>Boswellia, Commiphora</u> spp., including Wooded Grasslands	20.00	16.0
Sub Total	27.69	22.3
Other Lands	92.31	77.7
Totals	120.00	100.0

Source: Ministry Of Agriculture, 1991.

The current rate of deforestation is estimated to be 200,000 hectares per year. As a result large areas of the country are now exposed to heavy soil erosion. It is estimated that fertile top soil is lost at a rate of 1 billion cubic meters per year (FAO, 1981, Constable, 1985), resulting in a massive environmental degradation and serious threat to sustainable agriculture and forestry.

Most of the present forest is located in the southwest and central parts of Ethiopia (Fig. 5). It is also estimated that open savanna type of woodlands dominated by <u>Acacia</u> species cover more than 20 million hectares. These lands are used for grazing and crop production, while the trees are used for local fuelwood and charcoal production.



Source: Ministry of Agriculture, 1991.

Fig 5. FOREST COVER MAP OF ETHIOPIA AT THE END OF THE 1970'S

In addition to the natural forest cover, there are about 162,000 hectares of plantation forest and about 36,000 hectares of periurban fuelwood plantation. These are managed by the state, and Eucalyptus spp. are the main plantation species (MOA, 1991).

As might be expected in a country with such wide variations in climate, topography and soils, Ethiopia is one of the few countries in Africa where virtually all major types of natural vegetation are represented, ranging from thorny bushes to tropical forests and to mountain grasslands. The number of native flora species has been estimated at over 10,000, while more than 50 different botanical plant communities exist (Money, 1961).

Little of the natural vegetation of the highlands remains today except for south and southwestern parts of the country. The influence of man and his domestic animals has profoundly altered both the vegetation and the landscape. Ecological degradation, including deforestation and erosion, is widespread, particularly in the northern and central highlands. Though not as severely degraded, the southern parts of the highlands are being increasingly affected.

3.1.2.2. Present Forestry Development

Ethiopia's forest resource conservation, development and utilization today is not the product of a long evolving process in which different land-use planning measures have been devised and used to meet changing needs and various ecological conditions of the country. The absence of sound and comprehensive land-use polices encompassing the identification, selection and appropriation of suitable areas for forestry development based on production and environmental protection is the outstanding forestry problem in Ethiopia (MOA, 1990).

Despite this major problem, however, massive soil conservation and afforestation programs have been going on in Ethiopia since the early 1970's. These programs are undertaken by various agencies of the government through the assistance of many international and bilateral organizations. The three most important governmental and international organizations involved in soil conservation and afforestation programs are described below (Gamachu, 1990; Hurni, 1990).

The first organization is the Community Forests and Soil Conservation Development Department (CFSCDD) of the Ministry of Agriculture. It is the main government agency involved in the planning and execution of soil conservation measures and afforestation programs. The Department is involved in three main activities: farm forestry, community forestry and soil conservation.

In farm forestry programs, peasants are encouraged to establish small private plantations around their homes - usually various species of eucalyptus. The community forest programs provide technical and financial support in the establishment of nurseries and the planting of seedlings. The soil conservation unit is involved with terracing and other soil protection schemes. The CFSCDD has 109 forestry and soil conservation professionals with M.Sc and B.Sc educations and 608 technicians with diploma and certificate. In all its programs, the Department works directly with the Peasant Associations (PAs) who provide labor.

The State Forest Conservation and Development Department (SFCDD) of the Ministry of Agriculture is the second agency and is involved in the establishment, management and protection of National Forests and in the rehabilitation of degraded forests as a source of industrial wood. It is also involved in the establishment and management of fuelwood in rural areas and around urban areas. The SFCDD has 82 professionals with M.sc and B.Sc education and 258 technicians with diploma education. The Department also uses paid laborers for field work.

The remaining natural forest areas of the SFCDD are located primarily in the south and southwest of the country. High forest in these areas have been identified and efforts are being made to conserve, protect and manage these resources on a sustained yield basis. However, at present, accessible high forest areas are exposed to the various development project pressures, including coffee-and tea-cash cropping, human resettlement, grazing and logging operations (MOA, 1990).

Due to the immediate significance and the long-term impact of these problems, efforts have been made to identify the remaining high forest and designate them into 57 National Forest Priority Areas, covering 3.5 million hectares. However, the proper protection and management of these National Forest Priority Areas is questionable because of the lack of clear and efficient forest policy.

The third organization is World Food Program of the United Nations. It has been involved in and has continued to support soil conservation, afforestation and small scale irrigation projects in Ethiopia since the mid-1970's. Its assistance is mainly in the form of Food for Work programs in which peasants who come to work on the projects are provided with grain and vegetable oil.

Through the efforts of these organizations and others, between 1976 and 1985, a total of about 600,000 kilometers of soil and stone bunds were constructed on cultivated land;

about 470,000 kilometers of hillside terraces were built for afforestation of steep slopes; 500 million tree seedlings were planted; 80,000 hectares of land with steep slopes (over 60 percent) were established as "area closures" for natural regeneration; thousands of kilometers of checkdams in gullies on farmlands and rural roads were built; and by 1985 the total annual input into soil conservation and afforestation programs reached 40 million U.S dollars, excluding the substantial voluntary work inputs by peasants (Gamachu, 1990; Hurni, 1990).

Various documents of the CFSCDD indicate that by September 1986 close to 500,000 hectares of farmland and 175,000 hectares of hillside has been terraced and 181,000 hectares of land has been afforested by the community Forestry Program throughout the country. Although the achievements have been impressive, it has been reported by the CFSCDD that soil conservation and afforestation activities have declined over the years and the enthusiasm manifested in the early years of the programs seem to have failed in recent years.

The problems seem to be related to disincentives among peasants for soil conservation measures and afforestation programs. These activities, although part of a "development package" are not seen to ensure an immediate return to the peasants. The activities take some land out of production and place more pressure on existing farm and grazing land. This is particularly the case in northern Ethiopia where there is a shortage of agricultural land. Peasants are also required to provide their labor and time for activities which, from their point of view, do not generate immediate benefits.

Moreover, in the use of community forests, in particular, there is no clear legal basis for determining ownership. Farmers tend to assume that the forests belong to the State. The fact that even the small plantations around their dwellings are partially confiscated by the PAs is likely to produce further disincentives to plant or once planted to manage and protect the trees. Also, the massive national soil conservation and afforestation efforts between 1976 and 1985 (Gamachu, 1990; Hurni, 1990) are often seen as government-imposed activities, and since they are not accompanied by education, the advantages of these efforts are not associated with individual benefits.

3.1.3. CROP PRODUCTION AND SOIL EROSION

Favorable climatic and ecological conditions, sufficient rainfall, moderate temperatures, and well developed soils - were the basis for the early development of agricultural systems in Ethiopia (Hurni, 1990). A range of rural economies have developed, varying from highland animal rearing, to mixed farming systems and pastoralism (Wood, 1990).

Many of these farming systems were quite sophisticated and well adjusted to environmental conditions so that they permited permanent cultivation and settlement. However, agriculture gradually expanded from gently sloping land in the highlands onto the steeper slopes of the neighboring mountains on the one hand, and into the flat swampy plains of the plateau on the other. The clearing of forests for cultivated land and the attendant accelerated soil erosion gradually destroyed the soil resource, especially in the areas of the highlands that were settled first (Hurni, 1990).

In general, soil degradation in Ethiopia can be seen as a direct result of past agricultural practices on the highlands. The dissected terrain, the extensive areas with slopes above 16 percent, and the high intensity of rainfall lead to accelerated soil erosion once deforestation occurs. Also some of the farming practices within the highlands encourage erosion. These include cultivation of cereal crops such as teff (Ergrotis tef) and wheat (Triticum sativum) which require the preparation of a fine-tilth seedbed, the single cropping of fields, and the downslope final plowing to facilitate drainage. Furthermore, the socio-political influences, especially insecurity of land-and tree tenure have discouraged farmers from investing in soil conservation practice.

Thus, soil degradation is the most immediate environmental problem facing Ethiopia. The loss of soil, and the deterioration in fertility, moisture storage capacity and structure of the remaining soils, all reduce the country's agricultural productivity. Soil erosion is greatest on cultivated land where the average annual loss is 42 tons per hectare, compared to 5 tons per hectare from pastures. As a result, almost half of the loss of soil comes from land under cultivation even though they cover only 13 percent of the country. Not surprisingly the highest average rates of soil loss are from former cultivated lands currently unproductive due to degradation and with very little vegetative cover to protect them as shown in (table 4; Hurni, 1990).

Table 4. Estimated rates of soil loss on slopes in Ethiopia

Land cover	Area of country %	Estimated soil Loss tons/ha/yr	Total soil loss	
			million tons/yr	% of total
Annual crop	13.1	42	672	45
Perennial crops	1.7	8	17	1
Grazing and browse	51.0	5	312	21
Forests	3.6	1	4	-
Wood and bushland	8.1	5	49	3
Curr unproductive	3.8	70	325	22
Curr uncultivable	18.7	5	114	8
Total			1,493	100

Source: Hurni, 1990.

Fig. 6 shows a summary of the regional distribution of soil degradation. This confirms the severity of the problem in the north of the country and the Eastern Highlands, with the Wolo and Tigray Highland the most severely affected area.

Thus, it is no coincidence that the regions with greatest damage due to soil degradation are also the ones most affected by famines (Hurni, 1990).

The present status and rate of soil erosion in Ethiopia calls for immediate action to retard and reverse this degradation process. However, the present rate of population growth (3 percent) in comparison with economic growth (1 percent), (IAR, 1991), will lead to intensive use of cultivatable and pasture land to produce more food and feed for the growing human and livestock population. Hence, it is clear that intensification of land use must be accompanied by technological innovations which will lead to more production and conserve the soil resource at the same time.

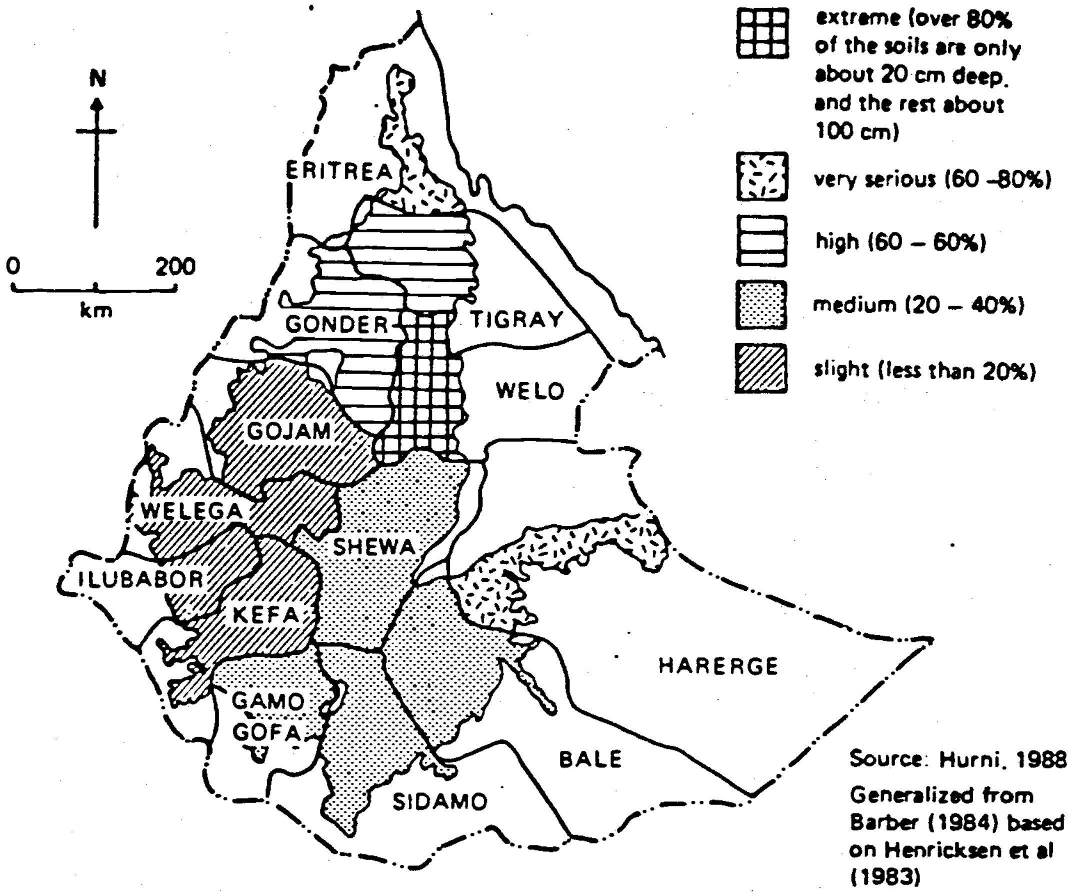


Fig 6. SEVERITY OF SOIL DEGRADATION DUE TO SOIL EROSION IN ETHIOPIA

3.1.4. LIVESTOCK AND PASTURE RESOURCES

Ethiopia has the largest livestock population in Africa, totaling some 30.6 m tropical livestock units (TLU). Cattle are the most important, numbering some 27 m head, followed by sheep (24m), goats (18m), equines (7m) and camels (1m). There are also 53 million poultry in the country. Because of its favorable climate, the majority of the livestock are found in the highlands, i.e., 80 percent of the cattle, 83 percent of the sheep, 73 percent of the goats and 76 percent of the equines and almost all poultry. The balance form an integral part of the lowland farming system (Table 5). Beside these, there are some 7 million honey-bee colonies, which in most cases are distributed in all areas of human settlement.

Table 5. Composition of livestock in highlands and lowlands of Ethiopia

Livestock	Total head ,000s	Highlands		Lowland	
		Head ,000s	%	Head ,000s	%
Cattle	27,000	21,600	80	5,400	20
sheep	24,000	19,900	83	4,100	17
Goats	18,000	13,100	73	4,900	27
Equine	7,000	5,300	76	1,700	24
Camels	1,000	0	0	1,000	100
Poultry	53,000	47,700	90	5,300	10

Source: Modified after Hoekstra et. al., 1990.

All rural systems in Ethiopia for various reasons have a livestock component. In the mixed-farming system, livestock are key elements, providing draught power and manure for crop production. In the pastoral system they are a production system themselves, providing milk, butter, meat and blood for consumption, and produce for sale. In both systems, they fulfill security functions, accumulating livestock as a "bank deposit" for use in difficult times.

Livestock feed in Ethiopia is derived mainly from grasses, forbs, shrubs and tree leaves. In addition, crop residues and processed byproducts contribute significantly to livestock feed in the highland areas. The main grazing resources are savannah grasslands (bushlands), temperate pasture, fallow land and crop residues. There are some 65.5m ha of grazing and browsing land in the country, with 66 percent of this in the lowlands where only 20 percent of the livestock are located (Hoekstra et. al., 1990)

The main problem facing livestock production is the supply of fodder. In general, the shortage is highest at the end of the dry season and at the beginning of the wet season, when cultivated land is occupied by crops and large areas of permanent pastures on the flat lands are waterlogged. An important factor contributing to a decline in fodder resources is the ever-increasing human population. This has resulted in an increase in cropland at the expense of traditional grazing areas such as bushlands, pasture and forests (Hoekstra et. al., 1990).

Because livestock is an integral part of the rural economy, it is important to consider the different options available to improve the livestock production system and to determine the implications in terms of fodder supply and herd management. One aspect which is clear if Ethiopia is to support more people on the highlands, is that better management of the resource base, with the appropriate innovations for fodder production and controlled grazing, are very important.

3.1.5. AGROFORESTRY POTENTIALS AND PRACTICES

The review in this section focuses in two parts: the first part deals with the theoretical background of agroforestry, while the second part addresses the traditional and current agroforestry practice on the Hararghe Highlands, Alemaya Basin.

Agroforestry has been defined by different people at different times, although the many definitions vary in some ways, substantive similarities are present. For further reference, see the different agroforestry definitions complied by Nair (1989a) in Agroforestry Systems in the Tropics.

However, in this study, agroforestry is used as has been defined by the International Centre for Research in Agroforestry (ICRAF) as:..."a collective name for land-use systems and technologies where woody perennials (trees, shrubs, etc,) are deliberately used on the same land management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions between the different components" (Nair, 1989a, 1990; Young 1989).

The concept of agroforestry is based on the development of the interface between agriculture and forestry. It is sustainable multipurpose production system whose outputs can be adjusted to local needs. The main components of agroforestry systems are trees and shrubs, crops, pasture and livestock together with the environmental factors of climate, soil and landform. Other components (e.g. bees, fish) occur in specialized system (Young, 1989).

The aim and rationale of agroforestry systems and their technologies are to optimize, based on the interactions between the components themselves (trees/shrubs and crop/animals) and between these and their physical environment. This will lead to a higher total and a more diversified and/or a more sustainable production than from a monoculture of agriculture or forestry under prevailing ecological and socio-economic conditions. In other words, the general aim of agroforestry is to supply an increase and sustainable outputs of the basic necessities (Beets, 1989).

There are a number of agroforestry systems practiced in the tropics and the types of systems used are diverse and complex. In order to evaluate the existing agroforestry systems and develop action plans for their improvement, it is necessary to classify these systems and thus provide a practical and realistic framework (Nair 1989a, 1990).

The most commonly used criteria to classify agroforestry systems and practices are: (1) structure of the system (nature and arrangement of components); (2) function of the system (role and output of components); and (3) socio-economic scales of management and ecological distribution. However, all systems are characterized by three basic components, such as, woody perennials (trees/shrubs); herbaceous plants (crops); and animals; thus, three basic types of agroforestry systems are classified according to their component compositions (Nair 1989a, 1990; Gholz, 1987).

(1) Agrisilvicultural systems

(2) Silvopastoral systems

(3) Agrosilvopastoral systems

Other specialized agroforestry systems can also be defined (for example, apiculture with trees, aquaculture involving trees and shrubs, and multipurpose-tree lots).

In any one agroforestry system, there can be more than one agroforestry practice. An agroforestry system is identified by certain types of practices that, taken as a whole, form a dominant land-use system in a particular locality, characterized by environment, plant species and arrangement, management, and social and economic functions. While, an agroforestry practice, is a distinctive arrangement of components in space and time. The main characteristics of the most common practices and their potentials are described and discussed in the following paragraphs.

1. Agrisilvicultural systems

This is an agroforestry system where agronomic crops are combined with shrubs/trees on the same unit of land for higher or better sustained production of annual crops, fodder and wood.

This combination could be arranged in time sequence such as a taungya sub-system and arranged in space such as hedgerow/mixed intercropping systems. The various forms that these sub-systems would be practiced are:

1.1. Taungya sub-system.

This is an agroforestry practice by which food crops and economically important tree crops are grown together until the healthy coexistence of the food crops and trees is disrupted by dense canopy closure. Later the trees will be allowed to grow in pure form. Once the trees are harvested a second rotation of taungya subsystem would start again.

This practice began in Burma, around 1806, as a means to grow teak through what has been called "taungya", (it involves hill cultivation, where lines of teak interspersed with food crops are grown for 3-4 years before the crops are shaded out). This practice has spread around the Indian continent and elsewhere in the world and was very popular with colonial foresters (Belsky, 1992).

1.2. Hedgerow intercropping

This is an agroforestry practice where trees/shrubs are grown in rows of hedges and agronomic crops are grown between the hedges in alleys. This cropping practice whereby food crops are grown in alleys between the hedges is called alley cropping/farming.

In alley cropping, the hedgerows are cut back shortly after planting and kept pruned during cropping to prevent shading and reduce competition with food crops. When there are no crops the hedgerows are allowed to grow freely. The main objective of alley cropping in a farming system is to improve soil fertility, reduce soil losses and to produce fodder and fuelwood.

1.3. Mixed intercropping

When rows are not required, trees would be grown in a scattered form over a crop field, 1 - 50 trees per hectare could be grown with less impact on the crop. In the mixed intercropping, lopping and pollarding would be practiced.

A good example of this practice is the Acacia albida-based agroforestry system. While crop yield improvement constitutes the most important benefit from the presence of Acacia albida, some other advantages, such as supply of fuel and fodder are of substantial importance as well. This system is very common in the eastern parts of the Hararghe highlands. Another example of this sub-system are trees grown in combination with plantation food crops such as coffee. Common shade trees in the coffee growing areas of Ethiopia are Cordia africana, Croton mycrostachya, Acacia spp and Albizia spp.. In addition to shade, these trees have other important uses, such as timber and maintenance of soil fertility and moisture. During the dry season, leaves of some of these trees are used for animal feed. This system is very common in the western parts of the Hararghe highlands.

2. Silvopastoral systems

This is an agroforestry system where range crops and/or animals and trees are combined for better production of grasses and fodder.

This combination can be arranged as a pure stand with fodder trees/shrubs planted as a protein bank (with cut-and-carry fodder production) and/or mixed in different configurations such as living fences of fodder trees and hedges. The trees and shrubs and grass components are arranged in such a way that their healthy coexistence is not disrupted. The acacia-dominant system in the arid parts of Ethiopia, Kenya and Somalia are good examples of this system.

This system can be practiced on both range and forest lands for the production of both feed and woody materials. This system could also be practiced on sloping ground by growing grasses and trees/shrubs together for soil conservation purposes. The main objective of this practice to supply feed for livestock during the dry season with high quality tree leaves and pods. This will substantially increase the productive capacity of poor and scarce pasture lands common on the Hararghe highlands. Fuelwood and construction poles can also be produced with this system.

3. Agrosilvopastoral systems

This is an agroforestry practice by which food, pasture, and tree/shrub crops are combined on the same unit of land for the production of grass and browse feed, biomass for fuelwood and green manuring, and food for human consumption.

This system is practiced when the farmer needs all the benefits that would be obtained from silvi-pasture and agri-silviculture systems from a unit of land. Usually, such a system is practiced on cultivated land. Alternative rows of hedges, grass strips and/or crops would form such a system, a form of alley cropping.

Agrosilvopasture is also practiced when the cropland is constrained by slope and threatened by erosion. These are very common problems of land-use on the Hararghe Highlands in general and Alemaya Basin in particular, which makes the potential of this system to be practiced in the region very high.

The above definition and discussions made about agroforestry systems and practices encompasses many well-known land-use systems long practiced in the tropics and the Hararghe highlands. Thus, it is apparent that agroforestry is only a new word for an old practice: it is based on forestry, agriculture, animal husbandry, land resource management and other disciplines which all form the systematic background of land use. Furthermore, it encompasses an awareness of interactions between man and environment and between demand and available resources in a given area. True, science can improve agroforestry practices, but an important aspect of the problem of Ethiopia is to mobilized and implement what is already known.

3.1.6. RELEVANT AGROFORESTRY EXPERIENCE AND EXPERIEMENTS

The ecological crisis in Ethiopian highlands is indeed immense. The degradation process shows a strong southward shift where the defective land-use systems of cereal-based northern and central highlands are spreading, through both natural and planned population shifts, towards the south and south western regions (Getahun, 1988).

Similarly, traditional land use practices coupled with over-exploitation of forests have led to very severe soil erosion and land degradation problems in the Hararghe highlands. As a result large areas of the agricultural lands are degraded with the formation of big gullies and rock outcrops. The over-exploitation of the forest resources in the region has also resulted in a shortage of fuelwood, construction poles and fodder for livestock (Bishaw and Abdulkadir, 1989).

To overcome the degradation of land resources and improve agriculture and forestry in Ethiopia, it has been recommended by various international organizations, such as, the World Bank and FAO, that conservation-based integrated development be used as a strategy (Constable 1985; Davidson, 1988). With this as a background traditional agroforestry systems and current agroforestry practices are discussed in the subsequent paragraphs in the context of the Alemaya Basin.

The concept of Agroforestry is not totally new to the Hararghe Highlands and the Alemaya Basin in particular. In traditional farming practices, farmers were exercising this system of land use by maintaining trees in crop lands. Such woody perennials are retained for their multiple use such as nitrogen fixing properties, soil improvement capacity, and harvesting of fodder, fuelwood, fruits etc.

