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THE ECONOMICS OF SOIL CONSERVATION INVESTMENTS IN THE TIGRAY REGION OF ETHIOPIA

By

Berhanu Gebremedhin

A DISSERTATION

Submitted to
Michigan State University
in partial fulfilment of the requirements
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Department of Agricultural Economics

1998

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ABSTRACT

THE ECONOMICS OF SOIL CONSERVATION INVESTMENTS IN THE TIGRAY REGION OF ETHIOPIA

By

Berhanu Gebremedhin

Land degradation, mainly in the form of soil erosion, constitutes the basis for the problems of the low productivity and sluggish growth of Ethiopian agriculture. A national campaign against land degradation has been going on in the country for more than twenty-five years. However, farmer adoption of conservation practices has been low and adopted practices have not been sustained. This study seeks to understand the determinants of farmer adoption and sustained use of conservation practices in the Tigray region of Ethiopia, one of the regions where soil erosion is most severe.

The study analyzes the impact of stone terraces on wheat and fava bean yields and farm profitability, the levels and determinants of farmer perception of soil erosion and conservation, and the factors affecting farmer adoption and intensity of use of conservation practices. Primary data were collected during 1995/96 crop year from a sample of 250 farm households in the Tigray region. Analysis of variance and investment analysis are used to determine the impact of stone terraces on crop yields and farm profitability. Ordered probit and probit models are used to identify and estimate the quantitative impact of variables affecting farmer perceptions. A double hurdle model is used to find out the factors influencing adoption and use intensity of conservation practices.

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Stone terraces increased crop yields significantly and enhanced yield stability. The profitability of investment in stone terraces dropped almost to break-even at a farmer discount rate of 50 percent. An average farmer had 58 percent probability of perceiving soil erosion on his plots as severe and the perceptions were influenced chiefly by village and plot physical characteristics. Village and field physical factors, household capacity to invest, riskiness of investment, socio-institutional and household demographic characteristics affected farmer adoption of stone terraces and soil bunds. However, contrary to stone terraces, investment in soil bunds was made from a low-cost short-term perspective. The factors influencing intensity of use of stone terraces differed from those that affected adoption. Intensity of use was influenced by foregone land productivity and opportunity cost of labor. Farmers were likely to maintain stone terraces once they were built. Implications for conservation policy, research and extension are presented.

To my parents **Gebremed**

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To my wife **Elfu Gebrem**

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To my late friends **Berhe**

Gebresemayat Woldu w

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To my parents **Gebremedhin Gebreegziabiher** and **Sesen Woldegebriel** who never went to school but who hold firm belief in modern education and do all they can to help their children achieve the highest level of education,

To my wife **Elfu Gebremariam** and our son **Samrawi Berhanu** whose continuous support and patience played a significant role in the successful completion of my graduate program, and

To my late friends **Berhe Kiros**, **Yemane Gebreegziabiher, Girmay Gebre** and **Gebresemayat Woldu** who were always eager to see me achieve my dream, and whose untimely death will always pain me.

First and foremost,

Dr Scott Swinton, my dis

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and Dr. Mitiku Haile

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I was impressed by the cooperation I got from officials at different levels in Tigray. Especially, I would like to thank Berhane Haile, head of the Regional Bureau of Agriculture, and Belete and Gebru Teka, from the then Regional Bureau of Natural Resource Development and Environmental Protection. My recognition also goes to the district level administrators, agricultural experts, development agents and farmers in the study area. The diligence and hard work of the enumerators is greatly acknowledged.

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INTRODUCTION

1.1 Background

Land degradation, mainly in the form of soil erosion, has been a major cause of declining agricultural productivity in Ethiopia. Despite its potential to be a net exporter of agricultural and food commodities, Ethiopia has been dependent on food imports for some time now. Moreover, this second most populous country in Africa is reeling from rapid population growth.

Due to recurrent drought and famine, which is partly a result of declining productivity of the land due to soil erosion, environmental awareness has grown considerably. Institutions have been modified to give greater attention to environmental problems. The main focus of the extension work of the Ministry of Agriculture (MOA) has been on soil conservation practices. The Food-For-Work (FFW) Program has been used in mobilizing rural labor to build terraces and soil bunds, and afforest hillsides. A National Conservation Strategy (NCS) was adopted in 1989 to coordinate all natural resource related programs. In 1990, the Ministry of Natural Resource Development and Environmental Protection (MoNRDEP) was created which operated until 1996 when it was again merged with the Ministry of Agriculture (MoA).

However, the efforts of the government and NGOs have been minuscule compared with the magnitude of the problem. Many conservation practices that have been adopted have not been sustained by farmers. In fact, there is growing evidence that soil erosion is accelerating, particularly in the northern part of the country. The physical conservation structures, stone terraces and soil bunds, have encountered technical problems that have led to a reduction in cultivated area and increased incidence of pests. In short, the situation can be described as being characterized by a combination of inadequate resources for an extensive problem, faulty approaches, and inadequate adoption and sustained use of conservation practices.

Soil conservation policy in Ethiopia needs to be re-examined. But new approaches can only succeed if they are based on a thorough understanding of existing farming systems and how previous conservation policies have performed. Specifically, four questions need to be addressed:

a) What are the principal determinants of soil erosion in the Ethiopian farming systems?

b) What soil erosion control techniques have been recommended by the government?

c) Why are recommended soil conservation techniques not being adopted or sustained by farmers?

d) How should the current conservation interventions be modified to increase the adoption and sustained use of conservation practices?

1.2 Problem Statement

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1.2 Problem Statement and Justification of the Study

The highlands[1] in Ethiopia occupy about 43 percent of the country and support 88 percent of the population. In the 1980s about 3.7 percent (2 million hectares) of the land area was taken out of production because of soil erosion (Wood, 1989). Nearly a third of the highlands have slopes exceeding 30 percent and about three quarters are estimated to need soil conservation measures in order to support cultivation. Soil erosion is estimated to reduce yields by 1 percent per year and biological degradation by another 1 percent per year (Stahl, 1990). Moreover, eroded lands grow less nutritious grasses which means poor grazing for livestock and consequently low livestock productivity.

Soil erosion is more severe in cultivated lands because of single cropping and associated practices. Small seeded crops require fine tilth seed beds. Dejene (1990) has shown that crop land covers about 16.3 million hectares and is the largest contributor to soil erosion in Ethiopia. Hans Hurni as quoted by Dejene (1990) estimated that soil loss on cultivated land is four to ten times higher than on grazing land and about 80 percent of the annual soil loss occurs during the months of plowing and in the first month after planting.

Natural resources in Ethiopia are the foundation for increasing the rural standard of living. However, land resources continue to be degraded. Wood (1989) argues that unless land use changes are made so that erosion is slowed, 10 million hectares (10

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[1]Highlands are areas which have altitude of 1500 meters above sea level or more.

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Ethiopia. Its cultivation i

percent of the crop land) will be taken out of cultivation by 2010 which will affect the lives of 10 million people.

The Tigray region is one of the most seriously degraded environments in Ethiopia. Tigray is located in the northern part of the country and it covers more than 80,000 square km with a population of about 3.2 million. It is the region that had been severely affected by recurrent drought and declining agricultural productivity. About 80 percent of the population lives in the highlands and depends on agriculture. Most arable land lies on the plateau, on altitudes ranging from 1000 to 3400 meters above sea level (m asl). The intensity of cropping is once a year. The predominant crops are cereals, which account for 70-75 percent of the cultivated land. High on the plateau, major grains are teff[2], barley and wheat while on the lower plateau and in the lowlands white sorghum, millet and maize predominate. Farming practices include plowing with a pair of oxen and iron tipped wooden plow, sowing by broadcasting seeds, hand weeding, harvesting by a short handled sickle, and threshing by oxen hooves. Crops are typically rotated among grains with occasional crops of legumes.

Agriculture in the region is characterized by increasing land pressure, continuous cultivation of arable land, inadequate manuring and cleared forest lands. As a result, the land is left barren and highly susceptible to erosion. Although land degradation is a pressing problem throughout Ethiopia, the areas that are in greatest need of soil conservation are the northern and eastern highlands (Wood, 1989).