This has been explained by Poschen (1986) in his evaluation of Acacia-based agroforestry practice on the Hararghe highlands, where results of the investigation has shown that significant increase of crop yield, by 56 percent on the average, was reported for crops under the tree canopies compared to those away from the tree. Additional benefits from <u>Acacia</u> <u>albida</u> trees includes supply of fuelwood and fodder. Similar study in the Alemaya area showed that farmers also keep Cordia africana trees in their fields for shade, fodder, timber, and use the pruned branches for fuelwood.

Another aspect of agroforestry called alley cropping/farming is practiced on the Hararghe Highlands using chat (Catha edulis) as hedgerows and this has contributed significantly to the conservation of soil on the steep slopes of the region. The woody component of this shrub enhance soil protection, nutrient recycling, provision of browse, fuelwood and wood for construction of fences and houses. Thus, resulting in low input sustainable and profitable system.

The role of agroforestry in satisfying the basic needs of the rural people of Hararghe is large. Realizing the practice of traditional agroforestry and alley cropping in the region, a scientific approach should be made to evaluate the existing system and to carry out research to identify appropriate technologies and management practices to make the system more beneficial to the farmers.

While traditional agroforestry practices are well-known, little research has been initiated to develop still better agroforestry technologies for Ethiopia. Some results have been generated by research undertaken at the Forestry Research Center, the Alemaya University of Agriculture (AUA), the Institute of Agricultural Research (IAR), Community Forestry and Soil Conservation of the Ministry of Agriculture (MOA) and International Livestock Center for Africa (ILCA), in identifying suitable and compatible combinations of various tree species and shrubs with the agricultural crops (Hoekstra et.al., 1990).

Few multipurpose trees (MPT's) have been tried in the alley cropping systems in the Hararghe region. However, studies which will figure prominently in section 6.3 and 6.4 are described. The first study was initiated in 1987 to generate information on the potential productivity of four selected tree and shrub species in combination with crops. These species were Acacia saligna, Leucaena leucocephala, Sesbania aculeata and Prosopis juliflora. The experiment was conducted at the Alemaya and Babile Research Centers by a multidisciplinary research team at AUA (Bishaw et.al., 1988).

The experiment was laid out in a randomized complete block design and each treatment was replicated three times. The plot size was 10 m x 20 m or 200 m^2 . In each plot, hedgerows were established at a 4-meter distance and the in-row spacing between trees was 0.50 m. The required number of seedlings for the trial were raised at the AUA nursery and later transplanted into the experimental plots at 120 seedlings per plot in six ten meters rows or at 6000 seedlings per hectare.

The results of the investigation showed that initial height growth and survival rates for all species were high indicating that the species performed well at the early stage of establishment. However, this early promise did not continue for *Sesbania aculeata* or *Prosopis juliflora*. *Prosopis* never reached the required height for pruning. Similarly *Sesbania aculeata* had very good productivity at an early stage, but failed to survive two to three prunings. However, *Acacia saligna* and *Leucaena leucocephala* were found to perform well.

Since this study further investigates the potential productivity of *Leucaena leucocephala* hedgerows with maize and beans, the discussion in this section will focus only on the results from this species. The annual dry matter production from the leucaena hedgerows was estimated by weighing the pruning biomass yield per plot and converting to yield per ha. The results of the total biomass, wood and foliage yields in tons/ha for four consecutive years after planting as hedgerows at Alemaya is shown in Table 6.

Table 6. Periodic fresh biomass, wood and foliage yields (tons/ha) of <u>Leucaena leucocephala</u> at Alemaya between 1988-1992.

Period	Total Biomass	Wood yield	Foliage
(1) 1988/89	4.64	2.05	2.59
(2) 1989/90	8.67	4.47	4.20
(3) 1990/91	17.06	6.82	10.24
(4) 1991/92	5.94	1.84	4.10
Mean	9.08	3.80	5.28

Source : Modified after Abdulkadir 1992.

The estimated periodic biomass, wood and foliage yield varies from period to period as shown in table 6. The total biomass increases from 4.64 t/ha in period 1 to 17.06 t/ha in period 3, and then the total biomass declines to 5.94 t/ha in period 4. The mean total biomass for the whole period is 9.08 t/ha, Using an average moisture content of 65 percent for woody components at harvest in leucaena, this would result at 5.90 t/ha/year dry matter production. Forty percent of the dry matter consists of woody components and is assumed to be used for fuelwood, some 2.34 t/ha. The remaining sixty percent is leafy material and small branches and will be used as a mulch or fodder.

The summary results of alley cropping with the four leguminous tree species on the seed yield and yield components of maize is shown in table 7.

Table 7. Seed yield and yield components of maize as influenced by leguminous tree species.

Treatments	Seed yield (kg/ha)	Seed size (g/1000 seeds)
Sesbania aculeata	3817	395
Acacia saligna	3234	396
Leucaena leucocephala	6109	415
Prosopis juliflora	5553	422
Check	6562	430

Source: Bishaw et. al., 1988 LSD 0.05, CV 0.01

Results of the alley cropping on growth and development of maize varieties indicated that, when different maize varieties were grown in association with leguminous tree species at a recommended rate of fertilizers (100 kg di-ammonium phosphate (DAP) and 50 kg urea), the yield of maize grown in the alley was comparatively lower than that of the check plots by 29 percent for the first year. However, when the different leguminous species were compared, considerable differences were observed with regard to seed yield of maize. That is, when maize varieties were grown in association with Leucaena, they out-yielded the maize grown with Acacia, Sesbania and Prosopis spp. by 41, 37 and 1 percent, respectively. Subsequent year yields for alley cropping have improved in Nigeria (Bishaw et. al., 1988).

The results of the chemical analysis for the three browse species: such as, Acacia saligna, Leucaena leucocephala and Sesbania aculeata has be reported in table 8. The crude protein content of Leucaena, Sesbania and Acacia indicate that these fodder species can meet the protein requirements of small stock (sheep and goats), if there is an adequate supply. Sesbania is reported to be free from anti-nutritional or metabolic factors as opposed to Leucaena and Acacia which contains mimosine and condensed tannin, respectively.

Table 8. Dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, ash, and ADF-ash of the browse legume trees

Sample description	Mineral contents (%)						
	DM	CP	NDF	ADF	Lignin	Ash	ADF-ash
Leucaena leucocephala (leaves)	27.2	28.7	24.1	24.1	12.1	6.1	-
Sesbania aculeata (leaves)	30.1	29.1	13.0	8.6	2.7	7.2	0.50
Acacia saligna (leaves)	38.9	25.2	46.4	28.7	12.4	8.0	0.56

Source: Bishaw, et. al., 1988.

The lower level of fiber component is indicative of the potential for browse of the tree leaves. The low ADF-ash content is related to the presence of a small quantity of silica. The mineral content of the browse tree leaves is within the range of National research requirements (1984). However, very little is known about the effect of tree leaves on performance of livestock. This is important in areas where shortage of land for grazing and browsing are emphasized.

Although, immediate changes in the physico-chemical characteristics of the soils under alley cropping studies are discernable, the incorporation of the mulches from pruning of the hedgerow trees and crop residues is believed to bring substantial improvements. In this regard, subsequent studies will be conducted to monitor the impact of alley cropping on soil properties.

The increase in population in the Alemaya Basin and the subsequent demand for food, feed and fuelwood has led the traditional farming in the Alemaya Basin to be characterized by decreasing farm size, problems of soil erosion, shortage of fuelwood and fodder, and lack of appropriate technology. Therefore, there is an urgent need to provide farmers, faced with progressively degrading soil, decreasing crop yields, and limited access to commercial inputs, with technologies that have significant returns and long-term sustainability.

Various crop production technologies have been tested in the humid tropics to replace the traditional shifting cultivation system to increase food production. One of the alternative promising methods is the alley cropping system (Kang, 1981; 1985; 1989; Nair, 1989b; Young, 1989). Such system has been widely acclaimed as a solution to tree depletion, soil degradation and declining yields under shifting cultivation.

Thus, the maize-leucaena alley cropping system has been identified as a potential promising technology to overcome the problem faced by the traditional farming in the Alemaya Basin. Leucaena hedgerows retain important functions of a traditional shifting cultivation for nutrient recycling, source of green manure, firewood and staking material. The mulching effect also increase the soil moisture retention (Kang 1981; 1985; 1989, Nair 1989b; Young, 1989).

Repeated application of leucaena prunings increased total soil N and organic C level. It also increased exchangeable K, Ca, Mg and nitrate levels. The amount of nitrogen in the prunings were rather substantial ranging from 180-240 kg N/ha annually.

The total annual dry matter yields from the prunings were rather substantial, ranging from 5 to 8 tons/ha. Leucaena hedgerows also stabilize soil erosion when planted on the slopes along contours. The hedgerows also suppress weeds through partial or full shading. Presence of mulch cover has been reported to suppress weed growth and reduce run-off.

Since there is only one year crop yield data at hand for the alley cropping trial at AUA, I am forced to use the results of an alley cropping experiment conducted in southern Nigeria to extrapolate yield data for this study. Kang et.al

(1981, 1985, 1990) reported the results of an alley cropping experiment carried out on alfisols and associated soils in southern Nigeria for the low-humid and subhumid tropics. He indicated that Leucaena leucocephala and Gliricidia sepium are the best-performing hedgerow species for alley cropping.

Although these two sites are at different geographic locations and have different climatic and soil conditions, until better data are forthcoming one could use with caution the alley cropping yield data from southern Nigeria as a basis to extrapolate yield data for alley cropping at Alemaya. The results of this study have shown that with the addition of leucaena prunings, even without N application, maize yield can be sustained at a reasonable level of about 2.0 t/ha (Table 9). Higher yields were obtained when the prunings were supplemented with fertilizer N. This technique thus provides more flexibility in developing a low-chemical input production system (Kang et.al., 1985, 1990).

Table 9. Grain yield (t/ha) of main season maize in Maize-cowpea rotation growth on a sandy soil in alley farming with Leucaena, adapted from Kang et. al., (1990).

Treatment	Mean	Year (yields in tons/ha)						
		1979	1980	1981	1982	1983	1984	1986
N=0, -R[1/]	(0.62)	-	1.04	0.48	0.62	0.26	0.69	0.66
N=0, +R	(1,91)	2.15	1.91	1.21	2.10	1.91	1.99	2.10
N=80, +R	(3,05)	3.40	3.26	1.89	2.91	3.24	3.67	3.00
LSD	(0.36)	0.36	0.36	0.29	0.44	0.41	0.50	0.18

1/ Kang et.al., (1990) provided no control yields in the absence of leucaena. Assuming 30% occuping for leucaena the traditional yield would be 0.81 tons/ha.
-R, leucaena pruning removed;
+R, leucaena pruning retained;
N rate, zero or 80 kg N/ha;
All plots received basal dressing of P, K, Mg, and Zn

The increase in crop yield in the alley cropping plots (Table 9) was obtained from the leaves and twigs added as a mulch, which were ploughed under into the soil to add soil nutrients through decomposition. Also, the additional fuelwood production contributed from the branches of the leucaena hedgerows will reduce the use of crop residues as fuel, thus, leaving additional material that goes into the soil.

Average crop yields for the different treatments from the seven years data was calculated to estimate the proportion of yield production from the different treatments. Yield increases associated with alley cropping with and without fertilizer is striking. The estimated mean crop yields for the treatments were 0.62 t/ha for leucaena pruning removed; 1.91 t/ha for leucaena pruning retained and 3.40 t/ha for 80 kg N/ha plus leucaena pruning retained. The least square deviation was 0.36. Thus, the ratio of crop yields for the three treatments was 1:3.08:4.92. These results will be used to estimate crop yields and biomass production for alley cropping and alley cropping plus chemical fertilizer technologies, which are proposed as alternative technologies for the Alemaya Basin in chapter 6.

From this review, we can see that agroforestry (i.e. alley cropping) as a land use system may have significant potential to alleviate the land degradation problems associated with poor traditional farming practices on the Hararghe highlands and improve the agriculture and forestry production on a sustainable basis. However, this technology, to be acceptable by users, needs to be technically and environmentally sound; socially desirable, economically affordable and sustainable.

3.2. DEMOGRAPHIC, TENURE, AND SOCIO-ECONOMIC CONDITIONS

3.2.1. POPULATION

The boundaries of Ethiopia embrace a wide diversity of cultures with a long history. Centuries of tradition have been overtaken recently by fundamental social and political change. With 49.2 million in 1990 (World Resources Institute,1992), Ethiopia is the third most populous country in Africa (after Nigeria and Egypt). The population growth rate is increasing: it is currently 2.9 percent and is projected to exceed 3 percent by the mid-1990s. Its people are also among the poorest and, in terms of social indicators, one of the least developed. About nine-tenths of the total population is rural. In peasant agriculture, land-holding sizes have diminished with the growth in the number of rural households (World Bank, 1990).

Ethiopia's rapid population growth implies a doubling of Ethiopia's population in less than 25 years (World Bank, 1990). This will absorb most of the predicted gains in economic growth, seriously impairing prospects for improving standards of nutrition, education and health care, and for coming to grips with Ethiopia's ecological degradation. The net impact could be stagnation or a further decline in the living standards of the Ethiopian people. Unless steps are taken to reduce fertility through an expansion of family planning services, there will be little significant improvement in per capita income or living standards. Ethiopia needs to expand and strengthen its basic maternal and child health services, into which family planning should be integrated (World Bank, 1990).

The population of the Hararghe region is about 4.5 million with an annual rate of growth of 2.9 percent. The Highland zone of Hararghe accounts for the larger portion of the population and the remaining few live scattered over the lowlands. The highest population density in the region is reported for Alemaya and Kersa sub-district with 573 and 454 persons per square kilometer, respectively. Moreover, pressure on land is high and the average size of a farm family is given as 4.8 (Poschen, 1987).

Like may African countries, Ethiopia shows tremendous ethnic heterogeneity. The largest ethnic groups in the country are the Oromo, the Amhara, the Tigray, but numerous other groups like the Gurage, the Somali, the Afar, the Hadya are represented with more than a million persons each. Amharic and English are used as official languages but more than 70 different languages are spoken in Ethiopia.

The ethnic composition of the Hararghe highland is mostly Oromo and their share is about 90 - 95 percent. The only other people represented in a substantial numbers are Amhara, but they tend to be concentrated in the small urban clusters, and in the rural Chercher highlands. After the 1974 revolution, the Amhara lost their former land ownership privilages and they were living among Oromo farmers with little difference in material wealth (Poschen, 1987).

In the past, rural settlements were usually in small clusters of 6 - 20 houses. However, after the revolution farmers were forced to establish villages to speed up the spread of services and development of an infrastructure among the rural population. As a consequence of this villagization program, trees planted around homesteads were abandoned and became suceptable to theft and other uses. Also, the construction of houses increased the demand for building materials, thus causing depletion of existing trees. However, during the field survey in the Alemaya Basin 1990, I have observed most farmers abandoning the villagization area and settling back to their former village sites. This was attributed to the mixed market policy of March 1990, which allowed farmers to dissolve cooperative farms and encouraged privatization of farming.

The Eastern Oromo of Hararghe call themselves "Kottu" which literally means farmer. They live in nuclear families, usually consisting only of the farmer, his wife and unmarried children. Polygamy is rare because of economic constraints. In contrast to the traditional division of labor in many other African countries, farming is the responsibility of men in Ethiopia. Women are predominantly occupied with household work like food preparation, nursing of children and fuelwood gathering. They also market farm produce and give a hand in farming. Children are responsible for cattle herding and assist in farming and marketing as soon as they mature. Women may privately own land and cattle in Kottu culture, but in family decisions men have the upper hand (G.Michael 1974, Poschen, 1987). Different forms of mutual assistance among farmers in cultivation, house building etc. are still very common.

3.2.2. LAND AND TREE TENURE

To review policy issues pertaining to forestry development it is necessary to examine the close interaction between forestry and land tenure. The tenurial issue is treated here in terms and conditions under which land is held and examines the extent to which these motivate small farmers and other developers to grow trees.

The Rural Lands Proclamation No. 31/1975 abolished the previous land-tenure system of the tenant-landlord relationship. All private ownership of land by individuals and organizations was outlawed; the transfer of land by sale, lease or mortgage was declared illegal and anyone willing to farm was to be given land. The maximum plot allotted to each household was to be 10 hectares (Brune, 1990). Despite the provision of 10 hectares, land holdings are still very small and range from 0.5 to 1 hectare per farm-family. There are few incentives for farmers to plant trees or improve the land through soil and water conservation measures, for their right to use the same unit of land is not guaranteed. In fact, it is often alleged that improved farms are more often taken away by the local leadership (Getahun, 1988).

The main law governing forests is the Forest and Wildlife Conservation and Development Proclamation No. 192/1980. This proclamation divides the ownership of forests into two groups. These are: (1) forests owned by the state and (2) forests planted and owned by Peasants' and Urban Dwellers Associations.

The state forest includes (1) forests which were state forests under proclamation No. 225/1965. These are forests which were either owned by or on behalf of the Government or not owned or possessed on behalf of any person at the time of issuing the proclamation; (2) forests designated as protective forests in accordance with the Protective Forests Proclamation No. 227/1965 or under Proclamation No. 192/1980. These are forests found or planted on land requiring the conservation and protection of soil and water and the control of floods; (3) forests which may be designated as state forest in accordance with Proclamation No. 192/1980.

Forest planted by Peasant Associations, or forests not designated as state forests are the property of Peasant

Associations, while forests owned by Urban Dwellers Associations are the property of such associations.

This proclamation prohibits any person utilizing the products of forests without the prior written permission of the Forestry and Wildlife Conservation and Development Authority. This prohibition also applies to the forests of Peasant Associations and Urban Dwellers Associations. This act has discouraged these associations from planting trees in their holdings because of lack of the right to use trees.

Thus, the lack of appropriate policies on land tenure and utilization of trees; lack of security of land and tree ownership, and lack of a clear policy which encourages community forestry, farm forestry and individual tree planting are some of the policy constraints that affect the rational and coordinated development of the Forestry sub-sector in the country.

3.2.3. THE ECONOMY

It is important to consider the present socio-political conditions of Ethiopia because understanding of this situation will help us comprehend under what environment we operate. Ethiopia is now in a state of political transition from a socialist-oriented government to a democratic and market-oriental government.

Agriculture is the dominant sector in the Ethiopian economy, accounting for about 40 percent of GDP, 90 percent of exports, and 85 percent of total employment (World Bank, 1990). Besides supplying food for domestic requirements, agriculture provides raw materials for local industries and is the main source of foreign exchange. As such, agriculture affects all sectors of the economy and the satisfactory growth of the sector is critical not only for improvement in the food situation but also for accelerating the growth of GDP, export earnings and industrial production.

Of the country's 124 million hectares, 65 percent are considered suitable for grazing and crop production. However, the area currently cultivated is estimated at 18.5 million ha for crops and 63.7 million ha. for grazing. Moreover, the country has a favorable climate which would allow two crops per year (Spring and Summer). Irrigated agriculture is estimated at 3 million ha, but only about 3.5 percent is currently developed (Hokestra et.al. 1990).

The main food crops in the country are teff (a locally consumed cereal), maize, barley, sorghum, wheat, pulses and oilseeds. Coffee is the principal export crop and generates over 60 percent of the country's export earnings. Other export crops include oilseeds, pulses, cotton, sugarcane, fruits and vegetables (World Bank, 1990).

The forestry sub-sector, as accounted for in economic statistics contributes less than 1 percent to the Ethiopian GDP (Constable, 1985), but this figure results from the omission of fuelwood in the calculation and grossly underestimates the sub-sector's importance. FAO estimated that the value of fuelwood used in Ethiopia equals 14 - 15 percent of GDP. This points to the fact that forest industrial products are of very limited importance to Ethiopia (Poschen, 1987).

However, the role of forestry in the Ethiopian economy becomes very clear when one recognizes that the great majority of rural as well as urban population depend on fuelwood for energy. A recent study made by the Ethiopian National Energy Council (ENEC) indicates that wood is most important source providing 77 percent of household energy, followed by dung (8 percent) and crop residues (8 percent). Charcoal provides 1 percent and fossil fuels account for the remaining 6 percent (ENEC, 1986). This study shows that 94 percent of the total energy comes from biomass, and of this the majority is fuelwood.

It is clear that, at present, the consumption of wood is in excess of the available growth from the forested area and that is the major cause of deforestation. In 1984, the use of wood was estimated to be 24 million cubic meters, which was over 60 percent in excess of the level of sustainable production, estimated to be 14.9 million cubic meters from all types of forests and woodland (IUCN, 1990). This has resulted a decline in the area of forests and woodlands by some 160,000 to 200,000 hectares per annum by conservative estimates.

Of the 1984 consumption of wood, only 10 percent went for industrial use and construction, while 90 percent was used for fuel. Hence, to meet the country's energy needs, to cover its demand for construction materials, to supply income and employment to the people, to reduce soil erosion and improve soil fertility, and to provide recreational parks and wildlife habitats, forestry has a crucial role to play in the Ethiopian economy.

Ethiopia's other known natural resources include gold, platinum, tantalum, soda ash, and potash. Some offshore petroleum exploration is taking place, but no petroleum reserves have yet been proven. Substantial gas reserves are believed to exist in the eastern region. None of these minerals has been exploited on a large scale, but large-scale gold mining has just commenced. The manufacturing industry, which accounts for about 10 percent of GDP, is heavily dependent on agriculture; agro-based industry constitutes around 70 percent of large and medium-scale industry.

The Ethiopian economy remains hampered by its weak infrastructure (notably roads), low productivity in agriculture, heavy dependence on one export commodity (coffee), a small industrial base, and shortages of skilled manpower. Apart from these unfavorable initial conditions, domestic resources for investment were limited by the government's large outlays on internal security, while import capacity is constrained by stagnating exports and by low levels of external resource transfers.

Although Ethiopia has a substantial agricultural potential, most agriculture takes place in rain-fed conditions or is subject to recurrent drought. Food security against harvest failure is therefore necessary. When this was inadequate in 1984/85, a famine occurred and a major international relief effort was mounted. A second, even larger, effort was mounted in 1988 which brought in nearly one million tons of food aid following poor rainfall.

Through the World Food Program, famine conditions, so far, have been successfully averted. The wide variation in topography and extremely rugged terrain have been serious obstacles to internal transportation, and economic development in general. Nearly three-quarters of Ethiopia's farms are more than a half day's walk from all-weather roads.

3.2.4. SOCIO-POLITICAL CONDITIONS OF ETHIOPIA

The transitional government which is led by the Ethiopian People's Democratic Revolutionary Front (EPDRF), has declared that the country's economic development will follow a free market policy. This economic policy will focus on privatization of land and other means of production. Also, it allows the market condition to determine the price of goods, based on principles of demand and supply.

Natural resource conservation and development of the country is also given a high priority by the transitional government. As a consequence, it has up-graded the Natural Resources Agency, which was previously under the Ministry of Agriculture, to be an independent Ministry of Natural Resources and Environmental Protection. This ministry has the responsibility to administer and control the forestry, land use and water resources of the country.

Selecting free market economic policies by the transitional government is encouraging for the future development of the country. However, it has to be realized that the goals of a free market economy will not be achieved without a democratic government that provides peace and stability to promote economic development in the country.

Thus, the well-being of natural resources will be determined by political stability. The current situation is a cause for uneasiness.

The present political trend in Ethiopia, which is based on ethnic politics, will not help the country from the present crisis of underdevelopment such as low living standards, famine and environmental degradation; rather it will lead to still more serious problems.

In a country like Ethiopia, where there are more than seventy nationalities, bringing ethnic politics as a major political agenda will not help the development of the country. I think we have to learn from our neighboring Somalia and former Yugoslavia in Europe, about the crisis of clan and ethnic politics. Thus, understanding the sensitivity and danger of ethnic politics, the transitional government in Ethiopia should handle this problem cautiously.

Hence, the right of every nationality should be respected and each ethnic group should have the right to keep its culture as a heritage. It should also be encouraged to work and strengthened the social and economic development to the best interest of its people. Moreover, they should also pull together with respect and equality to one another to form a nation to promote their economic development and improve their standard of living. Thus, realizing the need for complimentarity in economic development and understanding unity is strength.

When we see the historical development of Ethiopia, these different ethnic groups have lived together for centuries and shared their happiness and fought their enemies together. Because of centuries of migration for trade and job, there has been inter-marriage between the different ethnic groups. It is hard today for some families and children to identify their ethnic group, because they are not purely from one ethnic or tribe.

With this background in mind, in the subsequent chapters the study will investigate the limitations of tree planting and potentials of alley cropping in the farming system of the Alemaya Basin. The study will add original data from the land-use and socio-economic surveys to set the stage for a comparison of traditional farming with agroforestry farming. The study will then assess the economic feasibility and sustainability of the system by projecting the population, agriculture and forest production and income in the Basin.

4. METHODS AND PROCEDURES

4.1. IDENTIFICATION AND SOURCES OF INFORMATION

For the purpose of this study, the current biophysical and socio-economic conditions in the Alemaya Basin were defined in quantitative terms, because understanding of these circumstances would be helpful to determine how farmers make their decisions on the type of enterprises they are willing to undertake. Also, these factors have enabled the researcher to identify the problems and constraints which were faced by the resource-limited farmers, thereby helping to formulate appropriate alternative technologies and research programs that could alleviate the problems and constraints in the Alemaya Basin.

Thus, the required information specifically for the Alemaya were: (1) Physical resources (climate, geology, soils, topography etc); (2) Agricultural land-use (crops, fallow, livestock, pasture); (3) Forest and tree cover (natural forest, bushes, planted trees); (4) Socio-economic condition (population, farm size, income etc); (5) Infrastructure (roads/trails, towns, villages etc).

The necessary Basin-specific data for this study were collected (1) from existing documented sources: such as, the Alemaya University of Agriculture; Ministry of Agriculture;

Regional and District Administrative Offices; Peasant Associations in the study area; International Livestock Center for Africa (ILCA) and International Center for Research in Agroforestry (ICRAF). (2) Field surveys carried out on land use, Forestry/Agroforestry practices and socio-economic conditions of the Basin. The land-use surveys and socio-economic studies were carried out by separate groups of technical and field assistants with adequate technical knowledge, and language and cultural skills appropriate for the Alemaya Basin.

4.2. METHOD FOR LAND USE SURVEY

The objectives of the land use survey in the Alemaya Basin were twofold: (1) to estimate the composition of the study area into different land use categories using Table 10; (2) to identify the different forestry and agroforestry practice in the Basin.

Table 10. Classification for Land-Use (adapted with some modification from Anderson 1976)

Land-use type
1. Rural/semi-urban or built-up lands
1.1. Residential
1.2. Transportation
2. Agricultural land
2.1. Annual cropland
2.2. Perennial cropland
2.3. Annual/perennial
2.4. Fallowland
3. Pasture land
4. Forest land
4.1. Natural forest
4.2. Man-made forest
5. Bushland
6. Agroforestry
7. Water (lakes)
8. Wasteland (gllies and rock out crops)

To achieve the above objectives of the study, basic information on the Alemaya Basin was gathered from field surveys and secondary sources of information. Thus, the following paragraphs will elaborate the methods of land use inventory in the Alemaya Basin.

4.2.1. PLANNING THE LAND USE INVENTORY

Remote sensing and aerial photographs are generally the most advanced and effective approach to land-use inventory (Vink, 1975; Bryant et.al., 1983). However, availability and access to these devices were limited for the Alemaya Basin. Panchromatic aerial photographs at the 1:50,000 scale had been taken in the sixties. These old photographs could not be used to survey the current land-use pattern because too much has changed during the past 30 years (Uibrig, 1989). Therefore, the land-use inventory in the Alemaya Basin depended on a terrestrial survey. Also, due to the limited time and resources, I was restricted to the choice of sampling survey.

In this study, the stratified random sampling method was selected to carry out the land use survey in the Alemaya Basin. This sampling scheme is area weighted and gives a good estimate for the sample distribution and better area coverage of the study. It gives a bias-free selection of samples and has the advantage of easy application. The sampling frames, sample size, form of estimator and method of sampling, are outlined below:

Sampling Frames: The sampling design used in this study was areal-point sampling methodology. It is a two level sampling frame with stratification of the spatial area of interest. The first frame organizes the population of the land use classes into equally areas of squares, referred to as the primary sampling unit (PSU's). The second frame is the set of intersection and is referred to as a secondary sampling units (SSU's). An observational unit is an area mask or "decision cell" of specific size around each of the sampled SSU's (Bryant, 1983; Behm and Pease, 1985; Vesterby, 1988, Zabedah, 1989).

Data acquisition using a grid framework requires an optimal cell size to guide the final selection. This grid size reduces error estimates to an acceptable level and minimizes the locational error of data. Bircham (1979) conducted an extensive study on the effects of varying grid resolution. Assessment for an optimal size was made on the basis of land area to be sampled which is also indicative of potential costs. A 2 x 2 km PSU turned out to be the most cost effective size, and was adopted for this study.

A total of 67 PSUs were identified within the 20,000 hectare total area of the Basin. To obtain SSUs, each PSU was further divided by grid lines with equal spacing into 400 one hectares squares, except where the PSU was located around boundary or on water bodies. SSUs where then selected at random and were used to collect the land-use data.

Estimation Of Sample Size: The next step was choosing an appropriate sample size. There were sample sizes in two sampling frames to be considered: Sample size from a set of PSUs (areal units) and sample size from sets of SSUs (point units). The choice of these two sample sizes is a function of the precision required. According to Zabedah (1989), sampling all PSUs with four points per PSU gave the best estimate of sample distribution and good area coverage. Therefore, the land-use survey in the Alemaya Basin has sampled all 67 PSUs with four points of secondary sampling units per PSU, where the PSU was not located near a boundary or on water bodies. Thus, a total of 210 sample units (one hectare each) was sampled within the 20,000 ha of the Basin, representing approximately 1 percent of the land area.

4.2.2. SAMPLING METHODS AND PROCEDURES

Thus, four replications of observational units from each PSU were selected at random. However, if because of borders or water the size of the PSU was less than half, no SSUs were selected from that PSU since it would not be possible to calculate a variance. Hence, selection procedure involved two to four SSUs within each PSU.

The appropriate estimator for this sample design follow the formulas for single-stage sampling (Zabedah, 1989; Cochran 1977).

N = total number of primary units

M = total number of secondary units

n = sample size of PSUs

a(i) = No. of elements in i secondary unit in class

m = No. of elements (SSUs) in each PSU

f(1) = n/N ; f(2) = m/M

p(i) = Σ a(i)/m proportion for i PSU in class

p = Σ p(i)/n proportion of class.

Sample variance between PSUs = $s(b)^2 = \Sigma [p(i)-p]^2/n-1$

Sample variance between SSUs $= s(w)^2 = \frac{m}{n(m-1)} \Sigma [p(i)q(i)]$

Unbiased estimate of Population variance is :

$$V(p) = \frac{1-f(1)}{n} s(b)^2 + \frac{1/m - f(2)}{n} s(w)^2$$

4.2.3. TECHNOLOGICAL AND OPERATIONAL OPTIONS

The details of data collection procedures are as follows:

1. A 1:25,000 scale map developed by Uibrig 1989 was used as a reference base map for obtaining locations in sample selection;(Fig. 2)
2. Construction of an overlay grid to cover the entire study area with one grid cell 2 x 2 km; to identify PSUs
3. Initial plotting up to form SSUs on the PSUs and transfer on the 1:25,000 scale map;
4. Identification of SSUs in the field using topographic maps and compass. The system of roads/trails were very useful to locate sample plots on the ground.
5. Record keeping: data tally sheet (Appendix 1) was prepared to collect the land use information from each grid cell according to the land use classification by Anderson (1976) and later modified by the investigator to meet the conditions of the study area.
6. Two groups of Technical assistants, three-men in each group, were trained in land use survey and data collection to assist in the field work. A one week training was given for the technical and field

assistants on handling the survey instruments (compass, pacing and range poles), and on methods of land use survey, and data collection both in class room and on the field.

7. Field survey: collection of data was done by the team, by first locating sampling points on the ground, using the topographic map, compass and pacing. Then, the team laid out a 100 x 100 meters sample plot using range poles to identify the four corners of the sample plot. Once the sample plots were identified, information on land use, forestry and agroforestry were recorded using the data tally sheet prepared for the study.

4.2.4. DATA PROCESSING AND ANALYSIS

To analyze the land use survey data in the Alemaya Basin the following steps were considered. (1) immediately on the receipt of the tally sheet from the field, data editing was done to correct errors or replace missing data, (2) coding of the land-use information was put in a form suitable to fit the analysis, (3) data was then transferred by hand from the tally sheet to a spread sheet and later using computer, data was entered into Lotus spread sheet (using Lotus 3.1 package), with the rows representing the Primary and Secondary sampling Units and columns representing the corresponding different land use types.

Means, maximum, minimum and total (sum) values and frequency distribution of the various land use variables, were calculated using the LOTUS 3.1 package. The main focus of the data analysis was to find out the distribution of land use types in the Alemaya Basin.

4.2.5. TECHNICAL AND ORGANIZATIONAL PROBLEMS

It took three months to complete the land use survey with two survey teams. Although the team members had the necessary technical and language background to understand the tally sheet and communicate with farmers, sometimes they found it difficult to locate the sample points on the ground because of physical barriers, such as big gullies and water bodies, and lack of access on the property of the individual farmers.

There was some delay in field work because of funding problem. It took one month to transfer funds from the Higher Education Main Department in Addis Ababa to Alemaya University of Agriculture in Hararghe. The total cost for both land-use and socio-economic surveys was about 14,930.00 Ethiopian Birr (ETBirr) (7,212.56 U.S.dollars as of 1990/91 Exchange rate). Costs included stationery, duplicating questionnaires and tally sheets, purchase of maps and areal photographs, renting vehicles for 90 days and per-diem for enumerators. Range poles, measuring tapes, clinometers and compasses were borrowed from the college of Forestry, at the AUA.

4.3. METHOD FOR SOCIO-ECONOMIC SURVEY

This survey includes interviewing farmers, meeting with local leaders, and researchers. This activity provides site specific information pertaining to the socio-economic, conditions in which the low resource farmer operates.

One of the purposes of the socio-economic survey was to find the reason for lack of success in tree planting from the farmers perspective. This problem remains the major obstacle to successful afforestation and reforestation work in the Basin. Thus, finding the causes of this problem could help to suggest alternative solutions or policy strategies, hence, contributing to the general forestry development in Ethiopia.

Farmers' response whether or not they planted trees was considered as the dependent variable. The following independent variables were proposed to explain how farmers make their decision towards tree planting. These are: household food security, household income, family size, farm size, forestry extension, forestry policy, land and tree tenure. The selection of these independent variables were based on my personal experience, communication with farmers and literature. The following paragraphs explain why each independent variable was selected as a predictor of the dependent variable, tree planting. Further elaboration of these variables is given in chapter 5.3.

Household food security could be important because farmers give greater priority to growing annual crops which they can sell quickly or consume, than to trees which are slow to mature.

Household income was considered because as income increases farmers might be convinced or able to afford planting trees and wait for future return.

Family size was chosen because, as the family has more people within the household, it might be possible for the household to allocate extra family labor from food production to tree planting and management.

Farm size was considered because, if farmers have enough land to produce their food and graze their animals and secure the family survival, they might be interested in planting trees on the extra land which is not allocated for agriculture.

Forest policy was considered because, if farmers understand forest policy, it is possible that they can make a decision which would benefit the household and tree planting.

Forestry extension service was chosen because, it might influence farmers attitudes towards tree planting. As farmers get more and better extension service, such as demonstration tree planting techniques, availability of the right type of tree species for planting and incentives to the farmers, it is possible that farmers might be convinced to plant trees.

Land and tree tenure was chosen because there is general evidence that people are unlikely to plant trees when access to those trees, tree products or to the land upon which its growing may later be in jeopardy. Thus, it is safe to speculate that when farmers have the right to plant and harvest trees without restriction from the government or community, it might be possible for them to invest the time and resources to plant trees and become the beneficiaries of the products.

4.3.1. SURVEY METHODS

To gather the necessary information to test the above hypothesis a survey was carried out from October to December 1990 in the Alemaya Basin. The following paragraphs explain the survey methodology and how data was gathered from the field. In an effort to obtain more desirable sampling distribution, estimates of their characteristics, and particularly a reduction of sample variance, the target population, sampling frames, sampling design and sampling procedure were carefully considered.

Target Population: Here the term "population" is used to describe the total elements under study, where the "elements" are the units of analysis. In this study, farmers who were Peasant Association's (PA's) members represent the population under study, because the study was interested on the behavior and attitudes of individual farmers. Farmers who were Producers Cooperative members were not considered, because of the mixed economic policy of March 1990, most of the cooperative farms were dismantled in the Basin and private farming was encouraged.

Once the target population is defined, the next study-design question is who should be interviewed. Since the target population in the Alemaya Basin is large (i.e., 80,000 persons), a probability sample was required to make enough interviews which would permit generalizing the population under study.

Sample Design: For the purpose of this survey, stratified random sampling was used. This method of sampling provides a means of substantially reducing the effort required for sample selection and it is easy to apply. Also, stratified random sampling provides more information per unit of cost than does simple random sampling. (Mendenhall, w. et. al, 1979; Kalton, 1979; Weisberg, 1989).

Sampling Procedure: For the purpose this study farmers were sub-grouped into 17 PA's. For each of the PA's a list of farmers were obtained to serve as the sampling frame, and samples were drawn randomly from each.

A computer was used to generate the random numbers. Twenty random numbers were picked each time to select the 12 farmers from each PA for the interview. If a random number occurred twice, the second was omitted, and another number was selected instead. Thus, a total of 204 sample farmers were picked at random for the interview from the 17 Peasant Associations in the Alemaya Basin.

4.3.2. METHODS AND PROCEDURES

Personal interviews were conducted with individual farmers. A questionnaire was developed to undertake the household interview (Appendix 2). Questions were designed to provide detailed information on specific land-use practices, cropping calendar, division of labor, and access to income and resources. Moreover, questions were designed to provide information on description of land-use systems and problems.

For ease of application, the questionnaire was divided into five major categories: (1) Background information, Household income and labor, (2) Crop production sub-system,

(3) Government forestry development interventions (4) Land and tree tenure, and (5) Marketing and infrastructure.

Selection and Training of Field Workers: Six University Extension workers, who are native speakers of the local language with a high school education background, served as enumerators. They were given one week of training , both in the classroom and in the field, on how to complete the questionnaire.

Pretesting: Field testing of the questionnaire was done by the investigator, by randomly selecting and interviewing twelve farmers from the different PAs. The questionnaire was amended based on the findings of the pretest.

Organization of Field Work: Arrangement for interviews with the PAs was done in advance. Lists of farmers to be interviewed were submitted to the PA leaders two weeks earlier, to inform farmers ahead of time. Transportation was provided by the Alemaya University on a mileage bases. A 4-wheel drive car was allocated for the survey from the University car pool.

4.3.3. DATA PROCESSING AND ANALYSIS

To analyze data the following steps were performed: (1) questionnaires were edited for missing data, (2) coding of the questions was done in a form suitable for analysis, (3) coded data was then transferred by hand into a spread sheet, (4) data was entered into the Lotus Spread sheet (using LOTUS 3.1 package), with rows representing the farmers number and columns representing the corresponding different variables (response of farmers to the different questions). Statistical Analysis Systems (SAS) computer package was used during the analysis.

The main focus of the data analysis was to see if a relationship or association existed between the dependent variable (tree planting) and the various independent variables. A chi-square analysis followed by a logistic regression and a log-linear analysis were run to identify the most important variables that influence farmers decision towards tree planting. Results of the chi-square statistics with high values indicate that, there is assoication between the independent variables and dependent variable.

4.3.4. ORGANIZATIONAL AND MANAGEMENT PROBLEMS

A letter of permission was required from the regional and district administration offices and PA to carryout the socio-economic survey. It took one month to get permission and to organize the survey. The major problem was to find farmers for the interview as scheduled. Although the names of farmers to be interviewed was given ahead of time, it was difficult for PAs leaders to communicate the information. Also some of the farmers were afraid to appear for the interview because they were suspicious that they were called for military recruitment by the PA leaders.

Another problem faced during the interview was that some farmers were reluctant to respond on questions such as crop yields and cash income, because they assume that tax will increase if they report higher crop yield and income. Also, they expressed their frustration with previous interviews by different organizations and individuals which left them with lots of promise. Over all, it took three months for the enumerators to interview 204 farmers from the 17 PAs.

However, when farmers do not appear for the interview as scheduled, a substitution was made with another farmer, from those 20 farmers picked by randomization. If farmers were not willing to answer some of the questions asked, their response was considered as missing data. Since there were more than two hundred farmers interviewed for the study and about all of them responded, the missing data did not affect the outcome.

5. RESULTS AND DISCUSSION

This chapter presents the results of the land-use and socio-economic study carried out in the Alemaya Basin 1990/91. These results heavily depend on the field survey data collected according to the methodology designed in chapter 4 and literature review in chapter 3. It provides knowledge of the present land-use pattern, agriculture and forestry practices, and socio-economic conditions of the Basin. These are discussed in the subsequent sections in this chapter.

5.1. RESULTS OF THE LAND USE SURVEY

This survey identified the proportion of the different land-use types in the Basin according to land-use classification modified and adapted from Anderson 1976 (Table 11). The result summarized the different land-use types from 52 PSUs and 192 SSUs, which were sampled during the land-use survey. In each PSU there were 2 to 4 SSUs.

The proportion of land-use types was first calculated for each PSU by estimating a mean from the SSUs within that PSU. Then, the sample area of land-use types were estimated by adding the mean areas of land for the respective land-use types from the 52 PSUs sampled. Finally, proportion of land use type was estimated by dividing the sample area by the sample size(n). The results of the land-use survey is shown in table 11. The Basin was estimated to be 19,542 hectares as it was computed on the topographic map using a polar planimeter (Uibrig, 1989).

Table 11. Present land-use pattern Alemaya Basin 1990/91

Land-use type	Sample area (ha)	% sample area	Land area (ha)
Rural/semi-urban	3.72	7.06	1,380.00
Resident	3.09	5.87	1,147.00
Transport	0.63	1.19	233.00
Agriculture[1]	31.99	60.73	11,867.00
Annual	19.38	36.78	7,188.00
Perennial	2.23	4.23	827.00
Annual/pern.	7.52	14.27	2,788.00
Fallow	2.87	5.45	1,064.00
Pasture	4.76	9.04	1,766.00
Forest	2.91	5.52	1,079.00
Natural	0.35	0.66	129.00
Planted	2.56	4.86	950.00
Bushland	3.69	7.00	1,368.00
Water	3.88	7.37	1,441.00
Wasteland	1.73	3.28	641.00
Total	52.68	100	19,542.00

1/ Agroforestry sample area is 8.01 ha or 2,971.00 hectares and is included in annual/perennial agricultural and planted forest types.

As it exists today, (table 11) agriculture accounted for about 61 percent of the Basin, confirming subsistence farming as the main activity in the Basin. Pasture land, which is the source of livestock feed accounted for 9 percent of the Basin.

Forest land, which is the source of fuelwood and poles covered about 6 percent of the Basin. Bushlands, which is another source of fuelwood and grazing, accounted for some 7 percent of the Basin. The survey also identified agroforestry land-use types and it covered about 15 percent of the Basin.

Rural and semi-urban areas accounted for 7 percent and the remaining 11 percent were water bodies and wastelands.

Besides identifying the different land-use types in the Basin, the degree of inclination or slope was also considered. It is the most essential physical property of land in the Basin to characterize its suitability for tillage.

To characterize land-use types into different slope classes the 52 PSU were sorted into four slope classes: flat (0-4 percent), gentle (5-7 percent), moderate (8-30 percent) and severe (31+ percent). Then the land areas within each slope class was calculated. The distribution of land-use types in the different slope classes is shown in table 12.

Table 12. Proportion of land-use types in the different slope classes in hectares in the Alemaya Basin (1990/91)

Land-use type	Land area (ha)	Slope classes (ha)			
		Flat (0-4%)	Gentle (5-7%)	Moderate (8-30%)	Severe (31+%)
Rural/semi-urban	1,380	104	746	471	59
Resident	1,147	-	694	401	52
Transport	233	104	52	70	7
Agriculture1/	11,867	1,306	5,553	4,478	530
Annual	7,193	1,095	3,671	2,153	274
Perennial	827	26	200	519	82
Annual/pern.	2,788	68	1,124	1,418	178
Fallow	1,065	119	556	390	-
Pasture	1,766	350	782	564	70
Forest	1,079	-	223	578	278
Natural	129	-	4	33	92
Planted	950	-	215	549	186
Bushland	1,368	-	45	452	871
Water	1,441	488	905	22	26
Wasteland	641	7	78	515	41
Total	19,542	2,255	8,332	7,080	1,875

Gentle slopes account for about 43 percent, while moderate slope covers 36 percent. Flat lands represent about 12 percent and severe slope about 10 percent of the Basin. Most of the Agricultural lands (about 95 percent or 11,337 hectares) are located on flat to moderate slopes while all forest lands (1079 hectares) are on moderate to steep slopes.

The proportion of land under agroforestry land-use is also classified into the following slope classes. Some 85 hectares is flat land, about 1458 hectares moderate slope and the remaining 211 hectares is steep slope class.

The survey indicates that about 46 percent or 8,955 hectares of the Basin is located on moderate to severe slope (i.e., > 8 percent slope) which needs some form of soil conservation measure to keep production from these sites for a longer period. Thus, terracing and agroforestry practices such as, alley cropping could be potential conservation measures to maintain and sustain the productivity of these sites in the Basin.

The study has also identified the variance for the associated land-uses to assess the efficiency of sampling in the survey. Lumping residential and transportation uses together, recognizing forest and bush as similar, and recognizing that agriculture and agroforestry are overlapping uses, we have five major aggregated categories of uses. The selection of 4 sample points per primary sampling unit was based on work in Canada and Oregon where there are larger units but also more uses. Also because of the availability of photo-survey, pre-stratification was possible in Canada and the US. A post-survey examination of the Alemaya sample results shows that the 4 sample-point design provided low relative variance in even minor land uses such as water or waste (Table 13). This suggests that, even more efficient sampling schemes might be found but 4 samples per PSU and 192 SSU's gives adequate precision and coverage. More efficient sampling designs, however, would depend on an improved basis for stratification or beforehand knowledge of variability of the subject matter to be studied.

Table 13. Variance associated with major and minor land-uses in percent.

	Land-use						
	Rural Urban	Agri.	Pasture	Forest	Bush	Water	Waste
% of area	7.06	60.73	9.04	5.52	7.00	7.37	3.28
% variance	0.09	0.35	0.11	0.10	0.10	0.10	0.02

5.2. RESULTS OF AGRICULTURE AND FORESTRY SURVEY

Historically as well as today, grain crops (cereals) and horticultural farming are the predominant land-use in the

Hararghe highlands. Livestock production is also important. Most of the natural vegetation in the area has been destroyed by human and livestock interference. According to the land-use system classification for the Ethiopian highlands (Hoekstra et.al., 1990), the Alemaya Basin is characterized as mixed cereal - livestock farming system, where most of the agriculture is practiced on flat to moderate slope lands.

Thus, in subsequent paragraphs the different farming practices, such as crop, livestock and tree production subsystems in the Alemaya Basin will be discussed. This is intended to give insight as to how the Basin functions at the present and thereby identify land use constraints and potentials of the Basin for future recommendations.

5.2.1. CROP PRODUCTION SUBSYSTEM

The major cereal crops grown are sorghum and maize. Wheat and barley are also cultivated to a limited extent. Sorghum (38 percent) and maize (34 percent) account for about 72 percent of the annual crop, and are the main stable food of the farmers in the Alemaya Basin. The leaves of these crops are removed for animal feed and the stalks used as a source of fuel and construction materials. With no crop residues added to the soil, the fertility status of the existing farm land is very low.

However, to some extent sorghum and maize are also cultivated with haricot beans and chat (Catha edulis). Mixed cropping accounts for 23 percent of the agricultural land and 14 percent of the Basin. The intercropping with haricot bean (a legume) is intended to increase food production and to improve the soil fertility. The intercropping with chat is done for cash, fuelwood and soil conservation. This traditional farming practice, carried out by the farmers in the Alemaya Basin in particular and the Hararghe highlands in general, is one of the agroforestry systems (alley cropping) in the Basin.