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[2] Teff (*Eragrostis abyssinica*) is a small seeded grain used as a staple food in Tigray region and other parts of Ethiopia. Its cultivation is almost limited to Ethiopia.

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1.3 Research Objectives

The general objective of this study is to determine the physical, social, institutional and economic factors influencing farmers' decisions to invest in soil conservation practices in the Tigray region of Ethiopia.

The specific objectives are to:

1. Study the farm management and farming systems characteristics of the study area,
2. Estimate the effects of stone terraces on crop yields and farm profitability.
3. Discover the levels and determinants of farmers' perceptions of soil erosion,
4. Identify the social, economic and technical determinants of farm household adoption of soil conservation practices,
5. Determine what factors explain the intensity of use of conservation practices by farm households,

1.4 Organization of the Dissertation

The dissertation is organized in nine chapters. Chapter 2 reviews the literature on farmers' adoption of soil conservation practices, policy instruments used by governments, and approaches and stra

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Description of the study a

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and approaches and strategies applied in conservation intervention. Chapter 3 describes the conceptual model and research methods used for the study.

Chapter 4 presents the background information on the problem of land degradation in Ethiopia and the Tigray region. It describes the social, political, and physical conditions that have bearing on land degradation. Agricultural production and the natural resource base are discussed. Chapter 5 discusses the farming systems characteristics of the study area, south central Tigray. It presents descriptive statistics on land tenure, agricultural inputs and constraints on agricultural production. Chapter 6 presents the results of an on-farm research on the effect of stone terraces on crop yields and farm profitability. Description of the study area and method of study is followed by statistical and investment analysis results.

Chapter 7 deals with the levels and determinants of farmer perceptions of the problem of soil erosion and effects of conservation on crop yields. Determinants of preferences of farmers between private investment on soil conservation and community campaign work are discussed. Chapter 8 examines the determinants of farmer adoption and intensity of use of conservation practices. Chapter 9 summarizes the results and draws conclusions and policy implications for national and regional conservation intervention strategies. Implications for research and extension are outlined. Finally the limitations of the study and possible future research topics are presented.

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CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Land Degradation and Conservation in Developing Countries

Developing countries in general and sub-Saharan African countries in particular are facing the triple problems of how to increase agricultural production, reduce poverty, and use their natural resources sustainably. High population growth rates in Africa necessitate that future growth in agriculture will have to come increasingly from yield increases rather than through area expansion (Eicher, 1994). Natural resource sustainability has become one of the central objectives of development. Production will have to increase in such a way that future production capacity of the natural resources is enhanced rather than diminished (Delgado and Anderson, 1993). These concerns are embodied in the paradigm of sustainable development which links together population, poverty and the environment.

Environmental degradation has attracted the attention of policy makers, researchers, and development practitioners for some time now. However, understanding of the problem of environmental degradation has been difficult due to difficulty in obtaining accurate measurements of the problem, and inseparability of the effects of natural conditions from that of humans (Anderson and Thampapillai, 1990). Environmental Economics, concerned with the impact of human activities on the environment, has developed as a coherent body of knowledge since the 1960's. Its applications to the conditions of developing countries began around the 1980's (Pearce and Maler, 1991).

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The forms of environmental degradation can be classified into three general categories: land degradation, pollution and loss of biodiversity. Land degradation is a process by which the productivity of the land is reduced if production inputs, technology and weather conditions are held constant. In other words, land degradation refers to the diminution of the productive capacity of the land. This diminution can arise due to soil erosion, deforestation, deterioration of soil structure, waterlogging, salinization, alkalization, or nutrient depletion.

While the problems of pollution and loss of biodiversity are more important in the industrialized countries, the consequences of land degradation are more prevalent in developing countries. The impact of soil erosion on the productivity of land, for instance, is stronger in developing countries than in developed countries partly because of the higher rate of use of commercial inputs in the latter (Stocking, 1988).

2.1.1 Causes of Land Degradation

Land degradation results from inappropriate land use. The real causes of inappropriate land use are social, economic and institutional rather than technical (Sanders, 1992). State policies may fail to encourage conservation behavior or even induce environmental degradation. Subsidies that encourage mechanization may induce degradation while controlled farm product prices may hinder conservation investments by lowering the profitability of farming. Public subsidy of commercial fertilizer could boost production in the short run but can also be a disincentive to farmers to adopt conservation practices (Barbier, 1990; Anderson and Thampapillai, 1990).

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Extraction of economic surplus from the rural population weakens the rural economic base and can result in degradation of the land. White et al. (1995) have argued that in Haiti, rural environmental degradation is the consequence of the government's systematic taxing the rural population without providing agricultural development services. National governments in their attempt to solve urban social problems such as unemployment may devise erosive land development projects. The development of state farms in Ethiopia in the 1980's is a case in point. Resettlement schemes can be a response to land degradation aimed at reducing the pressure on land. However, land degradation of even a larger scale can occur in the newly settled areas due to fragile lands, unproven technologies, and lack of experience (Anderson and Thampapillai, 1990).

Marginalization of farmers can be another cause of land degradation. The fact that most of the soil erosion that occurs in developing countries is on land areas operated by resource poor farmers is an indication of the forced movement of people into marginal lands (Anderson and Thampapillai, 1990). Colonial settlers in Africa pushed the native Africans into less fertile lands which put a lot of pressure on the marginal lands. As a result, more severe soil erosion was seen in native agriculture (Stocking, 1985).

Market failures induce land degradation (Bojo, 1991). Market failures include imperfection of existing markets, incomplete markets or nonexisting markets. Lack of insurance markets in developing countries coupled with high discount rate of resource poor farmers hinder investment in resource conservation measures whose pay offs are more likely to be long-term. Poorly defined property rights, common in developing countries, result in e

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Environmental degradation is not only the result of social and political factors. It can also become an important factor that influences social and political conditions. Land degradation, for instance, was among the major factors that contributed to the decline of major civilizations in China, Mesopotamia, Egypt, and Greece (Sanders, 1992). Stocking (1988) indicated that soil erosion was directly related to a disruption of Nepal's economy. Lanz (1996) argues that environmental degradation can weaken the structural linkages between government and people.

Agriculture is one of the major sectors that causes environmental degradation. Its impact on the environment has been manifested through four major problems: food security due to land degradation, food safety due to chemical inputs, environmental quality due to water and air pollution and loss of biodiversity. In Africa, land degradation has been at the base of food supply problems (Dejene, 1990). Land degradation can also incur costs on the national economy through increased food imports, increased susceptibility to drought, and higher fertilizer imports (Stocking, 1988).

2.1.2 Soil Erosion: The Major Form of Environmental Degradation in Developing Countries

The soil resource is a complex structure which provides a growing medium for plants by providing rooting zone, soil moisture and air. It also serves as a source of nutrients. While nutrient loss can be easily replenished by growing legume crops, manuring or commer

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manuring or commercial fertilizer, maintaining the other functions of the soil require maintenance of the proper topsoil depth and structure. Application of commercial fertilizer, for instance, can compensate for nutrient loss due to soil erosion but can not offset other effects of topsoil loss (Anderson and Thampapillai, 1990). In the event that the rate of soil loss exceeds the tolerable limit (i.e the rate of soil formation plus deposition), the net loss in topsoil represents deterioration of the quality of the soil resource. Reduced organic matter and water retention capacity of the soil, reduced infiltration and increased runoff are all results of soil loss.

Among the forms of land degradation, soil erosion stands out as the major environmental problem in developing countries. The direct impact of soil erosion is the loss in land productivity through topsoil loss. Soil erosion can also cause field operations to be delayed due to crusting and compaction of soils. Delayed field operations in turn affect crop yields. In the extreme, soil erosion can force farmers abandon their land and migrate to other areas, often to marginal lands inducing further land degradation.

Different methods have been used to estimate the effect of soil erosion on crop yield including (1) removal and addition of top soil, (2) comparative study of soils at different erosion levels, (3) analysis of yield data from plots under varying management practices and landscape positions, (4) use of factor analysis and application of geostatistics and (5) simulation techniques (Olson et al., 1994). Time series data on erosion rates and crop yields have also been used to determine the effect of soil erosion on yield over time (Weesies et al. 1994). The comparative analyses of crop yields from eroded and non-eroded lands, or from lands under different management practices or landscape locations, on the other hand, us

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on the other hand, uses a cross-sectional approach to determine the productivity effect of soil erosion on yield. Simulation models such as the Erosion Productivity Impact Calculator (EPIC) and Nitrogen-Tillage Residual Model (NTRM) have been used to identify agroecological and crop factors that limit productivity under specific conditions.

Multivariate analysis have been used to identify soil and other variables that affect crop yields while geostatistics have been applied to analyze spatial variability of soil and crop parameters of a given site. Econometric damage functions have been estimated to specify the relationship between crop yield and soil depth. The effect of soil erosion on yield reduction depends on the level of erosion that has already taken place. This results in a non-linear relationship between soil loss and yield reduction (Stocking, 1988).

2.2 Conservation Policies and Programs: Lessons From Past Efforts

2.2.1 Past Soil Conservation Strategies in Developing countries

Modern soil conservation efforts have a history of only about 50 years (Sanders, 1992). In Africa, the necessity of soil conservation was first recognized in the 1920's (Stocking, 1985). State intervention to encourage soil conservation has been direct through programs and projects or indirect through policy instruments. When conservation practices are profitable to society but not to individuals, public subsidies are justifiable on economic grounds. Seitz et al. (1979) as quoted in Anderson and Thampapillai (1990) showed, for the US corn belt, that private net returns with conservation were $50 per hectare lower than those without conservation. McConnel (1983) applied a dynamic model to the problem of soil conservation and concluded that it may be rational for

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farmers to let soil erode. Barbier (1990) showed that farmers in the uplands of Java, Indonesia, need economic incentives in order change their land use and management practices. In Kenya, direct cash payments were used as incentives for individual farmers to use on-farm conservation practices (Admassie, 1992). In Ethiopia, FFW payments have been widely used for conservation purposes.

The strategies available to governments to mitigate the effects of land degradation include direct expenditure on public works, provision of education and information, and regulatory measures or indirect through policy instruments to influence farmers land management behaviors (Cary and Wilkinson, 1997; Ervin, 1982). Policy instruments to encourage soil conservation in developing countries include appropriate production subsidies, institutional credit for construction of conservation practices, price and tax incentives, monetary policies that encourage investment in soil conservation, and land and tree tenure security (Anderson and Thampapillai, 1990).

In addition to public subsidies when conservation practices are profitable to society but not to individuals , soil conservation practices need to combine the twin objectives of conserving soil and providing short term real benefits to farmers (Sanders, 1992). The short term benefits may be in the form of yield increase, or the reduction of risk or drudgery. While soil erosion can induce suboptimal input use, conservation practices can push the input mix to optimal (Barbier, 1990). Hence, another way of improving farm level profitability of conservation practices is by encouraging farmers to grow high value crops.

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Past soil conservation programs and projects in developing countries were based on two major assumptions (Norman and Douglas, 1994): (1) the solution to land degradation is primarily technical, and (2) farmers are aware of land degradation and are willing and able to invest on it. Hence the classical approach to soil conservation followed the three steps of problem identification, planning, and implementation. Problem definition proceeded in terms of soil loss rather than productivity loss, and the solutions proposed were engineering structures that would keep soil in place (Sanders, 1992). Inappropriate land use and management were rarely considered, and farmers were not involved in the design of conservation programs. Such top-down approaches have tended to lack adaptability to local conditions (Stahl, 1990). An extreme example of the consequence of coercive top-down approach to soil conservation can be found in Kenya. Due to the coercive nature of soil conservation strategy during the colonial period, soil conservation was totally rejected by farmers for nearly a decade after independence; it took the establishment of a Permanent Presidential Commission on Soil Conservation in 1981 to reinstitute conservation intervention programs (Admassie 1992).

The soil conservation programs and projects promoted by governments and non-government organizations (NGOs) have been expensive in terms of land conserved or soil retained and government effort required (Sanders, 1992). Hence these programs have proven difficult to expand. The mechanical soil conservation practices promoted by such projects were labor intensive, provided little short term benefits, and were not familiar to farmers. The practices required external assistance for adoption, and were usually abandoned after project termination (White et al., 1995).

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Norman and Douglas (1994) identified the reasons for the failure of past soil conservation programs and projects as follows:

(1) they considered loss of top soil separately from loss of productivity,

(2) they were unable to provide short-term benefits to farmers,

(3) they excluded farmers from the design process, and

(4) they ignored the factors that hinder adoption of conservation practices.

The failures of past conservation projects prompted researchers to investigate factors associated with successful adoption of practices. Understanding why indigenous conservation practices have often been abandoned might indicate what needs to be done to facilitate the adoption of modern practices. After reviewing the performance of soil conservation efforts in Africa during the colonial era Stocking (1985) concluded the following:

(1) conservation designs and systems of land use planning need to be simple,

(2) familiar techniques with short term benefits have higher chances of success,

(3) labor demanding techniques have lower chances of success,

(4) local people need to be involved in planning of conservation programs and projects, and

(5) implementation should be primarily the responsibility of local people.

de la Briere (1996) found that FFW incentives would bring poor farmers into conservation in the Dominican Republic. But once the FFW program is over, these farmers do not follow up with the conservation practices due to high opportunity cost of labor. In their study of Colombian farmers, Ashby et al. (1996) found that involving farmers in the design

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farmers in the design of soil conservation technologies and consideration of farmers' criteria for acceptability improved adoption of conservation practices. They identified short term benefits as the most important acceptability criterion. Sain and Barreto (1996) found that farmers in one area of El Salvador successfully adopted conservation practices because the twin objectives of conservation and productivity were linked by economic and institutional incentives. The institutional incentive was provided through the coordination of research, extension and credit institutions.

Similarly, White et al. (1995) in their Haitian study concluded that widely accepted conservation practices shared the traits that they (1) provided multiple benefits, (2) required limited labor and low financial expenditure, and (3) were simple, locally adaptable, improved indigenous techniques that could be constructed using local resources. However, it appears that research and development efforts in both developed and developing countries have neglected the simultaneous pursuit of productivity and environmental quality objectives (Ervin and Graffy, 1995).

2.2.2 Towards a New Approach for Soil Conservation in Developing Countries

Lessons from the failures of past conservation programs and projects and the few success stories have led to the development of a new approach to soil conservation based on the following principles (Norman and Hudson, 1994):

(1) Since productivity loss rather than soil loss is the main problem to be addressed, soil conservation must be considered within the overall framework of agricultural development; improved farming practices should be the basis for conserving soil.

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(2) The focus should be on preventing land degradation, not on curing it.

(3) Soil conservation efforts need to involve farmers in the design, planning and implementation phases.

(4) Soil conservation projects should incorporate short term tangible benefits to farmers

(5) Biological or cultural practices can be more effective than mechanical ones.

(6) The combat against land degradation should be a long term effort supported by emerging research findings.

This new approach to soil conservation implies that in order to develop effective soil conservation programs, every country needs to aim at improving land use, involving land users, and developing appropriate institutions (Sanders, 1992). The first step in developing a soil conservation strategy should, therefore, be to understand the causes of inappropriate land use and management.

The choice of policy instruments needs to be based on information derived from research on 1) the economic status of farmers in the target area; 2) effectiveness, technical feasibility and profitability of the practices, and 3) factors influencing their adoption. Comparison of project-assisted vs control group to analyze the effect of policies and basic infrastructure on the adoption of conservation practices may reveal the effectiveness of particular policy instruments. Since different policies may have contrary effects on soil conservation, coordination of policies that have bearing on soil conservation becomes necessary. Moreover, the flow of information from research and the refinement of policy instruments needs to be a continuous process. In sum, the solution to environmental problems in developing countries lies in an approach which gives more power to farmers and less to govern

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2.3 Farmer Perceptions of the Problem of Soil Erosion and Technology Attributes of Conservation Practices

2.3.1 Farmer Perceptions of Soil Erosion

An understanding of how farmers perceive soil erosion can be more important in designing conservation programs than the physical quantification of soil loss, once the threat due to soil erosion is widely understood. Hefferman (1982) classified the factors often overlooked in soil conservation programs into farmers' perception of the problem of soil erosion, non-economic motives for farming, community influence on farmers to conserve soil, and norms of good farming. Pender and Kerr (1996) claim that farmers' subjective perception of soil erosion are more relevant for their decision on conservation investment than objective measures.