Root crops such as sweet potato are cultivated as a stable food by the farmers in the Alemaya Basin. Most of the time this crop is mixed with sorghum, maize and chat. It serves as ground cover for soil conservation purpose. It also survives with little water, and thus helps farmers through drought periods.

Vegetables such as cabbage, lettuce, onion, Irish potato, beets, and carrots are mainly grown as cash crops. They mostly require irrigation and are produced and marketed both to the domestic market, such as Harar and Dire Dawa, and exported to Djibouti by rail.

Chat is important cash crops both for export to Djibouti and Somalia and for the domestic market. Daily chewing of chat is also an indispensable ingredient of Kottu culture. Biologically as well as economically it is a very stable cash crop. Pests, diseases or climatic hazards do not seriously affect it (Poschen, 1987). Initially, cultivation of the shrub had been confined to terraces on the well-drained soils of the hillsides. However, due to high demand, it was extended to better land and intercropped with food crops. According to the present survey, chat accounted for 19 percent of the agricultural land and about 12 percent of the Basin.

Fruit crops such as peach and guava are mostly grown around homes for food and cash income. However, they cover a very limited area in the Basin. The potential for fruit crops, both biologically and economically, is high. Thus, introduction of fruit crops into the farming systems could help farmers improve their food production and cash flow.

Farming methods used by small-holder farmers are poorly developed and cultivation and harvesting is largely done by hand and simple farm tools, although, oxen plowing and tractor farming are gradually gaining significance. Thus, generally poor cultural practices coupled with degraded crop lands and other natural and socio-political factors have lead to low crop yields. Average yields are given in Table 14.

Table 14. Estimated average yields of the major crops in tons per hectare in the Alemaya Basin 1990/91

Types of crops	Yield tons/ha
Cereals	
Maize	1.64
Sorghum	1.55
Pulses	2.05
Vegetables	5.50
Sweet Potato	3.75
Chat	1.00

Source= Socio-economic survey 1990/91

Although average yields look good, the survey result (page 109, table 20) from farmers interviews indicate that food produced by most households was inadequate. Some 85 percent of the respondents replied that they did not produce enough food. Trends in Basin crop yields, summary estimated or measured between 1980 and 1990 are presented in Table 15.

Table 15. Crop yields in tons per hectare for major crops in Alemaya and Eastern Hararghe Highlands for periods between 1980's and 1990's.

Reference Area Year	Alemaya* (1980)	Alemaya* (1984)	Eastern* Hararghe (1982)	Eastern* Hararghe (1986)	Alemaya 1990/91
Sorghum	1.0	0.96	1.10	1.57	1.55
Maize	0.8	1.44	1.60	1.92	1.64
Pulses	-	-	-	-	2.05
Vegetables	5.0-8.0	-	-	-	5.50
Sweet potato	-	-	-	-	3.75
Chat	1.0	-	-	-	0.13
Methods:	Estimate	Estimate	Estimate	Sample Measured	Estimate

*Quoted after Poschen 1987, P.83.

When we see the crop yields for the different years (table 15), the yield of both sorghum and maize have increased from the early 1980's to mid 1986. But when we compare the yield estimated for 1990/91 with that of mid 1980's there is not significant difference for the yield of sorghum and maize. Howover, the yield increase for sorghum and maize from the early 1980's to mid 1980's could be attributed due to the use of limited improved technologies such as fertilizer.

Mean farm size in the Basin was 1.5 hectare in 1965, and 1.1 hectare in 1980 (Poschen 1987). The present survey showed the mean farm size to be 0.84 hectares as of 1990, a steady and substantial decline in farm size over a 25 year period. The range for the landholding was found to be 0.05-3.25 hectares per household in 1990 while it was 0.25-3.25 hectare in 1980. This will obviously contribute to differences in income per household because land is the most crucial production factor.

Farmers were asked during the survey, if they have ever purchased agricultural inputs. Of the 204 farmers sampled, 80 percent responded positively, while 20 percent did not. Of those who responded positively about half (53 percent) purchased fertilizer, the rest purchased a combination of fertilizers, pesticides and/or herbicides.

However, in the case of major pest outbreaks, for example, migrating locusts or army worms, which occur at irregular intervals, control is attempted by government agencies spraying pesticides from aircraft.

Another important source of fertilizer identified by the farmers was animal dung. The majority of the sampled farmers (94 percent) said they use animal dung as fertilizer, while only 6 percent did not, instead using it as fuel and/or for other purpose. Crop rotation was also identified as one of the cultural practices to improve the fertility of the soil. However, it was only practiced by 27 percent of the sampled farmers.

Intercropping is a very common cultural practice in the Alemaya Basin. It may increase crop yield or avoid climatic and market uncertainties. Some 89 percent of the respondents use intercropping, while 11 percent said they did not. The use of this practice makes the introduction of agroforestry practice easier.

Soil conservation is also the most important cultural practice used by the farmers to protect their soil from erosion. About 97 percent of the respondents said they use soil conservation practice on their farm, while only 3 percent did not. Farmers were further asked to identify the type of soil conservation measure they used: 36 percent responded that they use soil bunding, a combination of soil bunding and contour plowing was used by 10 percent of the respondents. Soil bunding and planting trees/grasses on the bunds was practiced by 19 percent, while 5 percent use a combination of soil bunding, contour plowing and planting trees/grasses. This shows that farmers are already aware of the need for conservation practices; however, trees are used to a limited extent, suggesting an opportunity to intensify this practice.

Finally farmers were asked to identify the major problems of crop production faced by the household. The results of farmers response to the problems of crop production in the Alemaya Basin is shown in table 16.

Table 16. Farmers response to the problems of crop production in the Alemaya Basin 1990/9

Major problems	Farmers response (%) and Number			
	Yes		No	
	%	Number	%	Number
Lack of fertilizer	89	182	11	22
Lack of cash	80	163	20	41
Lack of oxen	65	132	35	72
Insects	60	123	40	81
Shortage of rain	53	109	47	95
Lack of seed	47	96	53	108
Soil erosion	42	86	58	118
Wind	28	58	72	146
Lack of labor	27	55	73	149
Disease	27	55	73	149
Price too low	18	37	82	167
Wild animals	15	31	85	173
Lack of market	10	21	90	183
Flood	3	7	97	197
Frost	1	2	99	202
No problem	1	2	99	202

Source: Socio-economic survey in 1990/91

Lack of artificial fertilizer was identified as a major problem of crop production. Artificial fertilizers are used to a limited extent, because they are identified by the farmers as too expensive and too difficult to obtain. All artificial fertilizers are imported and the infrastructure to distribute them to rural areas is very poor.

Lack of cash to purchase agricultural inputs was also identified as one of the major problems. Oxen are one of those inputs required for draft power. In addition, fodder supply and grazing areas are limitations which hinders availability of oxen.

Shortage of rain, lack of seed, and soil erosion are also identified as the problems of crop production in the Basin in the order of importance as shown in the table 16.

5.2.2. LIVESTOCK PRODUCTION SUBSYSTEM

Livestock in the Alemaya Basin are used for food, income, draft power, and transport. In the study area, the important domestic animals are cattle, sheep, goats, and donkeys. The average number of livestock per household in 1990/91 is given in table 17.

On the average, there are 2.68 head of cattle per household. Cattle provide inputs for crop production, like draft power and manure. They also provide milk for the farm household and bring a cash return. It is a common phenomena that a household fatten at least one ox/bull for cash. Sheep and goats are reared second only to cattle for meat and cash.

Among the draft animals, donkeys are the only means of transportation other than human shoulders. Their contribution to the rural development is very significant where infrastructure is poorly developed.

Table 17. Development of Livestock per household in the Alemaya Basin between 1980-1990/91.

Livestock	Years	
	1980*	1990/91
	Number	Number
Cow	1.1	1.00
Ox/bull	0.7	0.68
Heifer	0.6	0.40
Calf	0.2	0.60
Cattle	2.6	2.68
Goat	1.2	1.90
Sheep	1.0	
Donkey	0.3	0.50
Non-cattle	2.5	2.40

Source: Socio-economic survey 1990/91
* Quoted after Poschen 1987

When we see the livestock development in the Alemaya Basin between 1980 and 1990/91 (table 17) the number of cattle per household has remained constant i.e. from 2.60 to 2.68 in absolute numbers. This shows that there is not much difference in the absolute number of animals per household during the last decade.

Farmers were also asked to rank the type of livestock feeding in the Basin. Some 45 percent responded that tethering was the most important, 34 percent responded that open grazing on crop residues was regularly used, and stall feeding as the last at 21 percent. Thus, the survey results verified that the tethering system is the major livestock feeding practice in the Hararghe highlands, a finding earlier identified by Poschen 1987 and Hoekstra et.al., 1990.

To identify the type of feed for the livestock, farmers were asked what they supply to their livestock. Some 32 percent replied that they use a combination of tree leaves, grasses and crop residues. Another 28 percent said, they supply a combination of grasses and crop residues. Some 13 percent identified a combination of tree leaves and crop residues. The remaining 27 percent identified a single feed type or different combination than above which includes in each case less than 10 percent of the respondents. From the results above we can see that farmers do not use purchased feed, a practice which would incur extra expense on the household.

Further, farmers were asked to rank the types of livestock feed they provide to their livestock. Some 62 percent identified crop and grain residues as the most important feed, 51 percent identified grass and range products as regularly used and 31 percent identified tree leaves as occasionally used. From the results above, we can see that farmers depend heavily on crop residues, a low quality feed. Thus, it is safe to speculate that the type of feed can influence the livestock structure in the Basin, hence farmers tend to keep more cattle than sheep and goats, which can use low quality feed. This conclusion also fits the results of the survey for livestock possession per household, showing more cattle than sheep and goats per household (table 17).

Finally, farmers were asked to identify the major problems of livestock production. Farmers response to the problems of livestock production is shown in table 18.

Table 18. Farmers response to the problems of livestock production in the Alemaya Basin 1990/91

Major problems	Farmers response % and numbers			
	Yes		No	
	%	Number	%	Number
Lack of grazing area	76	154	24	50
Shortage of forage/feed	67	137	33	67
Disease	47	95	53	109
Water shortage	30	62	70	142
External parasite	30	61	70	143
Lack of market	8	17	92	187
Low price for animals	6	13	94	191

Source: Socio-economic survey 1990/91

The problems of livestock production according to the response of farmers are prioritized as follows. Some 76 percent identified lack of grazing area as a primary problem, followed by shortage of forage/feed by 67 percent. Animal disease was identified as the third problem by 47 percent of the respondents, water shortage as the fourth problem with 30 percent, and external parasites as fifth problem with 30 percent of the respondents.

Farmers were also asked if lack of market and low price for livestock were major problems. Some 92 percent of the respondents said they do not have a marketing problem, and 94 percent said that price was not a problem either. This indicates that there is a market for livestock production in the region. Thus, this could encourage farmers to increase the livestock production, hence household income, by improving the supply of fodder from their farm, through agroforestry practice.

5.2.3. TREE PRODUCTION SUBSYSTEM

Forest land includes natural and man-made forests. Only 0.66 percent of the total Basin remains under natural forest cover. Natural forests are found on steep slope areas and tree stocking is light, the result of long exploitation by man. Grazing is common in natural forests. Junipers procera is one of the remnant species and it is mainly used for timber and pole production. It is not browzed by cattle. There are also a number of natural tree species remaining on the crop and grazing fields for use as fuelwood, shade and fodder. These are: Cordia africana, Olea africana, Acacia albida, Croton macrostachys , Calpurnia aurea, and Vernonia amygdalina.

Man-made forest is mostly found in moderate to steep sloping areas. They consist of woodlots, and roadside and gully plantings. The most common tree species are _Eucalyptus camaldulensis_, _E. globulus_, _E. saligna_ and _Schnus molle_. These man-made forests are established through food-for-work programs organized by the Community Forest Department of the Ministry of Agriculture (page 22). This tree planting program is planned and organized at the regional level without involving the farmers at the grass roots level, yet the doers and end-users of the program. This approach has left the impression in the minds of the farmers that tree planting is an activity imposed by the government and not the responsibility of the farmers. This attitude, in turn, leads to the low survival due to lack of care for newly planted seedlings.

Trees and their various spatial arrangements were also recorded in the land-use survey to identify the different agroforestry practices in the Basin. Accordingly, home garden planting, trees on farm and pasture lands, trees along farm borders serving as living fences and shelter belts, and agroforests (woodlots) are found as common agroforestry practices. For detailed information on landscape niches, species composition and agroforestry practices, see appendix 3. The existence of these different agroforestry practices increases the options and potential to bring more trees into farming systems.

From farmers interviewed, it has been found that there is a shortage of woodfuel as a source of energy in the Basin. Most of the farmers (about 91 percent) identified crop residue to be the main source of energy, followed by cow dung as the second source (50 percent). Both crop residues and cow dung could improve the organic matter and content of the soil if left on the field. However, the shortage of fuelwood in the Basin has made it difficult if not impossible to shift the pressure from these resources at present. This condition could be improved somewhat by producing more trees in the Basin through the introduction of agroforestry practices, thus leaving more crop residues and cow dung for soil improvement.

Most farmers (about 81 percent) have also foreseen future difficulties in meeting their fuelwood needs. The reason they identified was diminishing fuelwood supply in the Basin which increases the distance to collect fuelwood. This will lead to a competition for time and labor otherwise available for agricultural production of the household. Thus, this situation can force or convince farmers to plant more trees on their farm.

Farmers were further asked how they supply their needs for building poles and sawn wood. The major sources they identified were purchases from other farmers or the market place, or gifts from the community or individuals. The major problems identified were costs and distance to sources.

Most farmers (about 63 percent) stated that they had enough shade trees on their farms. However, they were still interested in planting more shade trees on their home compound and on the farm. Around home compounds they could bring in more fruit trees such as peaches and mangos, which could serve both as shade and a source of food and cash. The pruned branches from these fruit trees can be used as fuelwood.

Wind damage is identified as a problem by most of the farmers (72 percent). Thus, it is possible to introduce trees along farm borders with single story to serve as windbreaks and produce poles and timber, or to use double-story trees for production of poles, timber from upper story and fodder from under story. The double-story trees can also serve as living fences, still another form of agroforestry.

Soil erosion was also identified as a problem by about half of the farmers (54 percent); however, most of the households did not plant trees to protect their farm from erosion. Thus, alley cropping, with alleys parallel to contours, could reduce soil erosion in the Basin.

Finally, farmers were asked to identify the major problems of tree production on their farm. Table 19 show farmers response to major problems of tree production in the Basin.

Table 19. Farmers response to the problems of tree production in the Alemaya Basin.

Major problems	Farmers response	
	%	Number
No seedlings	56	109
No preferred species	1	2
Labor constraint	2	4
No land	26	52
Insecurity of land and tree tenure	2	4
Others	6	11
None	7	14
	100	196

In addition to other problems the farmers identified lack of seedlings (about 56 percent) and shortage of land (some 26 percent) as problems of tree planting. To overcome in part the land shortage problem calls for the application of agroforestry practices, which integrate more trees into the farming system.

Insecurity of land and tree tenure were not identified as a problem of tree planting by the farmer (only 2 percent). The probable reason for this could be the change in government policy in March 1990, which brought the country from a socialist-oriented economy to a mixed economy. The survey overlapped this change. This new policy has allowed the dismantling of cooperative farms and encouraged private farming.

5.3. RESULTS OF THE SOCIO-ECONOMIC SURVEY

According to the objectives of the study, the different hypotheses concerning socio-economic conditions laid down in chapter 4 (page 78) were tested for association using a chi-square test. To determine association, data were classified into bivariate (two variable) tables. Then the independent and dependent variables were carefully defined. If data had not been previously grouped, categories were determined at this point. The results of the chi-square test for each of the hypothesis is given below.

Hypothesis 1: Household food security affects the tree planting decision of farmers in the Basin.

The amount of food produced each year by the household was considered as an independent variable measuring food security. A farmer response to this question is categorized in one of the three ways (1) household produces enough food for the family consumption; (2) household produces not enough food for the family consumption; (3) household produces a surplus of food beyond family consumption. The dependent variable, farmers response whether or not they plant trees was categorized 1=yes, household plants trees; and 0=no, household does not plant trees.

A total of 204 farmers were surveyed and of this 201 farmers responded. The number and percent (in parenthesis) of farmers in each of the three categories is shown in table 20.

Table 20. Association of household food security and tree planting in the Alemaya Basin 1990/91.

Food security	Response to tree planting number of farmers/percent		
	No	Yes	Total
1. Enough	16 (8)	14 (7)	30 (15)
2. Not enough	97 (48)	74 (37)	171 (85)
3. Surplus	-	-	-
Total	113 (56)	88 (44)	201 (100)

In the first category, with about 15 percent of the sample, 8 percent responded they did not plant trees, while 7 percent said they did, a ratio of 1:1. In the second category, with about 85 percent of the respondents, 48 percent did not plant trees while 37 percent did, a ratio of 4:3. There were no respondents in the third category, because no farmer indicated that his household produced surplus food. When we see the marginal total for tree planting, there are 113 (56 percent) people who did not plant trees, while 88 (44 percent) of the people did plant trees.

When we see the results of the chi-square statistics, the value of the chi-square is not significant (0.119), which suggests no association between household food security and tree planting by farmers (P=0.73).

Hypothesis 2: Household income affects the tree planting decision of farmers in the Basin.

First, total income of a farm household was calculated by adding incomes from crops, livestock, trees and other sources. Then total income was divided into four quartiles creating four income classes or categories (table 20). The dependent variable, whether or not farmers plant trees, was categorized as 1=yes and 0=no.

A total of 204 farmers were surveyed, and 201 responded. The number and percent of farmers in each of the four categories is shown in table 21.

Table 21. Association of household income and tree planting in the Alemaya Basin 1990/91

Income class in ETBirr	Response to tree planting number of farmers/percent		
	No	Yes	Total
Class 1 681 or <	34 (17)	17 (8)	50 (25)
Class 2 682-1041	26 (13)	24 (12)	50 (25)
Class 3 1042-1600	27 (13)	23 (12)	50 (25)
Class 4 >1600	26 (13)	24 (12)	50 (25)
Total	113 (56)	88 44	201 (100)

Of the total 25 percent of the lowest income category 17 percent responded that they did not plant trees while 8 percent did plant trees, a ratio of 2:1. The proportion of people in the other 3 income categories, have a ratio of 1:1.

The results of the chi-square statistics showed that, the value of the chi-square is not large enough (3.085), to support the conclusion that there is an association between household income and tree planting (P=0.379). However, it appears from these data that families with low income are less likely to plant trees than those unstressed families.

<u>Hypothesis 3:</u> Family size affects the tree planting decision of farmers in the Alemaya Basin.

Family size was calculated by adding the number people in all age groups who live in each household. It was then divided into three categories (table 22). The dependent variable, whether or not farmers plant trees was categorized as 1 = yes and 0 =no.

A total of 204 farmers were surveyed and of this 200 farmers responded. The number and percent of farmers in each of the three categories is shown in table 22.

Table 22. Association of family size and tree planting in the Alemaya Basin in 1990/91

Family size	Response to tree planting number of farmers/percent		
	No	Yes	Total
1 - 4	29 (14)	12 (6)	41 (20)
5 - 8	68 (34)	52 (26)	120 (60)
> 8	15 (8)	24 (12)	39 (20)
Total	112 (56)	88 (44)	200 (100)

Some 20 percent of the respondents fell into the smallest sized family group. Of this 14 percent did not plant trees, while 6 percent did, a ration of 2:1. Some 60 percent of the respondents fell into the middle-sized family group. Of this 34 percent did not plant trees, while 26 percent did plant trees, a ratio of 1.3:1. For the largest family-size class, 8 percent of the respondents did not plant trees, while 12 percent did, a ratio of 1:1.7.

The results of the chi-square statistics showed that, the value of the chi-square is large enough (8.501), to support the conclusion that, there is association between family size and tree planting (P=0.014). Thus, this supports the notion that as family size increases more farmers tend to plant trees.

Hypothesis 4: Farm size affects the tree planting decision of farmers in the Alemaya Basin.

Total holding of the household was calculated by adding land for the farmstead, for annual and perennial croplands, and for grazing and fallow lands. The land holding was divided into four categories (table 23). Farmers response, whether or not they plant trees, was categorized as 1 = yes and 0 = no.

A total of 204 farmers were sampled and 201 responded. The number and percent of farmers in each of the four categories and their responses are shown in table 23.

Table 23 Association of farm size and tree planting in the Alemaya Basin 1990/91

Farm size	Response to tree planting number of farmers/percent		
	No	Yes	Total
Category 1 < or = .5 ha	44 (22)	25 (12)	69 (34)
Category 2 .5 - .7 ha	20 (10)	13 (7)	33 (17)
Category 3 .7 - 1.05 ha	27 (13)	24 (12)	51 (25)
Category 4 > 1.05 ha	22 (11)	26 (13)	48 (24)
Total	113 (56)	88 (44)	201 (100)

In the smallest farm size, 22 percent did not plant trees, while 12 percent did, a ratio of 1.76:1. In the next farm size group 10 percent did not plant tree while 7 percent did, a ratio of 1.5:1. In the two largest farm-size groups, the ratio of the respondents who planted trees and who did not is almost 1:1.

The value of the chi-square is not large enough (4.182) to suggest an association between farm size and tree planting (P=0.242). However, it appears from these data that farmers with the smallest farm size tend not to plant trees.

<u>Hypothesis 5:</u> Farmers' knowledge of forest policy affects their decision on tree planting in the Basin.

Farmers were asked whether or not they know the various forest laws and regulations of the country, suggesting that their knowledge about forest policy might influence tree planting. Thus, this variable has two categories depending on whether the farmer is knowledgeable or not, i.e. 1 = yes and 0 = no. The farmers response whether or not they plant trees was categorized as 1 = yes and 0 = no.

A total of 204 farmers were sampled, and of this 201 responded. The number and percent of farmers in each of the two categories is shown in table 24.

Table 24. Association of farmers' knowledge of forest policy and tree planting in the Alemaya Basin in 1990/91

Familiarity with policy	Response to tree planting number of farmers/percent		
	No	Yes	Total
None	67 (33)	47 (24)	114 (57)
Familiar	46 (23)	41 (20)	87 (43)
Total	113 (56)	88 (44)	201 (100)

From the table we can see that 57 percent of the respondents do not understand the forest policy of the country. Of these 33 percent did not plant trees, while 23 percent did, a ratio of 1.4:1. Those farmers who responded that they are familiar with forest policy account for 43 percent; the ratio of those who planted trees and who did not is almost 1:1.

The value of the chi-square is small (0.697), which supports the conclusion that there is no significant association between farmers knowledge of forest policy and their decision on tree planting (P=0.404).

<u>Hypothesis 6:</u> Forestry extension service in the district affects farmers tree planting decision in the Alemaya Basin.

Farmers were asked whether or not they obtain forestry extension service from the Ministry of Agriculture in the form of material support, such as free seedlings, hoes, etc. Their response to this question was recorded in two categories, 1 indicates those who get extension service, and 0 indicates those who do not. Farmers response whether or not they plant trees was categorized as 1 = yes, and 0 = no.

A total of 204 farmers were surveyed and 200 responded. The number of farmers and their responses are shown in table 25.

Table 25. Association of forestry extension and tree planting in the Alemaya Basin 1990/91

Forestry extension service	Response to tree planting number of farmers/percent		
	No	Yes	Total
Received	57 (28)	64 (32)	121 (60)
Not received	56 (28)	23 (12)	79 (40)
Total	113 (56)	87 (44)	200 (100)

Of the farmers who do not receive extension service, 28 percent did not plant trees, while 12 percent did, a ratio of 2.43:1. However, when we see the response of farmers who do receive extension service, 28 percent do not plant trees, while 32 percent do plant trees, a ratio of 1:1.12, which is almost 1:1.

The chi-square value is large enough (10.996) to support the conclusion that there is a significant association between forestry extension service and tree planting (P=0.001). Thus, this suggests that households that receive extension service, more farmers tend to plant trees on their farms.

<u>Hypothesis 7:</u> The tree tenure policy in the country affects farmers decision on tree planting in the Alemaya Basin.