The way farmers perceive erosion problem on their lands versus on others lands may be different. Ervin and Alexander (1981) found that the percentage of farmers in Monroe county, Missouri, USA, who felt that soil conservation was a problem in agricultural land in general was much higher than those who felt the same on their own lands. The same study showed that farmers believed that there was more erosion on rented than on owned lands. Moreover, Carlson et. al. (1976) as quoted in Hoover et. al. (1982) found that farm operators in Palouse area of Northern Idaho and Eastern Washington believed that erosion on their land was one-half that of their neighbors.

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Researchers have also been interested in knowing what factors influence farmers' perceptions of the erosion problem. Gould et. al. (1989) used farmers' area-wide perceptions of the problem of soil erosion in a probit analysis. They found that education level, farming experience, contact with soil conservation services, and proportion of steeper soils influenced perceptions positively while land size had a negative influence. Hoover et. al. (1982) compared Nebraska farmers' perception of soil erosion in 1978 and 1982, and found that increased access to information and knowledge of soil erosion explained the higher perception of the problem of soil erosion found in 1982. Carlson et. al. (1994) investigated changes in farmers' attitudes and behaviors towards soil conservation between 1976 and 1990 in Palouse and Camaras prairies of north-central Idaho, eastern Washington and northeastern Oregon, some of the areas with the highest erosion rates in the United States. They found that farmer awareness of the erosion problem increased and that while socioeconomic variables were important in explaining adoption of conservation practices in 1976, attitudinal factors were more important in 1990.

Farmers' estimates of yield loss due to soil erosion can be inaccurate due to the difficulty in isolating the effect of erosion from that of climate and inputs. Nevertheless, it is important to understand these perceptions because they drive farmers' decisions on conservation investment. Farmers' perceptions need to be interpreted with caution. It could be that farmers are unaware of the problem because they are so accustomed to it that they may consider it as a natural outcome of farming. It could also be that they are

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Studies aimed at determining whether or not perceptions are actually translated into adoption and use of conservation practices have used actual or predicted perception as explanatory variables. Ervin and Ervin (1982) used actual perceptions in their adoption and intensity of use equations and found that perception explains positively both adoption and use of conservation practices. Gould et.al (1989) used predicted probability of perceiving an erosion problem in their tobit model of adoption and found that perception explains adoption positively.

2.3.2 Farmer Perceptions of the Technology Attributes of Conservation Practices

In addition to the understanding of farmers' perceptions of soil erosion, perceptions of the technology attributes of conservation practices need to be considered in conservation programs. Farmers' criteria for the effectiveness of conservation practices include factors other than reduction in soil loss, such as feasibility of the practices, ease of farm operation, effect on yield and profitability. Feasibility of the practices was assumed given in most studies. Perceived rather than actual profitability of conservation practices may be important for adoption of conservation practices (Cary and Wilkinson, 1997; Ervin and Alexander, 1981). This may not be true for intensity of use of the practices, because once the practices are tested, observed profitability is likely to be more important. New technologies entail two types of risks: subjective (due to learning) and objective (due to such factors a

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such factors as weather conditions etc.), of which the subjective risk may be more important in determining adoption of innovations (Feder et al., 1985).

Ervin and Alexander (1981) reported that farmers in Monroe county, Missouri, USA were concerned about the tillage, cultivation and drainage difficulties caused by terraces and efficiency loss was the primary concern regarding contour plowing. Adesina and Zinnah (1993) studied farmers' perceptions of improved rice varieties in Sierra Leone and found that perceived technology attributes explained most of the variation in adoption and intensity of use. These results indicate that omission of technology perception variables from adoption studies can result in biased estimates of adoption variables. However, since perceptions about the technology attributes of the practices can be influenced by experience, their use in predicting conservation behavior needs to account for simultaneity bias.

2.4 Factors that Affect Conservation Behavior of Farmers

2.4.1 Research on Factors Affecting Conservation Adoption

Economic analysis can play a role in combating environmental degradation through project level cost-benefit studies, macro policy analysis, cost assessment of damages at national or international level, and identification and quantification of the factors that influence farmer adoption of conservation practices. Understanding of the factors that affect adoption of conservation practices is important in order to choose the appropriate policy instruments that would influence how farmers manage the land. Quantitative and qualitative research geared towards this end has been going on since the 1930's.

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However, most adoption studies have been limited to the developed countries. These studies tended to use detailed technical information and much rigor. By contrast, the studies in developing countries tend to be more qualitative (Anderson and Thampapillai, 1990).

Following Nowak (1993), the paradigms for explaining conservation adoption decisions can be grouped into five: innovation-diffusion, economic constraints, infrastructure or organizational, physical or ecological, and macro or systems perspectives. These paradigms developed in a historical way, one following the other. Hybrid versions of these models have also been used. The innovation-diffusion paradigm, the first to be developed, focuses on information communication and social pressure as major forces driving adoption. The economic constraints paradigm emphasizes the importance of economic factors and profitability. The infrastructure or organizational perspective focuses on the organization and the system by which it promotes the innovation. The physical or ecological perspective focuses on the applicability of the technologies in different physical environments. Finally, the systems model gives more importance to macro policies and institutional arrangements. A new paradigm focusing on farmer perceptions seems to be emerging (Adesina and Zinnah, 1993). No model has proven to be consistently superior to others because the complexity and site specificity of adoption decisions involves factors from each paradigm to varying degrees.

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2.4.2 Empirical Models in Adoption Research

The predominant analytic method used in conservation adoption studies has been multiple regression analysis. Time series, cross sectional and panel data models have been the three basic statistical models used in the study of technology adoption in general (Besley and Case, 1993). The main focus of the time series models has been to study the aggregate diffusion process over time. Zvi Griliches' (1957) study of adoption of hybrid corn in the United States is a classic example. The dependent variable has typically been an aggregate measure of adoption. These models are of limited importance in explaining the relative influence of those factors affecting the decision to adopt. The cross-sectional studies either take a snapshot of use by farmers of a given technology or use recall data. In the former case the dynamic nature of the technology adoption process is ignored. In case the diffusion process is incomplete, parameter estimates may be biased and results could be misleading. If analysts are careful and explicit in differentiating between adoption and intensity of use of the technology, results from a cross-sectional studies could be indicative of important causal factors. Panel data models, which are based on data pertaining to farm and firm characteristics and adoption choices over time, can potentially address the drawbacks of both time series and cross-sectional models. However, the high cost involved in collecting the panel data have made use of these models somewhat restricted. Their use has been expanding recently.

Irrespective of the type of model used, research on the adoption of agricultural innovations shares some common shortcomings (Feder et al., 1985). These shortcomings include the following: (1) empirical analysis not based on theoretical models, (2) lack of consideration of endo

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consideration of endogeneity problem of explanatory variables, and (3) violation of statistical assumptions required for valid hypothesis testing. Perhaps as a result, the proportion of explained variation of the dependent variable has been consistently low (Lockeretz, 1992).

It is often difficult to interpret results of an empirical model which is inconsistent with underlying theory. The difficulty with using empirical models consistent with an underlying theoretical choice model arises from the data needs and the complexity involved. Researchers need to weigh the costs of using theoretically consistent models in terms of the data needs and complexity required and the benefits in terms of increased understanding of the choice problem.

Non-statistical models, including simulation and mathematical programming models, have also been used in the study of adoption of conservation practices. While the statistical models have been used to determine the factors that affect farmer adoption of conservation practices, the non-statistical models have, for the most part, been aimed at determining the profitability of the practices. Lopez-Pereira et al. (1994) used discrete stochastic a whole farm programming model to determine the profitability of a technical package of physical conservation practices, living tree barriers, seed and fertilizer technologies on low input hillside farms of Southern Honduras. They concluded that a combination of soil conservation, improved seed and fertilizer technologies could increase farm income substantially and facilitate adoption. Gray et al. (1987) used simulation to evaluate the profitability of zero-tillage and minimum tillage practices in central Saskatchewan, Canada. Painter et al. (1993) showed, using mixed integer programming, that adopt

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that adopting a more flexible agricultural policies (as opposed to mandatory set-aside policies) could result in significant economic and environmental gains in North Carolina, USA, diversified farming systems.