Farmers were asked during the survey whether or not they have the right to harvest and use the trees they have planted on their farm. Their response was categorized in two groups: 1=yes, household has the right to cut, 0=no, household has no right to cut. The farmers response whether or not they plant trees was categorized as 1 = yes and 0 = no.

A total of 204 farmers were questioned, and 200 responded. The number of farmers and their response is shown in table 26.

Table 26. Association of tree tenure policy and tree planting in the Alemaya Basin 1990/91

Tree tenure	Response to tree planting number of farmers/percent		
	No	Yes	Total
Have right	75 (37)	69 (34)	144 (71)
No right	38 (19)	19 (10)	57 (29)
Total	113 (56)	88 (44)	201 (100)

Some, 71 percent responded they do have the right to cut and use trees. Of this 34 percent plant trees, while 37 percent do not, a ratio of almost 1:1. Those farmers who believe they do not have the right to cut and use trees account for 29 percent of the respondents. Of this 10 percent plant trees, while 19 percent did not, a ratio of 1:2.

The value of the chi-square is not large enough (3.528) to support the conclusion that, there is a significant association between farmers knowledge of tree tenure policy and tree planting (P=0.06). This suggests,statistically at least, that the tree tenure policy of the country does not have influence on farmers' decision on tree planting. However, this finding could be masked by the change in the government policy in March 1990 towards a mixed economy which allowed the dismantling of cooperative farms and encouraged private farming.

From the above analysis of individual hypotheses, family size and forestry extension service have shown a significant association with tree planting. The other independent variables, such as household food security, household income, farm size, knowledge of farmers about forest policy and tree tenure were found to be not significant.

However, the above significant associations between the individual independent variables and the dependent variable do not tell us much about the importance or strength of the relationship. Thus, this requires a further investigation among the various independent variables and the dependent variable to see if the independent variables are correlated and also to identify the most important ones which can influence farmers' decision on tree planting. Therefore, logistic regression and log-linear analysis was carried out for continuous and discrete variables, respectively. The maximum likelihood estimates thus derived will tell us the unique contribution of the independent variables to the dependent variable.

The logistic regression was used to find if there is interaction between continuous independent variables, such as household income, family size and farm size and to see if this interaction influences the tree planting decision of the farmers in the Alemaya Basin. The log-linear analysis was done to find interaction between discrete independent variables, such as household food security, forestry policy, forestry extension and tree tenure and to see if this interaction influences farmers' decisions to plant trees in the Basin. A summary of results of the maximum likelihood estimates of the logistic regression and log-linear analysis are given in appendix 4.

From the analysis of the logistic regression family size with chi-square value 5.98 (P=0.015) and farm size with 3.34

(P=0.067) were found to be the important variables that can influences a farmers' decision towards tree planting in the Alemaya Basin. Thus, based on the analysis the following logistic regression model was developed to describe farmers' decisions toward tree planting.

Logistic regression function model:

$$\log \frac{P}{P-1} = b_0 + b_1\, x1 + b_2\, x2 + E$$

where:

P = the probability of a farmer's decision to plant

b_0 = intercept

b_1 = parameter estimator of family size

b_2 = parameter estimator of farm size

x1 = value of independent variable family size

x2 = value of independent variable farm size

E = error term

Assuming the E = 0, the logistic regression for the model is:

$$\log \frac{P}{P-1} = b_0 + b_1 x1 + b_2 x2$$

Thus, by fitting the value of the parameters and the corresponding independent variables from the results of the analysis, the logistic regression function model for describing the tree planting decision of farmers in the Alemaya Basin is as follows.

$$\log \frac{P}{P - 1} = 2.91 - 0.325 \text{ Family size} - 1.60 \text{ Farm size.}$$

The results of the log-linear analysis showed that there is a significant association between tree planting decisions of farmers and forestry extension service, with a chi-square value of 4.74 (P=0.029). Thus, this test confirm the result obtained in the individual hypothesis test (page 117). However, it was not possible to include the parameter estimates of extension service in the logistic regression model, because this result is based on log-linear analysis.

In summary, further investigation of the study showed that the main reasons for farmers not planting trees were related to lack of seedlings (which are provided by the forestry extension service). A second influence was farm size which is shrinking due to increasing population in the Basin. Thus, this confirms the finding of the regression analysis and strengthens the basis to propose alternative solutions to the problem. Family size probably (labor supply) was also shown to have a significant impact.

However we need to realize that the change in government, which occurred after the completion of this survey, could have a considerable effect on the outcome of this study because of the policy changes made since then. Thus, this could affect farmers attitudes towards tree planting. Also, farmers responses to some of the questions could have been influenced by social or political considerations. Thus, considering the political and social changes taking place in the country, suggests the need to update this study before making any major policy changes.

6. CHARACTERIZE A DESIRED STATE OF SUSTAINABLE AGRICULTURE AND FORESTRY FOR THE BASIN

6.1. INTRODUCTION

The results of the land use and socio-economic survey as well as personal observations, plus existing sources of information, show that population is increasing, farm size is decreasing, and marginal lands are being converted to agricultural production. Farmers are using crop residues for livestock feed and fuel, leaving little to return to the soil. As a result of declining soil fertility and lack of appropriate technology, there can be no substantial crop and animal yield increase to feed the growing population of the Basin.

Moreover, soil erosion is accelerating resulting in heavy sedimentation which reduces the size of water bodies in the Basin as well as effective farm size and further reduces productivity of upland farmlands. Siltation of the water bodies reduces potential irrigation by the farmers and as well as drinking water by the urban settlements at Alemaya and Harar city.

The effort of farmers trying to sustain their livelihood through the use of traditional farming has directly or indirectly led to degradation of the production potential. If this trend continues it is possible to speculate that the production capacity of the Basin will reach a point where it can no longer sustain the existing population, much less a growing one. This calls for alternatives systems which can reverse the degradation of the Basin. Against this background are the uncertainties associated with political change, surely a problem that must be resolved quickly.

Sustainable development is difficult to define. It is used differently by different people, depending upon their backgrounds, purposes and views. However, sustainable development is defined here as development involving changes in the production and/or distribution of desired goods and services which result, for a given target population, in increased welfare that can be sustained over time (Gregerson and Lundgren, 1990).

The emphasis in the above definition is on production with environmental protection in order to improve the well-being of people in a target population. It also focuses on those increases in desired goods and services that lead to increased welfare. Welfare relates to level and distribution of income, physical and mental health, food, education, housing, clothing recreational opportunities and many other factors. Sustainable development will enhances the capacity to utilize available resources effectively and efficiently over the long run to meet the needs of the present and future generations. Target population is a recognized group of people such as the national population of the country or the population of a given project region.

For a land-use system to be sustainable requires conservation not only of the soil but of the whole range of resources on which production depends. However, the most direct and primary requirement for sustainability is to maintain soil fertility. Thus, the long term maintenance of soil fertility, and hence the sustainability of agriculture and forestry is a distinguishing feature of agroforestry that needs to be emphasized (Young, 1989).

Therefore, to examine alternative technologies to achieve sustainable development in the Alemaya Basin, a hypothetical agriculture and forestry system will be proposed. The hypothetical model outlined here will be based on assumptions of existing government policies and technologies and partly from literature and partly from my field studies. The model will project the population in the Alemaya Basin and propose living standards for the farm household. Also projections will be made of crops, livestock and tree production using different levels of inputs, all of which are intended to identify appropriate technologies which can be adopted by the farmers in the Alemaya Basin to improve their situation.

6.2. PROJECTIONS OF POPULATION

Population growth is a major cause of environmental degradation. The accelerated population growth in Ethiopia, about 3 percent per annum, creates additional pressure on natural resources. The complete loss of forests and trees in the densely populated highland areas of the Northern parts of the country is a witness to this phenomena. This problem is no exception in the Hararghe Highlands and Alemaya Basin.

To understand the relationship between population pressure and natural resources and its influence on agricultural production and tree planting in the long run requires knowledge of the population growth in the Basin. The accuracy of population projections depends to a large extent on the assumptions one makes regarding the future course of fertility, mortality and migration. Also, these components of population growth change because of vagaries of nature and uncertainty in human behavior (CSA, 1988).

To prepare a population projection for the Alemaya Basin, assumptions regarding fertility and mortality are adapted from the Central Statistical Authority (CSA) (1985) in Ethiopia, which prepared population projections in Ethiopia from 1985 - 2035. There were three variants (i.e. high, medium and low) of population growth made for Ethiopia.

For the Alemaya Basin only the high variant is used. The assumptions made for the low variant regarding fertility has a target of reducing Total Fertility Rate (TFR) by 60 percent from 1995 to 2035, which is probably not achievable. Also, the medium variant assumes that some formal family planning will be launched to reduce fertility. It uses the same projection rates as the high variant for the period 1990 to 2000 and thereafter this projection used different rates of population growth, however, the differences are small. The assumptions made in regard to the initial size of the population and the levels in the components of the population growth for this study are as follows.

The total population for the Basin was extrapolated from the 1990/91 socio-economic surveys described earlier. The results from the survey for the average family size (6.5 persons)and the average farm size (0.84 ha) in the Basin are used to calculate the population for 1990, the base year of the projection. The population per hectare was estimated as 7.74 persons/ha and the total land area about 19,500 ha. From this the total population of the Basin was estimated as 155,000 persons.

The high variant assumes constant fertility with (TFR) 7.50 throughout the period of projection. Mortality was assumed an initial life expectancy of 45.0 years for males and 47.0 years for females, averaging 46.0 for projection purposes. Male and female life expectancy at birth improve by .25 percent every year until 2000 and thereafter at the rate of .50 per year until the end of the projection period. Migration was assumed nil in both cases (CSA, 1988).

The population growth for the Alemaya Basin is assumed to follow the net periodic population growth for all of Ethiopia. This in turn is calculated from population projection data provided by CSA in 1988. Based on this growth rate the Basin population is projected for the period 1990-2010. The result is shown in table 27. December 1990 is the base year with the initial population estimated at 155,000 persons.

Table 27. Population projection for the Alemaya Basin for the period 1990-2010.

Periods	**growth rate (%)***	**Basin population**
1990	2.87	155,000
1995	3.01	180,000
2000	3.21	210,000
2005	3.39	248,000
2010	3.57	296,000

Source: Socio-economic survey 1990/91
* Net periodic population growth rate of Ethiopia CSA 1988

The population of the Alemaya Basin is projected only for a period of 20 years (1990-2010) because the planning period for a tree planting project is assumed to be 20 years. In general, there are a lot of uncertainties in most developing countries, and Ethiopia is no exception, which force planning periods to be short. Thus, to project income or living standards for the population in the Alemaya Basin, a 20 years planning period will be used.

6.3. PROJECTION OF CROP, LIVESTOCK AND TREE PRODUCTION

Information on the potential of future yields of crops livestock and trees with present and alternative farming practices is essential. From this information, it is possible to estimate whether or not the production is sufficient to maintain and sustain the living standards of the growing population in that area.

Thus, to project the yield of crops, livestock and tree products in the Alemaya Basin required information on yields of the traditional farming practice and identified technologies that can help improve the problems of land use in the Basin were collected. Agroforestry has been identified as a potential technology to alleviate the problems of soil erosion, which leads to a decrease in crop yield, shortage of fodder and fuelwood in the Alemaya Basin.

There are a number of appropriate agroforestry technologies that can be applied to the farming system of the Hararghe Highlands to improve the low agricultural productivity and provide better ecological conditions. These are: alley farming, fodder tree planting; fruit trees around home gardens; trees as living fences; woodlot and farm boundary planting (Hoekstra et.al., 1990). However, for the purpose of the projection of crops, livestock and tree yields, alley cropping is chosen as one of the potential agroforestry practices.

This agroforestry practice is chosen because it has received a good deal of research attention and has shown great promise for sustainability (Kang et.al., 1981, 1985). Also, many research results have shown that alley cropping is a technology that could possibly contribute to solving some of the problems of soil erosion and land degradation (Kang et. al., 1985; Nair, 1989b; Young, 1989; Atta-krah, 1990). Therefore, it is believed that alley cropping can help reduce the soil erosion and land degradation that have threatened the survival of the farmers and future sustainability of the Alemaya Basin.

Thus, it is speculated that, by integrating alley cropping into the farming system of the Alemaya Basin, it is possible to maintain crop production, supply of fodder and fuelwood to the farm household on a sustainable basis. Also, given the current food shortage in Ethiopia and the inevitable population growth which will lead to a decreased farm size, a production technology that will not only allow maintenance of current levels of production, but also that sustains production at higher levels than at present is required. Hence, considering the above premises, the study has introduced alley cropping plus fertilizer as an alternative technology to increase production. However, the affordability and adoption is subject to government policy.

Therefore, the objective of this study is to determine whether or not it is beneficial for a farmer to adopt the different alternative technologies, such as, alley cropping and/or high input technologies, by making a comparison of the farmers return in the "with" and "without" situation.

In this analysis, it will be assumed that the existing land use practice will form the basis for the "without" situation, while two alternative technologies that will be proposed serve as the basis for the "with" situation. These alternative technologies include: (1) Alley cropping with *Leucaena leucocephala* with 4-meter width hedgerow spacing, (2) As (1) above + application of full recommended rate of chemical fertilizer.

Information required for this analysis on inputs such as seeds, seedlings, labor, materials and output of crop yields for the traditional and alternative technologies were partly estimated from the present land-use survey and partly from research conducted at the Alemaya University of Agriculture (AUA). Also, information was derived from literature from the Institute of Agricultural Research (IAR) in Ethiopia, International Center for Research in Agroforestry (ICRAF) in Kenya and International Institute of Tropical Agriculture (IITA) in Nigeria.

Traditional farming is defined as the cultivation of agricultural crops, such as, cereals and legumes and vegetables under the common farming systems of the Hararghe Highlands. Hoe culture is used for land preparation and little effort is put into soil conservation practice. No use is made of such inputs as improved seeds and fertilizer. In this study intercropping of maize and beans, one crop a year, represents traditional crop farming. Vegetable gardening, chat farming and livestock rearing are also considered as part of the traditional farming practice.

Alley cropping consists of hedgerows made up of fast growing leguminous trees spaced 4 m apart, with food crops cultivated in the alleys between. Hedgerows are oriented in an east-west direction to minimize shading and also parallel to contours to minimize erosion. The trees are periodically pruned, to prevent shading of the companion crop. Pruned foliage and small branches are incorporated into the soil as green manure. However, some portion of the foliage may be fed to livestock, particularly small ruminants (Kang et.al., 1981, 1985; Young, 1989; Atta Krah, 1990). In this study Leucaena leucocephala was chosen as tree species, because it provided best results at the AUA research center and is the most popular species for hedgerow intercropping in Africa.

Leucaena hedgerows within maize and bean fields will reduce the area available for cropping by about 30 percent. This assumes a 4-meter spacing of hedgerows each 1 meter wide. This spacing was adopted from the most promising alley cropping research at AUA (Bishaw, et.al., 1988).

Based on the research at Alemaya the recommended pruning height for leucaena hedgerows is 0.5m and two cuttings/year (Bishaw et.al, 1988). The higher biomass yield of Leucaena leucocephala at the third year and the decrease at the fourth year (see table 6) indicates that the coppicing ability of the species after successive pruning has been lowered. If longer coppicing periods are used it may lead to much lower biomass yield than has been indicated in the trial. Thus, suggesting the hedgerows have lost their vigor and should be replaced on a five year rotation.

Another promising alternative technology is the use of chemical fertilizer to increase yield. This technology involves application of recommended rates of nitrogen and phosphorus fertilizers on the maize and bean crops in addition to the leucaena alley cropping (Kang et. al., 1985; 1990).

To summarize from the land-use survey described previously, the average family farm in the Alemaya Basin is 0.84 ha in size, with average family size of 6.5 persons, i.e 2 adults (male and female) and 4.5 children. It is assumed that two of the children are above age 15. The average number of animals per household is estimated to be one ox/bull, one cow and 2 goat/sheep and a hen (table 16). Land-use of the average family farm is shown in table 28.

Table 28. Land allocation (area in ha) in the traditional farming and alley cropping in the Alemaya Basin.

Types of Land use	Traditional farming		Alley cropping	
Home stead	0.05		0.05	
Annual crops	0.60		0.60	
Cereals (Maize+Bean)		0.52		0.36
Leucaena hedgerows		-		0.16
Vegetable		0.08		0.08
Perennial crops	0.14		0.14	
Tree		0.02		0.02
Chat		0.12		0.12
Grazing	0.05		0.05	
Total	0.84		0.84	

Source: Socio-economic survey 1990/91

The alley cropping system used here takes about 30 percent of the land from the annual crops to plant the leucaena hedgerows. The high input technology introduces the use of fertilizer into maize/bean crops in combination with alley farming.

Available agricultural labor in the family assumes 250 working days/year and 6 working hours/day, which gives 1500 person hours for the man, 750 person hours per year for the woman and 750 person hours per child or 1500 person hours for 2 children above age 15. It is assumed that half of the woman's work hours go into the home and half the children hours are spent on school. Thus, from the above assumptions, there is a total of 3,750 person hours of available agricultural labor in the family per year. The market price of labor is estimated about 2 Ethiopian Birr (ETBirr)/day ($1.00 U.S. at the exchange rate of 1990/91), which is based on the average wage of daily laborer in Ethiopia.

Labor requirements for both traditional farming and alternative technologies, such as land preparation, sowing, planting seedlings, cultivation/weeding, fertilizer application, pruning and mulching are based on a cropping calendar developed for the Alemaya Basin (Appendix 5), based on personal experience and literature (Swinkels, 1991). The labor requirement for the traditional farming and alternative technologies is shown in Table 29.

Table 29. Labor requirements of traditional farming and alternative technologies per hectare and plot in the Alemaya Basin 1990/91.

	maize + beans	maize + beans + hedges	maize + bean + hedges + Fertilizer	Vegetable plot	Chat plot
Plot (m^2)	5200	5200	5200	800	1200
Family labor (Person-hrs)					
land prep.	500	500	500	500	500
sowing	150	150	150	-	-
planting	-	160	160	250	150
weeding	250	200	200	250	250
Fertilization/	-	-	150	-	-
manure	-	-	-	150	-
Pruning hedges	-	(60)(110)	(60)(110)	-	-
Harvesting	450	450	450	450	450
Total (ha)	1350	1630	1780	1600	1400
plot	(702)	(847.6)	(925.6)	(128)	(168)

The labor requirement estimated for land preparation, sowing and weeding is high because it is assumed that farmers use manual labor and hoes to prepare and cultivate the land. Also, planting rates for seedlings assume that farmers plant 38 trees/hr, and a total of 170 hours are needed for two prunings according to Swinkels (1991a).

Resource allocation of farm inputs (quantity and price) such as seeds, seedlings, manure, fertilizer hoe and machete for the traditional farming practice and alternative technologies is given in table 30.

Table 30. Resource required for the traditional farming practice and alternative technologies per hectare and plot.

Inputs	Quantity kg/ha or number	Price/kg or item (ETBirr)	Total Price/ha (ETBirr)	Price/plot (ETBirr)		
				Trad. (1)	Hedge (2)	Hedge+Fe. (3)
Seed						
maize	70	0.70	49.00	25.48	17.64	17.64
bean	20	0.80	16.00	8.32	5.76	5.76
Fertilizer						
Urea(N)	135	0.84	113.40	-	-	40.82
DAP(P_2O_5)	100	1.16	116.00	-	-	41.76
Seedlings	6000	0.05	300.00	-	48.00	48.00
Hoe	6	5.00	30.00	15.00	15.00	15.00
Machete	4	5.00	20.00	-	10.00	10.00
Total				48.80	96.40	178.98

The quantity of maize seed required for sowing is estimated based on the assumption of 150,000 plants/ha seeding rate by farmers which will be later thinned to 30,000 plants/ha (Poschen, 1987). The price of maize and bean seeds, hoe and machetes, are based on the market price of 1990/91. The estimated price for fertilizer and seedlings are prices subsidized by the government in that period.

The outputs of crop yields and livestock products with and without <u>Leucaena leucocephala</u> hedges and with additional use of chemical fertilizer are estimated from the results of the present survey and also from the Alley cropping research results at AUA and literature (Kang et.al., 1981, 1985; Swinkels, 1991b) and personal experience. The outputs of crop yield and livestock products for the traditional farming and improved technologies for initial year is shown in table 31.

Table 31. Crop yields (kg/ha) and livestock products and total price in ETBirr for the traditional farming and improved technologies initial year 1990/91.

Output	Quantity kg/ha & other units			Price / Unit/kg	Total price (ETBirr)		
	Trad.	Hedge	Hedge+Fr		Trad	Hedge	Hedge+Fr
Crop							
Maize	1,600	1,120	1,600	0.70	582.40	403.20	582.40
Bean	800	560	800	0.80	332.80	230.40	332.80
Vegetable	2,750	2,750	2,750	0.75	165.00	165.00	165.00
Chat	1,000	1,000	1,000	5.00	600.00	600.00	600.00
Crop residue	6,500	6,500	6,500	0.10	338.00	234.00	338.00
Livestock							
Ox/bull	.6 head	.6 head	.6 head	800/head	400.00	400.00	400.00
Sheep/goat	2 head	2 head	2 head	50/head	100.00	100.00	100.00
Cow(Milk)	300lt.	300lt.	300lt.	1.0/lt.	300.00	300.00	300.00
Hen(egg)	150pes	150pes	150ps.	0.25/ps.	37.50	37.50	37.50
TOTAL					2,855.70	2,470.10	2,855.70

The maize and bean yields from leucaena hedgerows are less by 30 percent from the traditional practice during the initial phase of introducing the technology, because the hedgerows occupy about 30 percent of the farm land. It is also assumed that the use of chemical fertilizers with hedgerows can compensate the crop yield loss caused by the displacement of leucaena hedgerows. At the initial period (1990/91), the output from livestock, vegetables and chat are assumed to be the same for the traditional and improved technologies.

The outputs of crop yields and biomass production with Leucaena leucocephala hedgerows and leucaena hedgrows plus use of chemical fertilizer for the period 1995 is extrapolated based on the research results of alley cropping experiment (table 9) adapted from southern Nigeria. It is assumed that alley cropping technology requires a minimum of 3-5 years to obtain useful results (Young et. al., 1990). Thus, using the estimated crop yields for the traditional farming from the present survey (table 31) and the estimated proportion of crop yields (1:3.08:4.92) for the different treatments of the alley cropping experiment from southern Nigeria, the outputs of crop yields with leucaena hedgerows and leucaena plus fertilizer is calculated. The results of the crop yields per hectare and plots for the period 1995 is shown in Table 32.

Table 32. Estimated crop yields with leucaena hedgerows and with leucaena hedgerows plus chemical fertilizer per hectare and plot for the year 1995.

Outputs	Quantity kg/ha	Price ETBirr /Kg	Price ETBirr Total income (ha)	Kg/plot*	Price/ plot
Leucaena					
Maize	4,928	0.70	3,449.60	1,774.08	1,241.86
Beans	1,600	0.80	1,280.00	576.00	460.80
Firewood	2,344	0.50	1,172.00	375.04	187.52
Sub-Total			5,901.60		1,890.18
Leucaena+Fer.					
Maize	7,872	0.70	5,510.40	2,833.92	1,983.74
Beans	2,400	0.80	1,920.00	864.00	691.20
Firewood	2,836	0.50	1,418.00	453.76	226.88
Sub-Total			8,848.40		2,901.82
Vegetable	2,750	0.75	2,062.50	220.00	165.00
Chat	1,000	5.00	5,000.00	120.00	600.00
Livestock					
Ox/bull	1 head	800/head	800.00	1 head	800.00
Sheep/goat	2 heads	50/head	100.00	2 heads	100.00
Cow(milk)	300 lt	1/lt	300.00	300 lt	300.00
Hen(egg)	150 pes.	0.25/pcs	75.50	150 pcs.	37.50
Sub-Total			8,300.00		2,002.50
Total Leucaena			14,201.6		3,892.68
Leu.+Fer.			17,148.4		4,904.32

* Maize and bean plots occupy .36 ha and leucaena hedgerows .16 ha.

Crop yields per plot was estimated by multiplying crop yield per hectare with size of the plot allocated for each activity. Firewood is assumed as one of the products from alley cropping, which account for forty percent of the dry matter production. It gives a substitute for crop residues which was used under the traditional farming as fuel. Thus, leaving the crop residue to add organic matter to the soil.

Also, livestock production is assumed to increase due to the improved technologies by the production of additional fodder and/or use of crop residues, thus ox/bull production increases by .32 units, while sheep/goat production remained two heads per household. The total output for the farm was calculated by adding the outputs for crops, vegetables, chat and livestock products estimated for the average farm size i.e, .84 ha.

To determine whether the proposed alternative technologies are more beneficial than traditional farming requires an economic analysis to compare benefits and costs. The economic analysis is carried out using annual farm budgets prepared for the traditional and improved technologies, respectively. Then, the annual extra costs and extra benefits of the leucaena hedgerow and leucaena hedgerow plus chemical fertilizer are calculated. Thus, only the difference in costs and benefits between improved technologies and traditional farming are considered to evaluate the return on the extra ETBirr invested. This valuation technique is used for this analysis, because the data at hand limit the use of other techniques.

The results of the input-output analysis for the traditional farming and improved technologies based on costs incurred for labor and inputs, and total income generated from crops and livestock are summarized in tables 33 and 34. These are used to calculate the annual extra costs and extra benefits for the analysis. The total farm income considered for the improved technologies is based on the outputs for the year 1995. Total cost and income per hectare were calculated based on the cost and income per farm estimated for the annual farm budget.

Table 33. Total cost (ETBirr) per farm and hectare for the traditional farm and improved technologies.

Farming Practice	Cost/farm (0.84 ha)*	Total cost/ha
Traditional		
Labor	1,996.00	2,376.19
Inputs	48.80	58.10
Total	2,044.80	2,434.29
Leucaena		
Labor	2,287.20	2,722.86
Inputs	96.40	114.76
Total	2,383.60	2,837.62
Leucaena + Fer		
Labor	2,443.20	2,908.57
Input	178.98	213.07
Total	2,622.18	3,121.64

* Average farm size 1990/91

Table 34. Total income (ETBirr) per hectare, per farm and person for the traditional farm and improved technologies.

Farming Practice	Total income (ha.)	Income per	
		Farm (.84 ha)	Person
Traditional	3,399.64	2,855.70	439.34
Leucaena (1)	2,904.59	2,470.10	380.02
(2)	4,634.14	3,892.68	598.87
Leucaena+Fer.			
(1)	3,399.64	2,855.70	439.34
(2)	5,838.48	4,904.32	754.51

(1) 1990/91 income; (2) 1995 income

To compare the difference in costs and benefits between the improved technologies and traditional farming, total cost and revenue increments for the programs were calculated. The result is shown in table 35.

Table 35. Total cost and revenue increments for programs per hectare.

Programs	Costs	Income	Increment Cost	Increment income	Marginal gain per unit expense
Traditional	2,434.29	3,399.64	-	-	
Leucaena	2,837.62	4,634.14	403.33	1,234.50	3.06
Leucaena+Fer.	3,121.64	5,838.48	284.02	1,204.34	4.24
			687.35	2,438.84	3.55

The results in table 35 show the return from the different alternative technologies per unit of cost. The alley cropping gives a return of 3.06 ETBirr for an extra ETBirr invested to bring in this technology. When we consider the technology which includes alley cropping plus chemical fertilizer, it gives a return of 4.24 ETBirr for the additional ETBirr invested to bring in this technology instead of alley cropping alone. A return of 3.55 ETBirr is achieved for the extra ETBirr invested by introducing the alley cropping plus chemical fertilizer technology instead of the traditional farming practice. This analysis shows that both technologies are profitable, however, the return for extra ETBirr invested is higher (4.24) for the alley cropping plus chemical fertilizer technology as compared to the alley cropping technology alone, suggesting the former technology to be the best if capital is available.

Apart from return per land unit from both labor and cash investment, returns per unit of cash invested is a useful parameter when cash is scarce. In this analysis, it is assumed cash is scarce and labor is not constrained, because it will be supplied from the family labor. To compare the cost of inputs and benefits between the improved technologies and traditional farming, cost of inputs and income increment for the program was calculated. The result is shown in table 36.

Table 36. Inputs cost and total revenue increment for programs per hectare

Programs	Input costs	Income	Increment cost	Increment income	Marginal gain per unit expense
Traditional	58.10	3,399.64	-	-	
Leucaena	114.76	4,634.14	56.66	1,234.50	21.79
Leucaena+Fer.	213.07	5,838.48	98.31	1,204.34	12.25
			154.97	2,438.84	15.74

In this case, alley cropping gives a return of 21.79 ETBirr for the extra ETBirr invested in this technology to purchase inputs, while alley cropping plus chemical fertilizer gives 12.25 ETBirr for the extra ETBirr invested in this technology. A return of 15.74 ETBirr is gained for the extra ETBirr invested by introducing alley cropping plus chemical fertilizer instead of traditional farming. This analysis shows that both technologies are profitable, however, the return for the extra dollar invested is higher (21.79 ETBirr) for the alley cropping technology, suggesting it to be the best option in this case.

6.4. PROJECTIONS OF LIVING STANDARDS

Projection of income per person, as an indicator of living standards, was estimated for a 20 year planning period for the Alemaya Basin. This projection was based on total farm income calculated for traditional farming and for improved technologies. It also takes into account projected population growth for the Basin (table 27). The results of the Income/person projection is shown in table 37 and Fig 7.

Table 37. Projection of income/person in ETBirr for 20 years with high yield assumption for the traditional farming and improved technologies.

Period	1990	1995	2000	2005	2010
Farm size	0.84	0.72	0.62	0.52	0.44
Income/person					
Traditional	439.34	376.56	324.27	271.97	230.13
Leucaena	380.02	513.32	442.03	370.73	313.70
Leucaena+Fer.	439.34	646.72	556.90	467.08	395.22

If traditional farming continues and population grows as it is currently, we can see that the production or income/person continues to decrease further exacerbating problems of soil fertility and soil erosion. Alley cropping technology actually reduces income/person in the initial period (Table 36). However, it shows an increase in income/person for two consecutive periods (i.e 1995 and 2000).

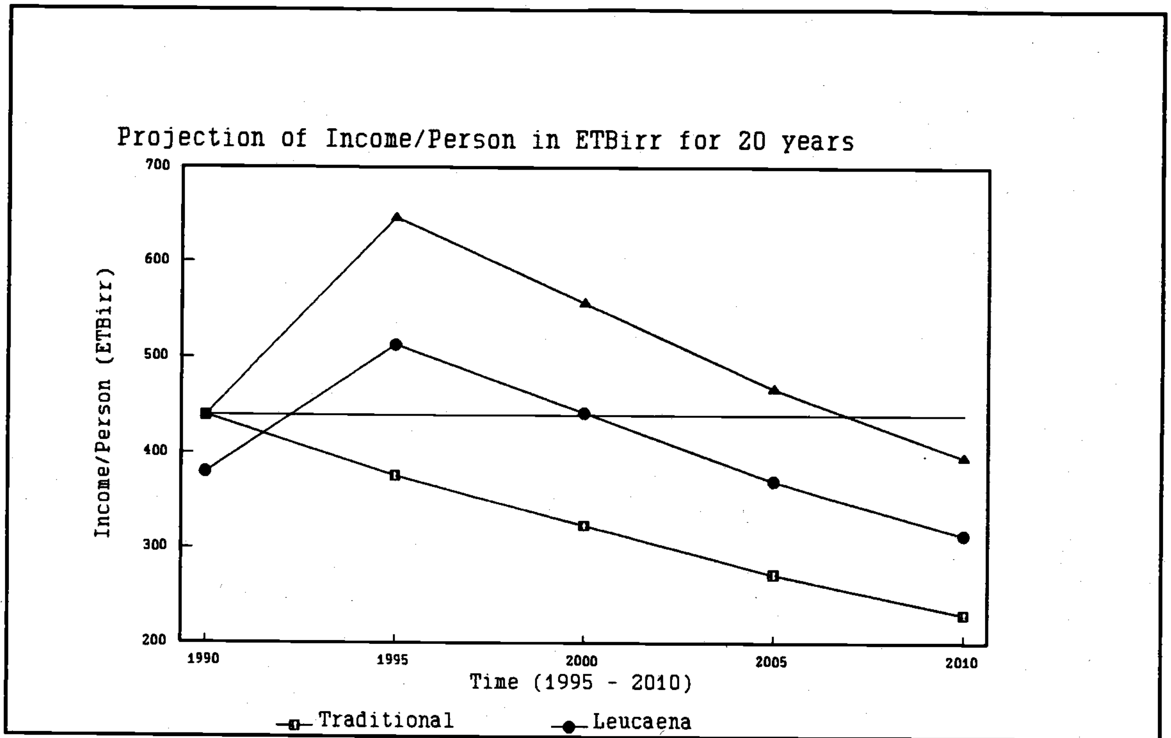


Fig 7. PROJECTION OF INCOME/PERSON IN ETBIRR FOR 20 YEARS WITH HIGH YIELD ASSUMPTION

From the year 2000 onwards alley cropping shows a decrease in income/person, but still a higher income than traditional farming. The probable reason is that, hedges will continue to exercise a positive effect on crop yield for sometime, offsetting the decrease in farm size resulting from population increases.

Taking the 1990/91 income per person for the traditional farming as a standard, the income/person for alley cropping plus chemical fertilizer technology remains above this level for 16 years and then goes down below this level at the end of the planning period i.e between year 2006 and 2010. Thus, fertilizer enhances productivity and income/person still more than the other alternatives. This shows that this technology is better than traditional and alley cropping technologies.

A sensitivity analysis was done assuming about 50 percent yield reduction for the alley cropping and alley cropping plus fertilizer technology. Thus, the proportion of yield increase was estimated as 1:1.5:2.5 for the traditional and improved technologies, respectively and was defined as low yield assumption. It was in turn used to estimate yields and respective revenues to compare the return from the traditional and improved technologies and to see the effect on the economic analysis. The projection of income/person in ETBirr for a 20 year planning period (1990-2010) with low yield assumption for the Leucaena and Leucaena plus fertilizer technologies is shown in table 38.

Table 38. Projection of income/person in ETBirr for 20 years with low yield assumption for the traditional farming and imprved technologies.

Period	1990	1995	2000	2005	2010
Farm size	0.84	0.72	0.62	0.52	0.44
<u>Income/person</u>					
Traditional	439.34	376.56	324.27	271.97	230.13
Leucaena	380.02	362.32	312.00	261.68	221.48
Leucaena+Fer.	439.34	429.02	369.43	309.89	262.18

It appears the outcome of economic analysis is extremly senstive to the yield decrease on the improved technologies. The 50 percent yield decrease sharply drops income/person for the projection period.

From this study, we can conclude that, to maintain the production of the Basin at its present state, adoption of alley cropping technology with high yield assumption could help to maintain production for about 10 years, while adoption of alley cropping plus chemical fertilizer helps to maintain the production for at least 16 years, provided sufficient cash is available for the farmers in the form of credit to buy the inputs required to adopt these technologies. However, when we consider the low yield assumption it is not possible to maintain the current income/person at present levels. Both the traditional and improved technologies remained below the current income/person, the leucaena plus fertilizer technology was still relatively better than the other alternatives.

Inspite of the short term benifits of high yield alley cropping this study also suggests a search for alternative policies to keep the Basin population at a level it can maintain, because improved technologies alone can not sustain production in the Basin. Thus, one of the appropriate policy options include stronger population control measures. Another option is a shift of the national economy from an agrarian society to an industrialized society. Both policies require long periods of time to implement.

Since Ethiopia is endowed with natural resources, such as minerals and oil, by developing the industrial sector to exploit these resources through cooperation of foreign investors, it can create jobs for people. This can attract the rural populations away from farms to new job sites including urban areas. Thus, the present open-market policy of the government can positively contribute to the industrial development of the country in the future. However, this will be realized only if there is peace and stability in the country, so that the scarce resources could be diverted for the development of the country. This is also equally important to foreign investors, because they have to make sure they get a return on the capital invested.

7. RECOMMENDATIONS AND CONCLUSIONS

7.1. GENERAL SUMMARY

The land-use study has shown scarcity of land resources, soil erosion and land degradation, shortage of fuelwood and fodder to be the major problems faced by farmers. The major contributing causes are increasing population pressures, poor farming practices, and lack of appropriate technology.

The socio-economic survey also identified family size, farm size and lack of forestry extension to be good predictors that hinder the tree planting practice in the Alemaya Basin. This suggests that availability of family labor and land have a positive correlation with farmers decision toward tree planting. This study also suggests that the forest extension policy and practice should be redesigned in such a way that a bottoms-up approach be made. This approach has been found to be successful in transferring new technologies to the farmers. Thus, involving farmers in the planning, design and implementation stages of tree planting is important. work.

Characterization of the desired state of sustainable agriculture and forestry for the Basin, based on the projections of population, crops, livestock, tree products and income have shown that adoption of alley cropping and/or alley cropping plus chemical fertilizers could maintain the income per person within the Basin for a 10 to 16 year period. This depends on the type of technology, availability of resources and adoption by the farmers. Thus, this study indicates that agroforestry practice is a potential technology, if properly practiced and managed.

7.2. TECHNICAL RECOMMENDATION

Based on available literature, some personal experiences, and the data and analysis from this study, alley cropping and alley cropping plus chemical fertilizer are promising technologies, to help improve the production potential and ecological conditions of the Basin. The results also suggest that large-scale tree plantations are not a fruitful option in the Basin, because of small farm size.

From the results of the agroforestry research at the Alemaya University and also from the on-station and on-farm research experience in Kenya and Nigeria, Leucaena leucocephala has been identified as the most promising tree species to date for alley cropping in the Basin. This species has such desirably properties as high biomass production, nitrogen fixing capacity, high nutrient content in the foliage and fast or moderate litter decay (Nair, 1989b; Young, 1989).

There are also other potential tree/shrub species which have the desired characteristics and deserve additional attention. These are: Gliricidia speium, Casia siamea, Calliandra callothyrsus, Flemingia macrophylla, Cajanus cajan and Acacia saligna (Kang et. al., 1985; Nair 1989; Kidane, 1988; Abdulkadir, 1992). Although, this study has chosen Leucaena leucocephala to demonstrate the potential of alley cropping for sustainable development in the model, it also acknowledges the importance of testing other species for alley cropping.

7.3. RECOMMENDATION FOR IMPLEMENTATION

These recommendations are designed to convey the improved technologies to farmers through an improved extension program, development of effective support measures, and the creation of proper institutional arrangements. A process is required in which research and extension frequently interact and exchange information. Creativity and compromise are required which encourage an alternative development paradigm altogether (Buck, 1990).

Based on the results of on-farm experience, yields often differ from those on experimental stations. Thus, there is a need to refine methodologies that should be appropriate to on-farm conditions. Formal and informal discussions with farmers could be of great help in designing methodologies and in learning their acceptance and attitudes towards the technology. Moreover, on-farm research needs to be based on conditions and constraints faced by the farmers with full consideration given to the scarce land resources and physical environment (Bishaw and Abdulkadir, 1989).

Thus, the following development plan, consisting of five components, is proposed:

(1) The establishment of an agroforestry research and demonstration center which include a tree nursery, seed orchard, demonstration plots and research programs. The center will be used to test the performance of alley cropping technology. It also serves as a training site for development agents and farmers;

(2) The collection and distribution of alley cropping tree/shrub seeds in order to supply seeds to local nurseries and farmers. These seeds will initially be imported and collected locally. As the seed orchards come into production, importation and local collection will be phased out;

(3) A network of nurseries will be set up throughout the Basin in order to supply the needed seedlings for alley cropping and other tree planting programs in the Basin;

(4) Initiation of an extension program in order to introduce alley cropping technology in the Alemaya Basin;

(5) Periodic monitoring and evaluation of the project by experts from the Alemaya University of Agriculture, which is located in the Basin and experts from the Ministry of Agriculture in the region.

Once the technology, or modifications thereof, prove effective under on-farm conditions and it is accepted by the farmers, the next step is to proceed with the practical implementation of the technology. However, this requires identification of sites to be treated, estimates of number of seedlings to be raised and the investment requirements to raise and distribute seedlings. Also, estimating the number of trees to be planted and the area covered, cost for planting and maintenance of trees and cost for outreach and training is essential.

Among the areas regarded as having high potential for agroforestry are sloping lands. According to the land-use survey, arable and grazing lands with moderate to severe slopes (>8 percent slope) can be treated with alley cropping to rehabilitate from land degradation encountered due to the traditional farming practice. Therefore, based on the land use survey 42 percent of the agricultural land (5,238 ha) and 36 percent of the pasture land (662 ha), which is a total land area of 5,900 ha or 30 percent of the Basin could be treated with alley cropping technology.

Since the total area to be treated is large (5900 ha or 30 percent), some five decentralized nurseries throughout the Basin are required, to minimize damage to seedlings during transportation. A half-hectare of nursery site with a capacity of 500,000 seedlings per year should be established.

Within 20 years about 300 hectares of hedgerows per year will be established. From the five decentralized nurseries, it is possible to raise 2.4 million seedlings/year, with an assumed 95 percent survival rate in the nursery. Assuming a 4-meter hedgerow spacing and 0.5 m. between seedlings, about 6000 seedlings/ha are required for the initial planting. Further, assuming a 30 percent replacement planting, about 7800 seedlings/ha would be required annually. Thus, the 2.4 million seedlings produced per year can cover about 300-305 ha of land.

With a conservative estimate, the price for a seedling is considered to be about 0.25 ETBirr as of 1990/91 prices. Thus, the cost required for seedlings to establish a hectare of hedgerows is about 1950.00 ETBirr, and the total cost estimate for 2.4 million seedling production per year is about 600,000.00 ETBirr. The planting cost is based on the assumptions made for labor productivity in western Kenya by Swinkels (1991a). He reported, that on the average, farmers plant 38 trees/hr. Thus, to establish a hectare with 7800 seedlings requires about 205 hrs. Assuming 6 working hours as one man-day, it requires 34 man-day to establish a hectare of hedgerows. With 2.00 ETBirr labor wage per man-days, it costs 68.00 ETBirr per hectare for hedgerow establishment.

The labor requirement for maintenance of hedgerows is assumed to require about 60 person-hrs for the first and 110 person-hrs for the second pruning. Assuming two cuttings per year, the total labor required is 170 person-hrs/ha, which is based on experience from western Kenya (Swinkel's 1991a). Assuming 6 working hrs as one man-day, it requires about 28 man-days/ha for maintenance of the hedgerows, which costs about 56.00 ETBirr/ha.

Other inputs required for the implementation of the alley cropping technology include: maize and bean seeds, chemical fertilizer and labor. From the estimation made in this study (Chapter 6), it requires 49 kg/ha maize and 14 kg bean seeds, 94.5 kg/ha Urea and 70 kg/ha DAP fertilizers and 1450 person-hrs or 242 man-days/ha of labor for sowing, weeding, fertilization and harvesting of one hectare of maize and bean. The cost of these inputs according to the 1990/91 price estimate are 45.50 ETBirr/ha for maize and bean seeds, 160.50 ETBirr/ha for Urea and DAP fertilizer and 484 ETBirr/ha for labor. Thus, the total cost of these inputs is 690.00 ETBirr/ha.

Therefore, the total costs of inputs and labor required to establish and manage a one hectare of alley cropping are: 2,074.00 ETBirr/ha to buy the seedlings and labor for establishment and maintenance, and about 690 ETBirr/ha for inputs and labor cost for sowing, weeding, fertilization and harvesting of maize and bean crops. The over-all cost for hedgerow and crop establishment and management for one hectare of alley cropping is about 2,764.00 ETBirr. A total of 829,200 ETBirr is required for 300 hectares of alley cropping.

However, the key to the adoption of the alley cropping technology in the project area will be the extension and training services. Initially, development agents will be identified and trained at the center. Part of their training will come from classroom work and part from tours of existing agroforestry programs in the country.

Following the development agents' training, they will initiate extension activities which will include: (1)

teaching farmers about the benefits of alley cropping and tree planting; (2) assisting interested groups of farmers in the establishment of tree nurseries, and (3) assisting farmers and interested groups in designing and establishing alley cropping on their farms. Thus, to support the extension program, training materials and extension bulletins will be designed by the project staff with the assistance from the development agents. These will be used both in the classroom and in the field as an aid in teaching alley cropping and agroforestry concepts.

7.4. SOCIO-ECONOMIC AND INSTITUTIONAL ASPECTS

The improved agroforestry technologies proposed by this study are not sufficient by themselves to solve land use problems, hence socio-economic and institutional factors must also be considered. To be effective the proposed change must accurately reflect the needs of the people and communities. These needs should be identified in consultation with the people themselves, through survey as has been done in this study or through formal and informal meetings with the farmers. This will help to reassure them that programs drawn up are relevant to their needs and will also help to give them a sense of responsibility towards ensuring success.

Also, in planning agroforestry, attention should be given to the creation of effective local management organizations and to the development of generally accepted rights to agrofrestry products. Such institutional arrangements at the community level are often key elements in planning agroforestry for field implementation projects. The FAO's experience in small farmer development work indicates organizing farmers into small homogenous groups of about 10-15 farmers or heads of families can help these people obtain government services. These informal groups work best when farmers have similar incomes, problems and aspirations (Rao, 1986). Thus, based on this experience farmers in the Alemaya Basin should organize into smaller groups to get services and incentives from government and NGO's.

Equally important, the organization of agencies at the national and local levels must be responsive to societal structures and emphasize participation of rural dwellers in rural resource management (Rao, 1986). In the program management of the agroforestry project in the Alemaya Basin, different agencies will be involved. These are: the Ministry of Agriculture, the Alemaya University of Agriculture and Non-Governmental Organizations. The Ministry of Agriculture will provide support and extension staff and will ensure the utilization of facilities. The Alemaya University of Agriculture will act as an advisory group for the project.

The Non-Governmental Organizations will provide technical and material support and see the project through its establishment and management phase.

The field program will be planned and implemented by individual and/or groups of farmers in consultation with the above agencies. However, it is essential at the start of the program designate the roles and responsibilities of the major parties involved and achieve agreement on these arrangements. Thus, in planning for implementation of agroforestry projects attention should be given both to "things to be done" and "to ways of getting things done". In addition, the need for possible reorientation of institutional arrangements should be considered (Wiersum, 1990). Thus, attention should be given to the development of proper institutions for effectively implementing this technology.

There is less likelihood that long-term agroforestry strategies will be adopted in areas where land tenure systems do not guarantee continued ownership of land. As Nair (1990) indicated, the incentive for investing in soil-fertility improvement for future use of the land is low unless the benefits accrue to the tree planter. This holds true in Ethiopia today, where land is still under the communal control of the government. Unless land is redistributed to the farmers and guaranteed continuous ownership, the success in the adoption of alley cropping in the Alemaya Basin is unlikely.

Therefore, the land and tree tenure policy of the country should be changed to give incentives to the farmers to invest in alley cropping or tree planting programs, which require long gestation periods. Thus, the government should introduce land and tree tenure policy changes to promote an agroforestry and tree planting program in the country. This requires suitable legislation to back it up and institutions to implement the laws. The creation of the current Ministry of Natural Resources and Environmental Conservation and Development by the transitional government is encouraging.

Institutional arrangements must create incentives for tree growing and otherwise adopting suitable agroforestry practices by rural people. Direct credit to farmers is another financial matter to be addressed. There is little experience in organizing credit for tree crop cultivation in developing countries; new mechanisms must be devised.

Incentives may involve supplying of seeds and seedlings either free of charge or at a nominal price, which was assumed in this study. Also the supply of hand tools for planting and food aid can encourage farmers to participate in the tree planting or adoption of alley cropping technology. Another way to provide incentives is by setting up a program where the community provides the land and the necessary labor while the forest service or NGO provides the seedlings, fertilizers, and technical assistance. When the crop is harvested, the net profit is shared on a proportional basis depending on inputs.

7.5. DEALING WITH UNCERTAINTY

Silvicultural uncertainties such as insect and disease attacks is one of the problems that should be considered. Even today, for example, the introduced insect Lucaena psyllid has been identified as one of the problems for the production of leucaena hedgerows in Africa. The onset of psyllid infestation is characterized by a sudden and dramatic decline or dieback of the leucaena plant (ICRAF, 1992).