2.4.3 Dependent and Independent Variables in Conservation Adoption Research

The dependent variables used have included farmer perception of the problem of soil erosion, use/non-use of conservation practices, and intensity of use of the practices. This last has been measured either as physical length of conservation structures (eg. bunds or terraces), outcome in soil loss reduction or financial expenditure on construction and maintenance of the practices. The binary dependent variable of use/non-use of conservation practices has been employed to examine the factors affecting the probability of adoption. These factors may not be the same as the ones that influence how intensely those practices which are adopted are used. Different factors may be associated with the adoption of different conservation practices (Ervin and Ervin, 1982). Moreover, adoption and continued use may be influenced differently by different factors. Rikoon et al. (1996), in their study of sixteen counties in Missouri, USA, found that the factors associated with adoption and continued use of banded pesticide application were not the same.

The most common explanatory variables used in the studies of technology adoption in developing countries included farm size, subjective and objective risk, human capital, labor availability, credit and type of tenure (Feder et al., 1985). The explanatory variables used to adoption of conservation practices could, in general, be grouped into personal characteristi

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personal characteristics, farm-firm characteristics, physical characteristics of the land, economic and institutional factors. Personal characteristics have typically included the age and education of the farm operator or farm household head, while the farm-firm characteristics included type and size of the farm. The physical characteristics of the land included slope and soil type. Economic and institutional factors related to farm and off-farm income, risk, farmer planning horizon, land tenure, technical and educational services, and other public policies. In addition to the use of different sets of explanatory variables, the operational measurement of the variables has also been widely different, making comparison of results difficult.

Researchers had to select the appropriate mix of variables for a particular study area. Clay and Reardon (1996) in their Rwanda study grouped the explanatory variables into demographic characteristics of the farm household, financial incentives to invest, physical incentives to invest, capacity to invest and riskiness of the investment. Ervin and Ervin (1982) in their Missouri, USA, study grouped the variables into personal, institutional, economic and physical factors. Cary and Wilkinson's (1997) study of Australian farmers used five sets of variables which emphasized perceptions: farmer perception of the environmental problem and technical feasibility of the practices, perceived profitability of the practices, farm size and environmental concern. They contended that non-economic attitudinal factors could play a more important role when profitability is low. Similarly, Hansen et al. (1987) argue that socioeconomic factors may be relevant in explaining adoption of practices that are commercially profitable but not ones that enhan

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ones that enhance environmental quality. However their distinction of commercial versus environmental quality enhancing practices was not clear.

2.4.4 Results of Past Research on Factors Affecting Conservation Adoption

The results of conservation adoption studies appear to be inconsistent regarding the micro-level variables that affect adoption of soil conservation practices; there seems to be a better consensus on the effect of macro-level variables (Ervin, 1994). A wide variety of factors were found to explain conservation behavior of farmers. Sureshwaran et al. (1996) found in the Philippines that education positively influences use of conservation practices. Ervin and Ervin (1982) found in Iowa, USA, that the farm operator's educational level favors perception of erosion problem, adoption and use of conservation practices. Gould et al. (1989) found education explaining adoption of conservation tillage positively in Wisconsin, USA. Operator age seems to work both ways (Rikoon et al, 1996; Sureshwaran, 1996; Hoover and Watilla, 1980).

Under imperfect capital markets, wealthier farmers are more likely to invest on conservation. Hence, farm income tends to encourage conservation (Rikoon et al., 1996; Gould et al., 1989). The effect of farm size varies by the type of practice considered. In general, farm size tends to have a negative effect on use of conservation practices (de la Briere, 1996; Sureshwan et al.,1996; Clay and Reardon, 1996). The effect of off-farm employment appears to mixed (de la Briere, 1996; Clay and Reardon, 1996; Gould et al., 1989; Blase, 1960). Off-farm employment may compete for labor with conservation investment while the income generated could ease liquidity constraint thus encouraging investment. Farme

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A farmers' planning horizon may not affect adoption significantly because the time period during which net return without conservation exceeds that with conservation can be quite long. This statement seems to be in line with the findings of Ervin and Ervin (1982) but contradicts the findings of Gould et al. (1989). Reinhardt (1987) and Lee (1980) found tenure security to be positively associated with conservation practices in their Colombian and US studies respectively. Ervin (1982) found in Missouri that there were fewer erosion control practices on rented than on owner operated lands. Distance of plot from homestead was negatively associated with use of practices in Rwanda (Clay and Reardon, 1996).

Farmer perception of the erosion problem tends to enhance the adoption and use of conservation practices (Ervin and Ervin, 1982; Blase, 1960). Perception of the attitude of local community towards farmers who fail to use conservation practices was found by Bultena and Hoiberg (1983) to be the only variable, in addition to age, that showed significant difference between early adopters, late adopters and non-adopters of conservation tillage. This variable is excluded from almost all conservation adoption studies.

In sum, the fact that demographic, physical, economic, institutional and perceptual variables all turn out significant in studies of soil conservation adoption clearly indicates the complexity involved in conservation decision making of farmers. As a result, the tendency in cons

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tendency in conservation adoption research should be towards expanding the number of explanatory variables considered.

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CHAPTER 3

LAND DEGRADATION AND CONSERVATION EFFORTS IN ETHIOPIA AND THE TIGRAY REGION

3.1 Land Degradation and Conservation in Ethiopia

In a study of land degradation, the physical and ecological conditions, agricultural practices and the policy environment need to be considered together. The feasibility of soil conservation techniques should be evaluated in terms of technical, economic, institutional and policy constraints. This section, therefore, presents the extent, form and effects of land degradation in Ethiopia and discusses the causal factors. The efforts expended in combating land degradation will be evaluated critically to draw lessons for future conservation policies and programs.

3.1.1 Extent and Form of Land Degradation in Ethiopia

Ethiopia is considered the most environmentally troubled country in the Sahel belt (Hurni, 1985). Environmental degradation in Ethiopia is almost synonymous with land degradation. Land degradation is manifested as soil erosion, loss of soil fertility and depth, reduced plant water availability, and deforestation. Of these, soil erosion is the most important environmental problem in the country and its causes are primarily human rather than natural factors. The most important human activities contributing to land degradation in Ethiopia are over-cultivation, overgrazing and deforestation (Dejene, 1990). Grepperud (1996) analyzed the relationship between population pressure and land degradation in I

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degradation in Ethiopia. He found that pressure variables that emanate from human activities are significantly positively associated with land degradation. Most of the soil loss occurs with the intensive rain storms. Constable (1984) as quoted in Grepperud (1994) estimated that 58-80 percent of soil loss in Ethiopia occurs during the intensive rainy period.

There are varying estimates of soil loss and its effect on Ethiopian crop yields. The Ethiopian Highland Reclamation Study (EHRS) as quoted in Bojo and Cassels (1995) estimated that by the mid-1980's about 50 percent of the highlands (27 million hectares) was significantly eroded while more than one-fourth was seriously eroded. The same study concluded that more than 2 million hectares of cultivated land was beyond rehabilitation.

Cultivated land is the major contributor to soil loss. According to EHRS the estimated annual soil loss from cultivated land was 130 tons/ha while the average for all land was 35 tons/ha. On the other hand, Hurni (1988) estimated annual soil loss from cultivated land to be 42 tons/ha and an associated soil formation rate of 3-7 tons/ha/year (Table 3.1). Hurni estimated total annual soil loss to be 1.5 billion metric tons. Campbell (1991) reported that total annual soil loss could be as high as 2-3 billion metric tons.

In addition to the variations in the soil loss estimates, Bojo and Cassels (1995) argue that all previous estimates did not differentiate between gross and net soil losses. In particular, redeposition of eroded soil was not considered. According to them net soil loss is limited only to cultivated and unproductive land and nutrient loss is more important than soil erosion. They estimated that gross financial loss due to soil erosion amounts to US $2 millio

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million per year while nutrient loss due to removal of crop residues and use of animal dung for fuel results in a loss of US $100 million per year. In this vein, Wood and Stahl (1989) argue that use of dung for fuelwood reduces crop yield by 10-20 percent. Belshaw (1989) as quoted in Campbell (1991) indicated that soil erosion reduces cereal yields by 2 percent annually.

Table 3.1: Estimated Soil Loss Rates in Ethiopia by Land Cover

Land Cover	Percent area covered	Estimated soil loss	
		metric tons/ha/year	million metric tons/year
Crop land	13.1	42	672
Perennial crops	1.7	8	17
Grazing and Browsing land	51.0	5	312
Unproductive	3.8	70	325
Uncultivable	18.7	5	114
Forests	3.6	1	4
Wood and bush land	8.1	5	49
Total	100.0	12	1493

Source: Hurni, 1988, p. 127

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Various predictions have also been made regarding the impact of land degradation in the highlands in the absence of changes in agricultural practices, population growth and resource use. One scenario estimated that by the year 2010 the amount of total land incapable of supporting cultivation will reach 10 million hectares (Stahl, 1990). Another estimated that by the same period three-fourth of the highlands would be food deficit (Ministry of Agriculture and FAO, 1984; FAO/UNDP, 1984). While specific numbers differ, the evidence reviewed all suggest that soil erosion is severe in Ethiopia.

In addition to soil loss, the forest resources of the country have also been depleted. Trees have been used for fire wood, house construction, farm implements, animal yard and sheds. The wood supply used to come from homesteads, cultivated land , natural woodland and forests. Forty percent of Ethiopia's land area was covered with forests around the turn of the century. This figure reduced to 16 percent by the 1960's and to 3.1 percent by the 1990's (Wolde-Giorgis, 1993). A shortage of fuelwood has forced farm households to use animal dung for fuel. Fuelwood shortage is directly related to altitude; higher altitude zones use animal dung almost entirely as source of fuel.

The progression of land degradation proceeded with the population settlement pattern from the north of Ethiopia to the center and then southwards and westwards. Fertile soils, cool weather and abundant rainfall favored the beginning of mixed agriculture on the northern Ethiopian highlands about three thousand years ago. The Abyssinian kingdom dated back to the Axumite empire, which was based in central Tigray. Population pressure started to intensify in the 20th century. By the 1980's most of Tigray was se

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was severely eroded and the other northern provinces of Wollo, Gondar and northern Shoa exhibited rapid land degradation (Stahl, 1990).

3.1.2 Physical Factors of Land Degradation

About 43 percent of Ethiopia is highland, more than 1500 meters above sea level. This constitutes more than half of the African Highlands (Hurni, 1988). The topography can be characterized as mountainous plateau extending from north to south, surrounded by series of lowlands. The southern highlands are more productive and stable with lower population density than the northern highlands. In general, the Ethiopian highlands provide a favorable living environment and they have become home to 80 percent of the human population and 67 percent of the livestock. The population density in the rural highlands can go as high as 50 per km^2 (Lanz, 1996). Ninety percent of the country's crop land is also found in the highlands (Dejene, 1990).

More than 30 percent of the highlands, occupying 537 000 km^2 of land area, have slopes exceeding 30 percent gradient (Dejene, 1990; Hurni, 1988). Nearly 79 percent of the highlands have slopes of more than 16 percent gradient (Campbell, 1991). The rainfall pattern in Ethiopia is affected by altitude with the highlands, in general, having higher rainfall than the lowlands. Most of the rain falls in high intensity. Fifty to sixty percent of the rainfall in Ethiopia is lost as runoff (Lanz, 1991). It is estimated that about 80 percent of the water resource of the Blue Nile originates from Ethiopia.

Due to high population pressure the sloping areas in the highlands have been over-cultivated, often with inappropriate land management practices. Jointly, steep slopes, heavy

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heavy rains, high population density and intensive cultivation have resulted in severe soil erosion in the Ethiopian highlands. Conditions are most serious in the north, especially Tigray.

3.1.3 Agricultural Practices as Factors of Land Degradation

Agriculture in Ethiopia is predominantly mixed farming. There is strong interdependence between crop farming and livestock rearing. Land preparation and threshing is done using oxen power. Straw from crop production is a major contributor to livestock feed. Cows are reared mainly for oxen reproduction and milk production.

Increased demand for food crop production due to increased population is first met with expansion of cultivated land. The extensive cultivation strategy soon reaches its limit as new land becomes scarce. In the next stage, land is cultivated more intensively. At present the Ethiopian highlands are at this juncture. Fallowing is becoming obsolete. Crop residue and animal dung are increasingly used for fuel, and the practice of manuring is decreasing. This reduces the organic content of the soil. Lack of organic content in turn reduces fertility which reduces vegetative cover, contributing to soil erosion.

Crop lands that cover about 16 million hectares are the major contributor to soil erosion in Ethiopia (Dejene, 1990). Hurni (1983) found that the ratio of soil loss to soil formation is four to ten times higher for cultivated land than for grassland depending on agroclimatic zone. The high soil losses on cropland originate in the perceived need of small seeded crops for finely tilled seed bed. Plots are plowed from three to eight times after harvest. The ensuing dry periods are long. This hinders the development of vegetative co

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Soil erosion, in turn, reduces the water retention capacity of the soil. As a result crop production has become increasingly dependent on the availability of rainfall during the growing period (Stahl, 1990). Webb and Braun (1989) as quoted in Campbell (1991) estimated that a 10 percent decline in rainfall would result in a drop of 8-9 percent in cereal yields. The problem is compounded with rainfall being more erratically distributed.

Ethiopia has the largest livestock population in Africa. It is comprised of 27 million cattle, 24 million sheep, 18 million goats, 7 million equines and 1 million camels (Dejene, 1990). The number of working oxen is estimated to be 6 million. During the dry season livestock graze freely, mostly on croplands. During the rainy season livestock are limited mainly to mountainsides and pasture land.

The huge livestock population is another contributor to land degradation. Free grazing on croplands during the dry season reduces the vegetative cover of the land exposing the top soil to the torrential rainstorm. During the rainy season, mountainsides support livestock population beyond their capacity. Daniel (1988) as cited in Wolde-Giorgis (1993) estimated that the Ethiopian highlands support livestock population more than three times their carrying capacity.

3.1.4 The Policy Factor

The Ethiopian government began to expand state control into the rural areas in the 1940's (Lanz, 1996). After the second world war, capitalist elements started to be intr

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introduced into the feudal system. The modernization effort of 1950-1974 concentrated on building internal infrastructure, developing industry and commercial agriculture. Peasants were left out of the modernization process. During 1963-74, the share of state budget allocated to the development of agriculture was 4.2 percent of which the most part was spent on the commercial sector (Lanz, 1996). The expansion of commodity production forced peasants into marginal lands. Forest areas were cleared and mountainsides put into cultivation. Soil erosion intensified.

The modernization process itself fell short of success, and growth was very slow. Surplus extraction from the rural areas intensified and weakened the agricultural productive base. The modernization effort had a direct effect on the environment by destroying a substantial amount of forest without replacement.

In 1974, a revolution took place and a military dictatorship replaced the feudal regime. The following year, a land reform nationalized all land, abolished tenancy, prohibited land transfer and limitted land holdings to10 hectares. Land administration became the responsibility of local peasant associations. Private ownership of forest areas was also abolished. Peasant associations and government agencies took the responsibility of managing forest areas.

The agricultural policies of the military regime were aimed at strengthening state control over grain trade, expansion of state farms and promotion of agricultural cooperatives. Smallholder agriculture was once again left out of the scene although the productivity of individual farms was higher than that of the agricultural cooperatives (Stahl, 1990). To these were later added forced resettlement and villagization. Villagization was requiri

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requiring farmers to abandon their villages and build new residences on sites selected by the government. The government's grain marketing parastatal, the Agricultural Marketing Corporation (AMC), was mandated to fix grain prices and enforce quota delivery from farmers. The fixed prices were in most instances below the market prices. Private grain traders were either forced out of business or made to operate as agents for AMC.