Since Ethiopia is a member of the Agroforestry Research Network in Africa (AFRENA), this will provide the opportunity to share information and plant material on a number of pest problems. This network will help member countries to exchange their experience from research results conducted in the respective countries and also minimize duplication of efforts and resources.

Change in crop and energy prices is another uncertainty. If the price of vegetables and chat goes up, there is a tendency to shift from subsistence farming to cash crops. Also, the potential for oil in the Ogaden region is high, which could create jobs as well as make the availability of chemical fertilizers cheaper. This, in turn, could change land-use practices and the adoption of new technology. In this case perhaps technology should focus on the environmental role of alley cropping to reduce soil erosion and land degradation.

Population growth is another uncertainty. If the present trend of population growth continues as is projected today, the Basin can easily reach a point where it can lose its carrying capacity and not allow the introduction of agroforestry practices, because it takes land out of food production. Thus, there is an urgent need for the government to introduce birth control measures, before population numbers exceed the carrying capacity of the Basin. Also, the government should put effort in to developing the industrial sector of the economy, so that job opportunities are created in the cities and elsewhere in order to reduce pressure on the land.

Another important issue is political uncertainty, which is very common in most developing countries. As we all know forestry, agroforestry and natural resource conservation and development require time to provide a return on effort invested. Thus, unless there is a stable government which maintains peace and stability in the country, the resource and time devoted to create sustainable development could easily be jeopardized and the resource and time invested to transfer and adopt the new technology would be wasted. This has been witnessed from the previous experience in community forestry work in the Alemaya Basin, where farmers cut all trees and shared the products among themselves without consulting and considering the long-term benefits of trees. Thus, the need for a stable government and proper policy guidelines on land and tree tenure is very crucial to the success of tree planting and other natural resource conservation and development programs in the country.

7.6. SUGGESTED AREA OF RESEARCH

Further studies are needed to back stop establishment and management of alley cropping and other agroforestry practices. Study on pruning frequency and pruning height for *Leucaena leucocephala* and other promising species are needed. Also, inter and intra-row spacing is important for research since this affects the yield of both crops and trees. Moreover, study on soil nutrient yields and effect on the companion crops is very much required to understand the potential of various hedgerow species. On-farm research is required to assess the acceptance of alley cropping technology by farmers, who are the end users of the technology.

Another important area of agroforestry research is the introduction of multistory border planting. This technology is believed to be appropriate to the current land use practice in the Alemaya Basin, which is characterized by small farm size. This technology has the potential to produce poles and posts in the upper-story and fodder and biomass in the under-story with less competition for land. Thus, it helps to increase household income from the sale of poles and posts and increase production of crops and livestock by producing green manure and fodder. Therefore, research on species identification to find the best combination and appropriate spacing between the under-story and upper-story is important. These border plantings can also serve as living fences and wind breaks.

Finally, additional uncertainties creep into this study, because the results of the analyses are based on data in 1990/91. Since then much political and social change has taken place and more is likely. This inturn impacts the attitudes of farmers towards trees and land tenure. Also, the data used for the projection of living standards and potential of agroforestry is based on estimations and extrapolations of research results from Kenya and Nigeria. Thus, this limits the direct application of the results of the study and calls attention to further research needs on the existing social and physical conditions of the farmers in the Alemaya Basin.

8. BIBLIOGRAPHY

Abdulkadir, A. 1992. Report on Periodic Productivity of Acacia aligna and Leucaena leucocephala hedgerows grown in alleys with maize at Alemaya (Unpublished). Faculty of Forestry, Alemaya University of Agriculture, Ethiopia. p. 8.

Anderson, J.R. et.al., 1976. A Land use and Land Cover classification system for use with Remote Sensing Data. USGS Prof. Paper 964. Washington, D.C. Government Printing Office.

Atta-Krah, A.N. 1990. Alley Farming with Leucaena: Effect of short grazed Fallows on Soil Fertility and crop Yields. Experimental Agriculture 26:1-10.

Behm, K. and Pease J.R. 1985. A Pilot Study for Establishing Land use change in Fast growing Counties. Unpublished paper, Agreement No. 58-3198-2-00276, Dept. of Geography. Oregon State University, Corvallis.

Belsky, J.M. 1992. Sociological Dimensions of Agroforestry Research and Development. (Unpublished) Paper Presented at Oregon State University. Department of Sociology, University of Montana, Missoula. p. 8.

Beets, W.W. 1989. The Potential Role of Agroforestry in ACP Countries. CTA, Netherlands.

Bircham, D.P. 1979. Sampling Methodology study for Land-Use Monitering in Canada. A detailed Methodology and Data Report. Unpublished paper, Land Use Montitoring Division, Lands Directorate, Environment Canada.

Bishaw, B. and Abdulkadir, A. 1989. Strategies for on-farm Research in Agroforestry in the Hararghe Highlands, Eastern Ethiopia. In: IAR Proceeding, First Natural Resources Conservation Conference. Addis Ababa, Ethiopia. p. 164-173.

Bishaw, B. et.al., 1988. Evaluation of Multipurpose trees for Agroforestry land use and the Assessment of Agroforestry Systems in Hararghe, Eastern Ethipia. In: IAR/ICRAF National Aggroforestry Workshop Proceedings. Awasa, Ethiopia. p. 51-62.

Britenbach, F. Von., 1961. Forest and Woodlands of Ethiopia. Ethiopian Forest Review 1.

Brune, S. 1990. The Agricultural Sector. In: Pausewang, S. et.al., (ed.) Ethiopia Rural Development Options. Zed Books Ltd. London.

Bryant, C.R. and Russwurm, L.H. 1983. Area Sampling Strategies in Relation to Land Use Monitoring Needs and objectives Working Paper No. 24, Ottawa: Land Directorate, Environment Canada.

Buck, L. 1990. Planning Agroforestry, Extension Projects, the care International Approach in Kenya. In: Budd, W.W et.al., (ed.) Planning for Agroforestry. Elsevier Science Publishing Company INC. New York, U.S.A. p. 101-131.

Central Statistic Authority (CSA). 1988. Popolation Projection of Ethiopia: Total and Sectoral (1985-2035). Population Studies Series No. 2 Addis Ababa.

Cochran, W.G. 1977. Sampling Techniques. Third edition. John Wiley and Sons. New York. p. 279.

Constable, M. 1985. Ethiopian Highland Reclamation study. Working Paper 24. Addis Ababa, Ethiopia.

Davidson, J. 1988. Preparatory assistance to research for afforestation and Conservation. FAO/UNDP. Addis Ababa, Ethiopia.

ENEC 1986. Cooperation agreement in the energy sector between ENEC and CESEN-ANSALDO/FINMECCANICA Group. Addis Ababa: ENEC.

Ethiopian Mapping Agency (EMA), 1988. The Atlas of Ethiopia. Addis Ababa, Ethiopia.

FAO, 1981. Tropical forest resources assessment project (GEME). Forest resources of tropical Africa, part 2, Country Briefs, Rome: FAO.

FAO, 1984a. Geomorphology and Soils. Interim legend. Assistance to land-use planning. GOE/FAO Project. ETH/82/010, Rome: FAO.

FAO, 1984b. Land resources inventory for land-use planning AG:DP/ETH/78/003. Technical Report 1. Rome: FAO.

Gamachu, D., 1990. Environment and Development in Ethiopia. Department of Geography, Addis Ababa University, Ethiopia.p. 54-96.

G/Michael, D. 1974. The Kottu of Hararghe-An Introduction to the Eastern Oromo. Expt. Station Bulletin No. 68. Alemaya, Dire Dawa.

Getahun, A. 1978. Zonation of highlands of tropical Africa: the Ethiopian highlands. ILCA Working document. International Livestock Center for Africa, Addis Ababa, Ethiopia.

Getahun, A. 1988. An Overview of the Ethiopian Highlands: the need for Agroforestry Research and Development for national survival. In:IAR/ICRAF National Agroforestry Workshop Proceedings. Awasa, Ethiopia. p. 5-16.

Gholz H.L.(ed.) 1987. Agroforestry: Realities, Possibilities and Potentials. Martinus Nijhoff Publishers and ICRAF, Nairobi. p. 1-19.

Gregerson, H. and Lundgren, A. Forestry for Sustainable Development: Concepts and A Farmework for Action. Working Paper 1. College of Natural Resources, University of Minnesota. 1530 North Cleveland Avenue, St. Paul, Minnesota 55108. U.S.A.

Hawando, T. 1982. Brief Summary of the Soil Resources of Hararghe Highlands. College of Agriculture, Addis Ababa University, Ethiopia. p. 12.

Hoekstra, D.; Torquebiau, E.; Bishaw, B. (ed.), 1990. Agroforestry: Potentials and Research Needs for the Ethiopian Highlands. No. 21. ICRAF, Nairobi, Kenya. p. 1-115

Hurni, H. 1990. Degradation and Conservation of Soil Resources in the Ethiopian Highlands.In: Messerli, B. and Hurni, H. (ed.) African Mountains and Hughlands Problems and Perspective. Missouri, U.S.A. p. 51-63.

ICRAF, 1992. Agroforestry Today. Vol. 4. No. 4. ICRAF, Nairobi. p. 23.

Institute of Agricultural Research (IAR), 1991. Newsletter of Agricultural Research. Vol.6. No. 1. ISSN 1015-9762 Addis Ababa, Ethiopia. p.11.

IUCN, 1990. Ethiopia National Conservation Strategy. Phase I Report. Addis Ababa, Ethiopia. p. 163.

Kalton, G. 1987 Introduction to Survey Sampling. Bevery Hills, Sage Publications. CA. U.S.A..

Kang, B.T., Grimme, H. and Lawson, T.L. 1985. Alley Cropping sequantially cropping maize and cowpea with leucaena on a sandy soils in southern Nigeria. Plant and Soil 85: 267-277. Martinus Nijhoff Publisher. The Hague, the Netherlands.

Kang, B.T., Reynolds, L., and A.N. Atta-Krah. 1990. Alley Farming. Advances in Agronomy. 43:315-359. Acadamic Press Inc. London.

Kang, B.T., Wilson, G.F., and Sipkens, L. 1981. Alley Cropping maize (Zea mays) and leucaena (Leucaena leucocephala, Lam.) in southern Nigeria. Plant and Soil. 63:165-179. Martinus Nijhoff Publisher. The Hague, the Netherlands.

Kidane, G. et.al., 1988. Research review on the adaptation of leguminous trees and shrubs and their suitability in alley cropping in the IAR. In: IAR/ICRAF National Agroforestry Workshop proceedings. Awasa, Ethiopia. p. 63-71.

Kuru, A. 1990. Roots of Deforestation Problems in Ethiopia. In: Matti, P. et.al (ed.) Defforestation or Development in the third world? Volume III. Helsinki.

Mendenhall, W. et.al.,1979. Elementary Survey Sampling. PWS-KENT Publishing Company. Duxburg, Massachusettes.

Ministry of Agriculture (MOA), 1990. Ethiopia: Study on Forest Resource Base Identification, Conservation and Rational Use. (Unpulished) Addis Ababa. MOA.

Ministry of Agriculture (MOA), 1991. Forestry Report Ethiopia. Prepared for the Tenth World Forestry Congress. (Unpublished) Addis Ababa. MOA.

Mooney, H.E. 1961. The natural Vegetation of Ethiopia. Ethiopian Observer, Vol. 5. No. 3.

Murphy, H.F. 1968. A report on the fertility status and other data on some soils of Ethiopia. Experimental Station Bulletin No. 44. Dire Dawa: HSIU, College of Agriculture, Alemaya.

Nair, P.K.R. 1989b. The role of trees in soil productivity and protection. In: Nair, P.K.R.(ed.) Agroforestry Systems in the Tropics. p. 567-589. ICRAF, Nairobi. Kluwer Acadamic Publisher, London.

Nair, P.K.R., 1989a. Agroforestry Definition. In: Nair P.K.R. (ed.), Agroforestry Systems in the Tropics, p. 13-18. ICRAF, Nairobi. Kluwer Acadamic Publisher, London.

Nair, P.K.R. 1990. The Prospects for Agroforestry in the Tropics. World Bank Technical Paper ISSN: 0253-7494. No. 131. The World Bank Washington D.C.

Poschen, P. 1987. The Application of Farming Systems Research to Community Forestry. A case study in the Hararghe Highlands, Eastern Ethiopia. Tropical Scientific Books. D-6070 Langen Germany. p. 250.

Poschen, P. 1986. An Evaluation of the Acacia-albida based agroforestry practices in the Hararghe highlands of Eastern Ethiopia. Agroforestry systems 4:129-143. Dordrecht. Printed in the Netherlands.

Rao, Y.S. 1986. Some Socio-Economic and Institutional Aspects of Forest Land Use. In: Land Use, Watersheds, and Planning in the Asoa-Pacific Region. RAPA Report 1986/3 p. 3-10. FAO/UN. Bangkok,1986.

Swinkels, R.A. 1991a. Costs and Returns of farmers existing system. In: Evaluation of hedgerow intercropping on farms in Western Kenya. (Unpublished) A paper presented to the Zonal confrence 8-10 July 1991. ICRAF, Nairobi. p. 21.

Swinkels, R.A. et.al., 1991b. Economic analysis using on-station and on-farm data. In: Evaluation of hedgerow intercropping on farms in Western Kenya. (Unpublished) A paper presented to the Zonal Confrence 8-10 July 1991. ICRAF, Nairobi. p. 18.

Uibrig, H. 1989. Report on Land Use Survey in the Alemaya Catchment, Hararghe Highlands, Eastern Ethiopia. Faculty of Forestry, Alemaya University of Agriculture, Ethiopia. p. 1-54.

UNEP, 1983. Ecology and Enviroment: What do we know about dessertification? Dessertification Control 3: 2-9.

Vesterby, M. 1988. Land use change in Fast-Growth Counties, Analysis of study Methods. USDA, Resource and Technology Division. Staff Report. No. AGES 880510. Washington, D.C. p. 33

Vink, A.P.A. 1975. Land Use in Advancing Agriculture. Advanced Series in Agricultural Sciences 1. Springer-Verlag, New York.

Weisberg, F.H. et.al. 1989. An Introduction to Survey Research and Data Analysis. Publisher Glenview, Illinois.

Wiersum, K.F., 1990. Planning Agroforestry for Sustainable Land use. In: Budd, W.W. et.al.,(ed.) Planning for Agroforestry. Elsevier Science Publishing Company INC. New York. p. 18-31.

Wood, A. 1990. Natural Resource Management and Rural Development in Ethiopia. In: Pausewang, S. et.al. (ed.). Ethiopia Rural Development Options. p. 187-198. Zed Books Ltd. London.

World Bank, 1990. The World Bank, Trends in Developing Economics. Washington, D.C.

World Resource Institute, 1992. Population and Human Development. In: World Resources 1992-93. A Guide to the Golbal Environment. Oxford University Press. New York. p. 75-92.

Young, A 1989. Agroforestry for Soil Conservation C.A.B. International. U.K. BPCC. Wheatons Ltd, Exeter. p. 276.

Young, A. and Muraya, P. 1990. Soil changes under agroforestry (SCUAF): a Predictive Model. Computer program with users' handbook Version 2. ICRAF, Nairobi. Published by ICRAF.

Zabedah, S.A. 1989. Comparison of Systematic Unaligned Sampling Designs for Estimating Land Use. Master Thesis. Department of Geography, Oregon State University. p. 44.

9. APPENDICES

APPENDIX 1: TALLEY SHEET FOR LAND USE, AGROFORESTRY AND TREE HUSBANDRY SURVEY IN THE ALEMAYA BASIN

1. Sample plot No.______________________________
2. Administrative/management Unit:
   2.1. District______________________________
   2.2. Peasant Association ______________________
   2.3. Farmers Producer Cooperative______________
   2.4. Private Farm __________________________
   2.5. Other unit ___________________________
3. Natural Conditions
   3.1. Altitude:_______________________ m asl
   3.2. Landform (circle one)
   (a) Upland (b) Slope (c) Plains (d) Others.
   3.3. Slop/Inclination (circle one), indicate proportion land
   (a) flat (0-4%)______(c) moderate (8-30%)______
   (b) gentle (5-7%)____(d) severe (31+%)________
4. <u>LAND USE</u>
   4.1. Estimate the area (or proportion of land) under each major type of land use on the sample plot.
   4.2. What kind of soil conservation practices were applied on the sample plot?

1	2	3	4		5
Land use types classification	Area M^2	Slop %	Soil conservation		Rain fed (1) or Irrigated(2)
			Type	Length m	

<u>Instruction</u>

<u>Column 1</u>: For land use type please refer the land use classification (Annex 1)

<u>Column 4</u>: Soil conservation practices:

1. Bench Terraces
2. Soil Bunding
3. Stone Bunding
5. Cut-of Drains
6. Check dams
7. Planting trees/grasses

4. Contour ploughing 8. Others (Specify)

4.3. What proportion of the sample plot is:

_____ Rainfed _____ Irrigated

4.4. Name the major irrigated crops on the sample plot.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

4.5. Sketch the different land uses on the sample plot.

100 m

100 m

5. <u>Trees and shrubs in the landscape</u>

5.1. Where do trees and shrubs occur in the landscape?

_____Home Compound	_____ Property/boundary
_____Crop land	_____ Fences
_____Fallow land	_____ Road/trials
_____Pasture	_____ River banks
_____Woodlot	_____ Gullies
_____Woodlands, forests	_____ Other(Specify)

5.2. How are trees and shrubs arranged in the landscape?

1=Block 2=Clumps 3=lines 4=dispersed as a single tree.

<u>Arrangement</u>	<u>Size/area m</u>
__________	__________
__________	__________
__________	__________
__________	__________

5.3. Sketch how trees and shrubs fit on the sample plots.

100 m

100 m

5.4. If tree planting is usually successful or unusually poor, are any reasons obvious.

6. For each landscape niche in the land use system, indicate whether trees/shrubs are growing there, common species and agroforestry practices.

Landscape Niche	Trees?		Naturally occuring species	Planted (managed) species	Agroforestry practices
	Yes (1)	No (2)			

Instruction: For the different land use Niches refer Annex 2

Annex 1: <u>CLASSIFICATION FOR LAND USE</u>

1. RESIDENTIAL
    - 1.1. Town
    - 1.2. Village
    - 1.3. Single houses or tukuls
2. TRANSPORTATION AND COMMUNICATION
    - 2.1. Roads outside town/villages
    - 2.2. Trials outside town/villages
3. AGRICULTURAL LAND
    - 3.1. Annual crops
        - 3.1.1. Sorghum
        - 3.1.2. Maize
        - 3.1.3. Sorghum/Maize
        - 3.1.4. Beans
        - 3.1.5. Sorghum/beans
        - 3.1.6. Maize/beans
        - 3.1.7. Sorghum/maize/beans
        - 3.1.8. Wheat
        - 3.1.9. Barley
        - 3.1.10. Sweet potatoes
        - 3.1.11. Irish potatoes
        - 3.1.12. Fodder Crops
        - 3.1.13. Vegetables
        - 3.1.14. Others
    - 3.2. Perennial crops
        - 3.2.1. Chat
        - 3.2.2. Coffee
        - 3.2.3. Fruit trees
        - 3.2.4. Others.
    - 3.3. Perennial/annual crops
        - 3.3.1. Chat/annual crops
        - 3.3.2. Coffee/annual crops
        - 3.3.3. Fruit trees/annual crops
    - 3.4. Fallow land
        - 3.4.1. Short term
        - 3.4.2. Long term
        - 3.4.3. Private
        - 3.4.4. Communal
4. PASTURE LAND
    - 4.1. Natural pasture
        - 4.1.1. Private
        - 4.1.2. Communal
    - 4.2. Planted pasture
        - 4.2.1. Private
        - 4.2.2. Communal
5. FOREST LAND
    - 5.1. Natural forest
        - 5.1.1. State Natural Forest
        - 5.1.2. Communal Natural Forest
    - 5.2. Man-made forest
        - 5.2.1. State man-made forest
        - 5.2.2. Communal man-made forest
        - 5.2.3. Pre-Urban man-made forest

5.3. Bushlands
   5.3.1. Closed bushlands
   5.3.2. Open bushlands

6. AGROFORESTRY
   6.1. Home garden planting
   6.2. Trees on farm
   6.3. Trees along farm boarders
   6.4. Road side planting
   6.5. Conservation planting (gully planting)
   6.6. Alley farming
   6.7. Fruit trees on farm
   6.8. Chat planting

7. WATER
   7.1. Stream
   7.2. Lakes
   7.3. Channels / ditch

8. WASTE LAND
   8.1. Gullies
   8.2. Rock outcrops
   8.3. Others.

Annex 2: Types of landscape Niches in the Land use system.

No.	Types of Niches
1.	HOME COMPOUND
2.	AGRICULTURE
	2.1. Annual crop land
	2.2. Perennial crop land
	2.3. Annual and perennial crop land
	2.4. Fallow land
3.	PASTURE LAND
	3.1. Natural pasture land
	3.2. Planted pasture land
4.	FOREST LAND
	4.1. Natural forest land
	4.2. Man-made forest land
	4.3. Bushlands
5.	AGROFORESTRY
	5.1. Property boundaries
	5.2. Fences
	5.3. Roads and trials
	5.4. Public places
6.	WATER
	6.1. Drainage
	6.2. Irrigation channels
7.	WASTE LAND
	7.1. Gullies
	7.2. Rock outcrops

APPENDIX 2: FORMAL SURVEY QUESTIONNAIRE FOR HOUSEHOLD INTERVIEW IN THE ALEMAYA BASIN

CATEGORY A: BACKGROUND INFORMATION: HOUSEHOLD INCOME AND LABOR

District ______________________________
Peasant Association ____________________
Village _________________________________
Household Head _________________________
Interviewer ____________________________
Date ___________________________________

1. Population
<u>Particulars of household composition</u>

1	2	3		4	5	6	7
No.	Name of Household Members	Sex		Age	Major Occupation	Educational Background	Relationship to head of Household
		M	F				
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

<u>Note instruction</u>
<u>Column 5</u>:

1. Farmer
2. Trader
3. Weaver
4. Black smith
5. Carpenter/builder
6. Student
7. Others

Column 6:

1. Illiterate, no formal education
2. Literate, no formal education
3. Primary school education
4. Secondary school education
5. Vocational education
6. College or above

Column 7:

1. Head of household
2. Spouse
3. Daughter of Head
4. Son of Head
5. Mother/Father of Head
6. Mother/Father of spouse
7. Other relative
8. Not related

2. ECONOMIC STATUS

A. FARM RESOURCES AND ASSETS

Land: 1. What is the total land holding of the household?