The natural outcomes of the agricultural policies of the military regime were substantial land tenure insecurity of farmers and reduced agricultural profitability. During the first six years of the military regime only, food production declined by 6 percent (Lanz, 1996). Moreover, civil war intensified and the government was forced to withdraw more and more resources from development and allocate them into combat. The defence share during the military regime rose from 18 percent at the beginning of the 1970's to 50 percent in 1988 (Dejene, 1990). Forced enlistment of farmers became a routine practice. In effect, the military government replaced feudal lords in the appropriation of agricultural output and even peasant labor. Land degaradation intensified as land and forest resources were literally left without an owner, and the incentives for farm productivity diminished.

3.1.5 Conservation Efforts in Ethiopia

Ethiopian farmers are reported to be aware that soil erosion is a problem and that their agricultural practices are aggravating the problem (Stahl, 1990), although no study has been conducted to date on the level and determinants of their awareness. Despite their awareness, farmers continue to use erosive land management techniques unless provided with incentives to undertake soil conservation. The reasons for this could range from

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short-term liquidity problems to structural factors such as tenure insecurity or lack of farmer involvement in development administration. Although traditional conservation practices have a long history in the Ethiopian highlands, their use is decreasing with time except in few areas in the south (Tilahun, 1996). A successful example of traditional conservation practices is found in southern Ethiopia, among the peoples of Konso. Here the Konso effectively integrate terracing with crop and livestock production and forestry.

Based on descriptive results, researchers have also reported that Ethiopian farmers believe that conservation practices could increase crop yields. The determinants of these perceptions are unknown, however. Amare (1988) as cited in Tilahun (1996) found that out of 72 farmers interviewed in the southern part of the country, 80 percent believed that soil bunds increase crop yield. Admassie (1988) conducted a survey of 600 households in the north, south and east and concluded that farmers believe that conservation practices stabilize production due to increase in soil moisture. Research findings seem to confirm farmers views. Gebre Michael (1980) as quoted in Stahl (1990) found that yield on fields with soil bunds can be higher by 60 percent compared to fields without soil bunds.

The farmer awareness of soil erosion should create a favorable condition for conservation intervention by government or nongovernment bodies. Conservation intervention in Ethiopia started in early 1970 (Campbell, 1991). The interventions took almost entirely food-for-work (FFW) approach. In the 1980's FFW programs in Ethiopia became the second largest in the world, next to India (Campbell, 1991). The World Food Program (WFP) and the European Economic Community (EEC) were the main suppliers of gr

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grain and edible oil for FFW while other donors provided tools and technical equipment (Stahl, 1990).

By the late 1980's, more than 1 million km of soil and stone bunds have been constructed on cultivated land, plus more than half a million km of hillside terraces had been built, and more than 80 000 hectares of hillsides had been closed off (Hoben, 1995). Not surprisingly, most of the conservation work was done in the northern Highlands. Hurni (1988) argues that soil accumulation behind bunds can form bench terraces in 5-20 years. Martin Bundez as cited in Dejene (1990) found that in hillside closures, grasses and bushes could regenerate within 2-3 years, erosion significantly reduced in 3-5 years, and gully formation stopped in 10 years.

FFW was also instrumental in afforestation programs with support for the programs coming mainly from WFP, Swedish International Development Agency (SIDA), and the Federal Republic of Germany (FRG) (Dejene, 1990). Trees and forests help to reduce soil erosion by reducing the erosivity of rainfall, improving soil structure by increasing its organic content, keeping soil intact by the effect of roots, and reducing the velocity of winds. In the 1980's, about 300,000 hectares were planted with trees, and nurseries with a capacity of raising about 100 million tree seedlings annually were operating (Stahl, 1990). Grass seedlings to stabilize terraces were also raised.

Impressive as these results may appear, the FFW approach was confronted with several problems. The environmental reclamation effort was not based on any on-farm research on the production, economic or environmental impacts of the technical package, much less on the diverse agroecological conditions (Hoben, 1995). The conservation pract

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practices had technical problems. Stone terraces, in addition to reducing cultivated land area, were harboring pests. The land area covered was quite limited compared with the extent of the problem. The lack of involvement of local people in the planning and implementation of the FFW conservation projects made farmers view the conservation works mainly as a means of getting the FFW payments rather than as necessary means for environmental rehabilitation. As a result, sustainable use of the practices without the FFW payments was very low. The conservation techniques were labor intensive. The project preparation and implementation followed a pure 'top-down' approach where involvement of local people was minimal. In particular, implementation was coercive.

As for afforestation, there were no management plans for the closed areas and pressure from grazing animals increased on nearby areas. The afforestation programs did not provide any guidelines regarding tree ownership rights. Perhaps as a result, the survival rate of seedlings was low (Stahl, 1990).

3.2 Society, Agriculture, and Natural Resources in the Tigray Region

This section deals with the effect of agro-ecological, social and physical factors on the problem of land degradation in Tigray. The mechanisms by which the rural population adopt to changing agricultural and environmental conditions including drought, and input constraints are discussed. Current practices of crop and livestock production are presented. The level of natural resource degradation, farmers perception of the problem, and institutional and private efforts to combat land degradation currently underway in the region are assessed. Finally the role of rural institutions including land tenure, agricultural credit

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credit and extension services is discussed. Since most of the secondary information was available by administrative zones the discussion is, in most cases, accordingly structured.

3.2.1 Topography and Climate

Tigray is situated between 12°20′ and 14°40′ N latitude, and 36° and 41°30′ E longitude on the Sudano-Sahelian African drylands zone. It covers an area of approximately 80 000 km^2. The topography of the region is characterized by mountain plateau. A Plateau of height between 2500 and 3400 meters above sea level crosses the center towards the west with associated mountains on both sides. In the west the plateau join lowlands of less than 500 m a.s.l.. In the east an escarpment sharply extends into the salt mining depression of the Danakil desert.

Administratively, the region is classified into four administrative zones- southern, eastern, central and western. The basic administrative unit in the region is called a tabia which is a collection of villages. A group of tabias make up the next higher level administration referred to as a woreda. Several woredas make up a zone.

The climate of the region can be characterized as tropical semi-arid (Virgo and Munro, 1978). As such, Tigray is confronted with the challenges of development caused by a dryland environment including erratic and unreliable rainfall, shallow and infertile soils, and outbreak of crop pests and diseases. Agroecologically, the region can be classified into four zones, viz., highland, intermediate highland, lowland and desert, with relative area coverages respectively of about 5 percent, 41 percent, 49 percent and 5 percent (Regional Bureau of Agriculture, 1995).

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Atmospheric temperature in the region ranges from 5° to 40° celsius. Most areas in central, eastern and southern zones have temperatures between 15° and 19.9° C. The most important factor of agricultural production in Tigray is the amount, and spatial and temporal distribution of rainfall, particularly during the months of July and August.

Annual rainfall ranges from 450 to 980 mm. In general, rainfall increases as one moves from east to west and from north to south. However, depending on altitude, nearby areas may show wide differences in the amount of rainfall they receive. While most of the western zone has a unimodal rainfall pattern, the rest of the region has bimodal rainfall, with small rains falling during the period March to May, and the big rains falling in the period June to September. In some areas in the eastern and southern zones, the small rains may begin as early as January thus allowing double cropping.

The distinguishing characteristic of the precipitation is that most of it falls within the three months and in high intensity. It was estimated that 75 per cent of the precipitation falls at a rate of more than 25 mm/hour (Virgo and munro, 1978). Moreover, no strong correlation exists between number of rainy days and amount of rainfall (Tilahun, 1996). Another major characteristic of rainfall in the region is its inter-annual variability. A 27-year average rainfall indicates that rainfall variability is high in absolute terms and much higher than the corresponding national figure (Table 3.2).

Table 3.2: National and Regional Rainfall Averages and Variability (1961-87)

	Average Annual Rainfall (mm)	% of National Average	Standard Deviation	Coefficient of Variation
Tigray	578	63	162	28
Ethiopia	921	100	71	8

Source: REST, 1995, P. 31

There are two major drainage systems in the region. The Mereb river, which is seasonal drains northern Tigray in the west direction to the Sudan. The perennial Tekeze river drains central and southern Tigray to the Nile (Belay, 1995). Despite a substantial amount of potential irrigable land, estimated to range from 0.3 million to 0.5 million hectares, little irrigation is practiced by Tigray farmers.