1.1. Local Unit ______________________________

1.2. Hectares ______________________________

2. How is the land holding of the household distributed according to use?

No.	Use	Area	
		Local unit	hectar
1.	Homestead		
2.	Annual Crop land		
	2.1. Cereals		
	2.2. Vegetables		
3.	Perennal crop land		
	3.1. Trees		
	3.2. Fruits		
	3.3. Chat		
4.	Grazing land		
5.	Fallow land		
6.	Wood land		
7.	Wate land		
8.	Other (specify)		
	Total		

3. What proportion of the land holding of the household is rainfed and irrigated? (1/4, 1/2, 3/4, 1).

______ Rainfed ______irrigated

LIVESTOCK: Complete the following table

No.	Types of Livestock	Number
1	Oxen	
2	Bulls	
3	Cow	
4	Heifers	
5	Calves	
6	Goats	
7	Sheep	
8	Poultry	
9	Hourses	
10	Mules	
11	Donkeys	
12	Bees	
13	Others	

TREES, SHRUBS AND FRUITS

4. Note the species, amount/area cover, size, location and use of trees/shrubs on the land of the household.

No.	Species	Amount or Area cover	Size	Location	Use

Instruction:

A. <u>Size</u>: 1 = small (25 cm to 2m)
2 = medium (2m to 5m
3 = big (above 5 m)

B. <u>Location:</u> 1 = Home compound
2 = On farm
3 = Along farm boarder
4 = Road side
5 = Fence
6 = Gullies

C. **Use:** 1 = Fuelwood
2 = Food
3 = Fodder
4 = Poles/timber
5 = Shade
6 = Crafts
7 = Honey

NON FARM ASSET

5. Please check non-farm assets. if the respondent has the following.
   1. House with corrugated iron roof
   2. Round house with straw roof
   3. Bed: Metal
      Wooden
      Leather
   4. Tables and chairs
   5. Radio
   6. Masho (lump)
   7. Specify other important assets
      ____
      ____
      ____
      ____
      ____

B. SOURCE OF INCOME:

6. Farm Work
   6.1. Pattern of usage of farm products in the last 12 months and revenue generated (fill in the following table))

No.	Type of products	Unit	Total Output	Allocation		Total revenue in Birr
				Consumed	Sold	
1.	Cereals:Maize Sorghum					
2.	Vegetable					
3.	Chat					
4.	Eggs					
5.	Milk					
6.	Butter					
7.	Licestock					
8.	Sweet potatoes					
9.	Pulses					
10.	Fruits					
11.	Coffee					
12.	Poles					
13	Cut wood					
14.	Branches					
15.	Others(specify)					

6.2. Non-farm work

No.	Type of Non-farm work	Revenue generated in Birr
1. 2. 3.	Handicraft House work (Hoursehold repairs etc) Others	

6.3. Off-farm work

No.	Type of off-farm work	Revenue generated in Birr
1 2	Agricultural wage labour Other off-farm work	

6.4. Other income source.

3. LABOR/EMPLOYMENT

A. Major activities of selected household members

7. Whose job among the family members are the following activities?

No.	Activities	Husband	Spouse	Sons	Daughter	Adult Male	Adult Female
1	Plowing						
2	Planting / sowing						
3	Cultivation						
4	Weeding						
5	Harvesting						
6	Conservation						
7	Marketing						
8	Cooking food						
9	Collecting fuel wood						
10	Fatching water						
11	Harding of livestock						
12	Tree planting						
13	Other (specify)						

B. Peak working periods

8. Identify the first or primary work period for the household members.

No.	Activities	Husband from to	Spouse from to	Sons from to	Daughter from to	Adult male from to	Adult female from to
1	Plowing						
2	Planting / sowing						
3	Cultivation						
4	Weeding						
5	Harvesting						
6	Conservation						
7	Marketing						
8	Cooking food						
9	Collecting fuel wood						
10	Fatching water						
11	Herding of livestock						
12	Tree planting						
13	Other (specify)						

Instruction

List first and last month of peak labor period for each activity, for each person listed.

01 = January	02 = February	03 = March
04 = April	05 = May	06 = June
07 = July	08 = August	09 = September
10 = October	11 = November	12 = December

CATEGORY B: AGRICULTURE AND FORESTRY PRACTICES.

1. CROP PRODUCTION SUBSYSTEM

9. How much food do you produce each year?
   1. Enough for the family consumption needs
   2. Not enough for the family consumption needs
   3. Surplus beyond the family consumption

10. What kind of crop do you grow?

a) Rainfed

____
____
____
____

b) Irrigated

____
____
____
____

11. Have you ever purchased agricultural inputs?

Yes　　　No

11.1. If yes, which inputs did you purchased?

Fertilizers
Improved seed
Pesticides
Herbicides

11.2. If no, what are the reasons?
In puts were not available at all
In puts were not available on time
In puts were not profitable to use them
Lack of cash
Others (specify) ____________________

____

____

12. Do you use Animal dung as fertilizer?
Yes No

12.1. If no, what are the reasons?
used as fuel
sell it to others
Others (specify) ____________________

____

____

13. Which of the following cultural practices do you use?

1. Rotation of crops
2. Fallowing
3. Under plowing crop residues
4. Burning crop residues
5. Others (specify) ____________________

____

____

13.1. If you use crop rotation, explain the sequence of cropping used?

No.	1 Round crop	2 Round crop	3 Round crop

14. Do you use any kind of intercropping?
Yes No

14.1. If yes, what combination of crops do you use with intercropping?

____

____

____

15. Do you apply any soil conservation measures on your field?
Yes No

15.1. If yes, which of the following conservation practices were applied?

1. Bench terracing
2. Soil bunding
3 Stone bunding
4 Contour ploughing
5. Cut-off drains
6. Check dams
7. Planting trees/grasses
8. Others (specify)

15.2. What is the extent of erosion problems on your field?

Serious Moderate Normal

16. List your serious problems of crop production and prioritize.

- Lack of cash to buy inputs	Disease
- Shortage of rain	Insect
- Lack of labor	Wild animals
- Lack of Oxen	Flood
- Lack of fertilizer	Wind
- Erosion problems	Frost
- Lack of seed	No problem
- Lack of market	Other (specify)
- Price too low	

II. ANIMAL PRODUCTION (SUBSYSTEM)

Rank

17. How do you feed you livestock?
1. Stall feeding
2. Open grazing
3. Tethered/controlled
4. Others (specify)

17.1. Where do you graze your animals?
Community pasture
Private pasture
Other (specify)

17.2. What types of feed do you supply your animals?

Rank

1 = Leaves, flowers other tree products
2 = Grass, other range products
3 = Crop and grain residues
4. Purchased feed

17.3. What supplementary feed do you provide you animals?

Hay	Salt
Concentrate	Nobe
Crop residue	

17.4. Rank each type of feed and method of feeding by relative importance (Q. No. 17 and 17.2)

1 = Most important 4 = Rarely used
2 = Regularly used 5 = Never used
3 = Occasionally used

18. Have you ever had your animals vaccinated?

Yes No

19. List your main problems of livestock production and prioritize.

External parasite	Lack of market
Disease	Drought/water shortage
Lack of grazing area	No problem
Shortage of forage/feed	Others (specify)
Low price for animals	

III. TREE, SHRUBS AND FRUITS

20. Have you ever planted trees/shrubs on your land holding?

Yes No

20.1. If yes, what is the rate of survival?

a) < 40% (poor) c) > 60% (very good)

b) 40 - 60% (good)

20.2. If tree planting is usually successful or unusually poor, what are the reasons?

____

____

____

A. ENERGY SUBSYSTEM

21. What proportion of fuel wood is produced by the house hold?

a) 1/4 b) 1/2 c) 3/4 d) 1 e) 0

21.1. What percent of the following fuels are used by the household?

__________Trees Rating 3 = Most

__________Cow dung 2 = Some

__________Bushes 1 = Few

__________Crop residue

__________Charcoal

__________Kerosin

21.2. How are the remaining requirements met?

__________Collecting from off-farm sources

__________Purchase from other farmers or market

__________Others (specify)__________

____

21.3. If fuel wood is purchased, estimate annual expenditure for this purpose.

21.4. If fuel wood is collected from off-farm sources,

Note: Source __________(private,community,state)

Distance to sources __________

Collection rights and restrictions

22. Prioritize the important problems the household experience in supplying its fuel need?

1. Cost of purchased fuel
2. Time required for collection
3. Diminishing fuel wood supply in the area
4. Others (specify) __________

23. Does the household fore see future difficulties in meeting fuel needs?

Yes No

23.1. If yes, why? ______________________________

____

______________________________ 24.

Have you planted fuel wood trees now?

Yes No

24.1. If no, why not?

____

____

____

B. SHELTER SUBSYSTEM

25. How odes the house hold supply its need for building poles and saw wood?

____

____

____

25.1. Are there any problems with the way this is currently done?

Diminishing supply
Distance to source
Cost of purchase

26. Do you use fencing practice?

Yes No

26.1. If yes, where does this practice employed on the farm?

Boundary demarkation
Livestock enclosure or exclusion
Home compound hedges

26.2. What species are used for these purposes?

____

____

____

26.3. Do they have any additional uses?

____

____

____

26.4. Are fencing requirements currently being adequately met?

Yes No

27. Are there enough shade trees on the farm?

Yes No

27.1. If needed, where and for what purpose would additional shade trees be planted?

Home compound for human shade
Grazing land for animals
On farm for human shade
Others (specify) ______________________________

____

28. Is wind damage considered to be a problem by the house hold?

Yes No

28.1. If yes, have you planted any trees for wind shelter?

Yes No

28.2. If yes, what species?

____

____

____

____

28.3. What does the farmer think about protection planting?

____

____

____

29. Is soil erosion considered to be a problem by the house hold?

Yes No

29.1. If yes, have you plated any trees for protection of soil erosion?

Yes No

29.2. If yes, what species?

____

____

____

____

29.3. What does the farmer think about soil erosion control?

____

____

____

30. Are there other reasons to plant trees, (i.e. fodder, fruits, nuts etc.)? If no, for what purpose?

Yes No

30.1. If yes, what species, where and in what quantity would trees be planted?

<u>Species</u>	<u>Location</u>	<u>Quantity</u>

30.2. Why have you not planted them yet?

____

____

____

30.3. If you are given the chance now, do you want to plant trees?

Yes No

30.4. If yes, why or if no, why not?

____
____
____

31. What are the major problems which limited tree planting?

____
____
____
____

CATEGORY C; GOVERNMENT FORESTRY DEVELOPMENT INTERVENTION.

1. PERCEPTION OF FORESTRY LAND AND REGULATIONS

32. Do you know of the various forest laws and regulations in the country?

Yes No

31.1. Does the laws and regulations allow, encourage or restrict forest and land use practices.

	Encourage	Neutral	Restrict
a) Private ownership of trees/forests	____	____	____
b) Common property of forest resources	____	____	____
c) Homestead forests/ home gardens	____	____	____
d) Farm forests	____	____	____
e) Community forest	____	____	____
f) Access to forest	____	____	____
g) Settlement in or near forest areas	____	____	____

Key: 0 = No 1 = Yes

Comments ______________________________
____
____

II. FINANCIAL SUPPORT FOR ALL AGRICULTURAL ACTIVITIES

33. Do you get any agricultural credit?
    Yes No
    33.1. If yes, in what farm do you get the credit? (refer table below)
    33.2. Who provide the credit, indicate source and amount?

Type of Credit	Farmer response	Source and amount		
		Govt. $	AIDB. $	Other $
Oxen				
Improved seed				
Fertilizer				
Chemicals				
Cash				

Key: 0 = No 1 = Yes

34. Do you get any financial support for forest/tree program?
    Yes No
    34.1. If yes, indicate types of support and source?

Type of Support	Farmers response	Source and amount		
		Govt. $	AIDB. $	Other $
Credit				
Food aid				

Key: 0 = No 1 = yes

II. EXTERNAL SUPPORT SERVICES/EXTENSION

35. Do you get any agriculture and forestry extension services?
    Yes No
    35.1. If yes, what services do you get? (complete the table on the next page)
    35.2. Who provide those service, indicate source?
    35.3. What proportion does each one contributes?

No.	Extension Services	Farmer response	Source and Proportion		
			Govt Prop.	NIGOs Prop.	Other Prop.
1	Crop - Training - Demonstration - Tractors - Chemical - Others(specify)				
2	Livestock - Training - Demonstration - Dull service - Vaccination - Others(specify)				
3	Forestry - Training - Demonstration - Seeds/seedlings - Others(specify)				
4	Soil conservation - Training - Demonstration - Seeds/seedlings - Tools and equipments - Others(specify)				

Key: 0 = Household does not use service
1 = Household uses services.

CATEGORY D: LAND AND TREE TENURE

I. LAND TENURE

36. What are the major types of tenure status for the land holding of the household? (complete the table)

Type of Land	Tenure status
1. Homestead	
2. Annual Crop land 2.1. Cereals 2.2. Vegetable grader	
3. Perennial crop land 3.1. Trees 3.2. Fruits 3.3. Chat	
4. Grazing land	
5. Fallow land	
6. Wood land	
7. Waste land	
8. Others (specify)	

Types of <u>tunure</u>
1=Privately owned
2=Communally owned
3=Share cropping
4=State owned

37. How do you acquire new/more land in this watershed?
by using or inheriting parent's property
by claiming un used land near by
by seeking rights to un used communal land
by seeking rights to communal lands already in use
by purchasing un used agricultural land
by purchasing used agricultural land
by migrating to less populated zone
Others (specify)______________________________
____

38. How do you respond to increased land preasure in this watershed?
by moving to newly cleared land
by converting one land use type to another
by decreasing the average length of fallow
by increasing yields per unit of land
by tolerating reduced yields
by immigrating to urban areas
by immigrating to other regions
Others (specify)

II. TREE TENURE

A. THE HOLDING

39. Do you have the right to plant trees?
    Yes No

    39.1. Do you have the right to cut and use tree?
    Ye No

    39.2. If no, who has the right and why?

    ____

    ____

    ____

    39.3. If yes, it is because of the right in land on which the tree stand?
    Yes No

    39.4. If yes, are the rights in land and trees the same?
    Same Not the same

    39.5. Can such rights be transferred by:
    a) Sale 1) with the land
    b) gift 2) without the land
    c) loan

    39.6. Can such rights be inherited?
    Yes No

    39.7. If yes, by whom?

    ____

    ____

    39.8. If not, whose rights do they become and why?

    ____

    ____

    ____

B. ACCESS TO COMMON PROPERTY

40. Are there areas of land which are not held by households, but used by oil of you or by a group? (refer the table below.

Types of commons	Status	Household access to and use
Commons land		
Fallows		
Pasture lands		
Community forest		
State forest		

Instruction:

A. Status: 1 = Exist
0 = Not exist

B. <u>Access to and use</u> :

1. Household has access to unrestricted use.
2. Household has access to its use but access and use are controlled by the community.
3. Household has access to its use, but access and use are limited by season.
4. Household does not have access to it.

40.1. What uses are made of the common? List in order of importance.

____
____
____
____

40.2. Are there trees on the commons?
Yes No

40.3. What species?

____
____
____
____

40.4. Are the trees self-sown or planted? Indicate by species.

____
____
____
____

40.5. If planted, by whom?

____
____

40.6. Who has a right to use the trees in the common?

CATEGORY E: MARKETING AND INFRASTRUCTURE

A. MARKETING OF PRODUCTS

41. For each crops, livestock and tree products, indicate major Marketing channels, form of marketed product and marketing problems/constraints.

Products	Marketing channel						From		Problem	
	1	2	3	4	5	6	1	2	1	2
A. CROPS Maize Sorghum Barley Wheat Potatoes Fruits Vegetables										
B. ANIMAL Milk Meat Hide Manure										
C. TREE Fuel wood Charcoal Poles Saw timber Chat										

Key:

A. Marketing channels
1. Local barter/scale
2. Direct sale in village or regional market
3. Local or outside traders
4. Cooperatives
5. Marketing boards
6. Processing enterprise

B. Form of marketed products
1. Processed
2. Not processed

C. Marketing problems/constraint
1. Distance to market
2. Prince of products

APPENDIX 3: LANDSCAPE NICHES, TREE SPECIES AND AGROFORESTRY PRACTICES IDENTIFED IN THE ALEMAYA BASIN 1990/91

Landscaps Niche	Indegenous species	Planted species	Agroforestry practice
Home compound	Olia africana Prunus persica Euphorbia abyssinica Musa paradisiaca Croton mocrotachyus Cordia africana Opuntia vulgaris Juniperus procera Schinus molle Euphorbia terucalli Pterolobium stellatum Rosa abyssinica Carisa edulis	Schinus molle Eucalyptus globulus Acacia cyanophylla Opuntia vulgaris Annona cherimola Rosa abyssinica Cordia africana Ricinus communis Juniperus procera Persea americanan Douvyalis abyssinica Agave sisalana E. saligna Calpurnia aurea E. Camaldulensis Mangifera indica Casuarina equistifolia Cupresus lusitanica Prunus persica Casimiroa edulis Mosa paradisiaca	Home garden
Annual crop land	Acacia albida Olea africana Croton macrotachyus Cordia africana Juniperus procera Acacia abyssinica Vangueria linearisepala Calpurnia aurea Olea hochtetteri Vernonia amygdalina Ricinus communis Annona cherimola Zizyphus spina Schinus molle	Ricinus communis Junipres procera Citrus sinensis E. camaldulensis E. globulus Prunus prsica Psidium goajava Acacia saligna Schinus molle Casuarina equistifolia Vernonia amygdalina E. saligna Persea americanan	Trees on farm
	Lantana camara Euphorbia abyssinica Carissa edulis Rumex neruosus Euphorbia terucalli Agave sisalina Opuntia vulgaris Rosa abyssinica	Douvgalis abyssinica Euphorbia terucalli Euphorbia abyssinica	Trees along farm boarder

Landscape Niche	Indegenous species	Planted species	Agroforestry practice
Pernnial crop	Olea africana Croton macrotachyus Cordia africana Vernonia amygdalina Juniperus procera	Prunus persica Schinus molle Juniperus procera E. camaldulensis E. saligna Vernonia amygdalina E. globulus	Trees on farm
		Euphorbia abyssinica	Trees along farm boarder
Annual and perinnial crop land	Croton macrotachyus Cordia africana Vernonia amygdalina Olea africana Juniperus procera Phoenix reclinata Calpurnia aurea Acacia abyssinica Milletia ferriginea	Juniperus procera E. saligna Citrus aurantifolia E. camaldulensis E. globulus Vernonia amygdalina Coffee arabica Ricinus communis Cup. lusitanica Casuarina equistifolia Psidium guajava Persea americanan Schinus molle Annona cherimola	Trees on farm
	Lantana camara Euphorbia abyssimica Curissa edulis Pterolobium stellatum Euphorbia terucalli	Euphorbia terucalli Adathoda schiperiana Opuntia vulgaris Pterolobium stellatum	Trees along farm boarder
Fallow land	Ricinus communis Olea africana	E. saligna Cordia africana Juniperus procera	
Natural pastare land	Calpuria avrea Euphorbia abyssinica Olea africana Carissa edulis Opuntia vulgaris Rumex nervosus Lanatana camara Pterolobium stellatum	E. canbakulebsis	
Planted pasture land	Cordia africana Acacia abyssinica	E. saligna	
Natural forest land	Carissa edulis	Juniperus procera	

Landscape Niche	Indegenous species	planted species	Agroforestry practice
Man made forest land	Cordia africana Opuntia vulgaris Carissa edulis Vangveria Calpurnia aurea Euclea ramosa Croton macrostachyus Juniperus procera Olea africana Douvyalis abyssinica Rosa abyssinica Dodonia viscosa Euphorbia abyssinica Rumex neruosus Agave sisalina	E. camaldulensis Juniperus procera Acacia saligna E. saligna Cup. lusitanica E. globulus Acacia cyanophylla Cup. arizonica	Woodlots
Bush land	Rosa abyssinica Juniperus procera Euphorbia abyssinica Dodonia viscoa Pterolobium stellatum Calpurnia aurea Syzygium sp. Carissa edulis Rumex nervosus Opuntia vulgaris Acacia albida Acacia abyssinica Agave sisalina Olea africana Prunus persica Lantana camara Euclea ramosa Cordia africana Croton macrostachyus Zizyphus spina Dovuyalis abyssinica Jasminum floribundum Vangueria linearisepala	Juniperus procera Acacia cyanophylla E. globulus Cup. arizonica E. camaldulensis	

Landscape Niche	Indegenous species	Planted species	Agroforestry practice
Properity boundaries	Salix subserrata Rosa abyssinica Euphorbia terucalli Opuntia vulgaris Eucalyptus globulus Carissa edulis Calpurnia aurea Euphorbia abyssinica Pterolobium stellatum Agave sisalina Olea africana Douvyalis abyssinica	Eucalyptus globulus Opuntia vulgaris Euphorbia abyssinica Rosa abyssinica Rumex nervosus Douvyalis abyssinica E. camaldulensis Agave sisallina Euphorbia terucalli Schinus molle Sesbanic arabica Prunus persica Musa paradisiaca Ricinus communis Cupresus lusitanica pterolobium stellatum Veernonia amygdalina Calpurnia aurea Olea africana Eucalyptus saligna	Trees along farm boarder
Fences	Euphorbia abyssinica Carissa edulis Opuntia vulgaris Calpurnia aurea Dovuyalis abyssinica	Rosa abyssinica Opuntia vulgaris Euphorbia abyssinica E. globulus Ricinus communis Euphorbia terucalli	Living fences
Roads and trials	Olea africana Euphorbia abyssinica Opuntia vulgaris Lantan camara Rosa abyssinica Carissa edulis Calpurnia aurea Douvyalis abyssinica Croton macrotachyus	Euphorbia abyssinica E. camaldulensis E. globulus Acacia saligna Euphorbia terucalli Opuntia vulgaris Vangueria linearisepala	Raw planting
Drainage	Calpurnia aurea Carissa edulis Rumex nervosus Euphorbia abyssinica Douvyalis abyssinica	E. camaldulensis	
Irrigation channels	Cordia africana Milletia feriginea Ricinus communis Olea africana Croton macrostachyus	Ricinus cummunis Psidium guajava Juniperus procera E. camaldulensis	

Landscape Niche	Indegenous species	Planted species	Agroforestry practice
Gullies	Juniperus procera Euphorbia abyssinica Carissa edulis Olea africana Opuntia vulgaris Agave sisalina Croton macrotachyus Vangueria linearisepala Rumex nervosus Jasminum floribundum	Rosa abyssinica Douvyalis abyssinica E. camalddulensis E. globulus Opuntia vulgaris Juniperus procera Euphorbia terucalli Acacia saligna Ficus syscomorus Pterolobium stellatum Rumex nervosus Agave sisalana Carissa edulis	
Rock outcrops	Olea africana Carissa edulis Euphorbia abyssinica Acacia abyssinica Rosa abyssinica Ddouvyalis abyssinica Romex nervosus Calpurnia aurea Agave sisaline	Acacia saligna Juniperus procera E. camaldulensis	

APPENDIX 4: SUMMARY RESULTS OF LOGISTIC REGRESSION AND LOG-LINEAR ANALYSIS

ANALYSIS OF MAXIMUM LIKELIHOOD ESTIMATES

Effect	Parameter	Estimate	Standard Error	Chi-Square	Prob
INTERCEPT	1	2.9089	0.8724	11.12	0.0009
HHINCOME	2	-0.00015	0.000531	0.08	0.7711
FARMILYSE	3	-0.3246	0.1327	5.98	0.0145
FARMSIZE	4	-1.6034	0.8767	3.34	0.0674
HHINCOME*FAMILYSZ	5	0.000029	0.000062	0.22	0.6416
HHINCOME*FARMSIZE	6	-0.00015	0.000324	0.23	0.6347
FAMILYSZ*FARMSIZE	7	0.1690	0.1257	1.81	0.1788

MAXIMUM LIKELIHOOD ANALYSIS OF VARIANCE TABLE

Source	DF	Chi-Square	Prob
TREPLANT	1	0.92	0.3362
FOODSECU	1	47.95	0.0000
FOODSECU*TREPLANT	1	0.64	0.4254
POLICY	1	1.86	0.1725
TREPLANT*POLICY	1	0.10	0.7498
FOODSECU*POLICY	1	2.84	0.0918
EXTNSION	1	0.01	0.9060
TREPLANT*EXTNSION	1	4.74	0.0294
FOODSECU*EXTNSION	1	0.62	0.4303
POLICY*EEXTNSION	1	1.79	0.1813
TENURE	1	7.82	0.0052
TREPLANT*TENURE	1	0.34	0.5572
FOODSECU*TENURE	1	4.02	0.0450
POLICY*TENURE	1	8.86	0.0029
EXTNSION*TENURE	1	17.91	0.0000
LIKELIHOOD RATIO	12	6.00	0.9161

APPENDIX 5: CROPPING CALENDER BY AGRICULTURAL ACTIVITY FOR THE ALEMAYA BASIN*

Seasons	Fall			Winter			Spring			Summer		
Production system	S	O	N	D	JA	F	MA	A	M	JN	JL	AU
<u>Crops</u>												
Maize		$$	##	--		--		==	=	+	+	
Beans	$$									==	==	
Lucaena					XX	--	==				XX	
Vegetables	++	$$							--	--	==	++
Chat (rainfed)						--	=	=	++		$$	
<u>Animals</u> herding/ tether												
Collecting crop residues				CR								

* Modified after Poschen 1987.

<u>Keys</u>:

--- land preparation; === sowing; +++ cultivation; $$$ harvesting;

processing; xxx pruning; CRCR crop residue.