Very limited basic infrastructure is found in Tigray at the moment. Average walking distance to nearest all-weather road is estimated to be 6 hours (Woldegiorgis, 1993). A study conducted in central Tigray also indicated that average walking distance to nearest market place in the area was 2.5 hours .

3.2.2 People and Society

Population and social organizations

The population of Tigray is estimated to be 3.2 million making crude population density of 40/km^2 (Regional Bureau of Economic Planning and Development, 1995). Ninety percent of the population depends on agriculture for its livelihood. Average life expectancy i

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expectancy is 46 years (REST, 1995). The household, built mostly on nuclear family, is the basic unit of society. The rural population is organized into more than half a million farm households (Meles and Hagos, 1995). The household functions as an economic unit. It makes decisions on resource allocation dictated by the ecological and environmental conditions which determine climate and operating costs. Besides the household, several social organizations aimed at mutual help and cooperation exist, including neighborhoods, religious associations, savings associations, and labor and/or oxen exchange groups. The social function of these organizations is significant, particularly during drought and/or famine conditions.

The household in Tigray appears to be a stable unit of social structure. However, a close scrutiny into the development of a typical household indicates that vertical relationships within a family are easily liable to change. The household , although effectively bound together as a unit, can easily change in size. The vertical ties between the household decision maker and junior members can and do break at any time. Hence households and villages can rapidly change in size and adapt to environmental changes. The strong belief among the Tigrayans that status-honor should be achieved by own accomplishments and not by inheritance gives the motivation for every individual to find his/her role as an active member of the social system. This fluidity of social organizations facilitates risk taking, and would encourage innovation and rapid diffusion of innovations. Bauer (1985, p. 151) describes this situation as follows:

> " The apparent stability and rigidity of social stratification [in Tigray] are belied by the facts. The appearance of moribundity falls to a view

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> of social relations that encourage, almost force, innovation both social and technical. The family as a transgenerational unit is weak; emphasis is laid upon the leadership of individual household heads."

Children of non-working age, less than 15 years of age, constitute nearly 50 percent of the population. A study conducted in central Tigray indicates that proportion of children of non-working age in the survey area was 46 percent while that of old age people, above sixty-four years of age, was less than 4 percent (REST, 1995).

Settlement pattern in the region appears to be determined by soil type (Virgo and Munro, 1978). While fine textured and less easily drained soils favor nucleated settlement due to difficulty of traversing fields during rainy season, dispersed settlement is found in coarse textured and easily drained soils. The former is found in the southern zone and around Mekelle, the capital town of the region. The latter settlement pattern is found in the eastern and central zones. This difference in settlement pattern has a direct bearing on the possibility of using manure for maintaining soil fertility.

Rural labor supply

The major occupation of rural labor is farming, with limited involvement in off-farm work. Extent of participation in off-farm work, however, differs from zone to zone where participation is highest in the eastern zone followed by the central zone. Farmers in the southern and western zones show less involvement in off-farm work. The supply of labor in the region is regulated in part by the functioning of an institution of celebrating saints days which prohibit agricultural work during those days. A survey in central Tigray indicat

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indicates that on average 111 days in a year are work prohibition days (REST, 1995). During peak labor demand seasons, the most frequent source of additional labor is exchange labor. Use of hired labor is very limited although the daily wage rate of an agricultural laborer seems to increase from year to year.

Prior to 1975, seasonal migration of labor from Tigray to commercial farms in the southern and to the coffee growing areas of the western parts of the country was common. As many as 100 000 laborers used to migrate southwards from Tigray and the neighboring former province of Wollo every year in the 1960's (Lanz, 1996). Such an outflow of labor from the northern regions was an indicative of the fact that the north was converted into a progressively weaker economy and a source of surplus labor to the growing commercial sector which was part of the modernization strategy of Emperor Hailesselassie's regime. Although such opportunities for employment did not exist after 1975 due to the nationalization policy of the military government and civil wars, the outflow of productive labor from the region continued in the form of forced resettlement. In other words, the indirect forces of neglected and weakened economy were replaced by the direct military forces of resettlement. The outflow of labor from Tigray has been reversed since 1991. There is now an influx of returnees to Tigray, people who had migrated to other parts of Ethiopia, were dislocated by the resettlement programs of the military government or after staying in the Sudan as refugees. Most of these returnees are farmers (Wolde-Giorgis, 1993).

On the other hand, shortage of trained manpower, workers with post-secondary education, is still very critical. In 1994 the trained manpower in the regional bureaux of agricult

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agriculture and natural resource development combined consisted of only 45 M.Sc., 90 B.Sc. and 352 Diploma (two years of college education) holders. The manpower situation in the regional agricultural research center was even worse with less than 10 researchers having only M.Sc. or B.Sc. degrees and most of whom had limited research experience. One needs to see this acute shortage of trained manpower in conjunction with the urgent need to combat land degradation and increase food production.

The role of women

Households headed by women are a permanent feature of social organization in Tigray. Bauer (1985) indicates that in 1973, the proportion of female headed households in his survey area around mekelle, the capital of the region, was 20 percent. A survey conducted by REST in 1993-94 in central Tigray came up with a corresponding figure of 25 percent (REST, 1995). The latter figure is higher than the national average of 14 percent (Gebru, et al., 1995). Women's role in the region in household decisions, and political and administrative matters is increasing. Active participation of women in local administration from village to woreda level is particularly significant. Involvement of women in decision making at the household level is also high. A survey in central Tigray showed that most decisions at the household level are also made jointly by the husband and the wife (Table 3.3).

Table 3.3: Role of Household Members in Decision Making in Central Tigray

Decision	Decision Making Role (percent)			
	Husband	Wife	Both	Other
Planting	12.91	19.75	57.70	9.64
Selling/Buying Crop	8.71	16.49	69.67	5.13
Selling/buying livestock	11.35	20.68	62.74	5.23
Seed Selection	16.49	20.06	52.41	11.04
Social expenses	10.58	24.42	60.33	4.69

Source: REST, 1995, P.115

3.2.3 Crop Production

Land use and cropping pattern

Out of the total estimated regional cultivable land area of 1.5 million ha, about 1 million ha is currently under cultivation. Most of the uncultivated area, a relatively fertile land mass, is found in the north western lowlands of the region (Meles and Hagos, 1995). Forty percent of the total area is estimated to be used for grazing while forest cover accounts for only 0.3 per cent (Regional Bureau of Agriculture, 1995). Cereal crops production accounts for 84 percent of the cultivated area, while oil seeds and pulses account for 9 percent and 7 percent respectively.

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Cropping pattern is determined by a combination of factors including risk attitudes of farmers, preference for food, yield considerations and the time required by each crop for optimum planting. The most important factor perhaps is risk. Farmers prefer to plant fields in dispersed locations and use a variety of crops in order to avoid total crop failure due to erratic and unreliable rainfall or crop pest outbreak. Moreover, farmers seeding rate practice shows an inverse relationship between seeding rate, and depth and fertility status of the soil.

The three most important cereal crops in the region in terms of area coverage are sorghum, barley and teff (Table 3.4). Sesame accounts for more than 80 percent of the area covered by oil seeds while fava beans account for about 30 percent of area covered by oil seeds.

Table 3.4: Distribution of Area Coverage of Cereal Crops in Tigray (1993-95 average)

Crop	Percent of area covered
Sorghum	28.84
Barley	16.67
Teff	16.3
Millet	13.55
wheat	10.75
Maize	9.09
Barley/wheat mix	2.95
Other	1.85

Source: Abraha et.al., 1995, p.4

There is also a difference in cropping pattern among zones. While barley is the most important cereal crop in the southern and eastern zones, sorghum takes the lead place in the central and eastern zones (Table 3.5). Among oil seeds, linseed is most important in the southern, eastern and central zones while sesame takes the place in the western zone. Chickpea dominates the area devoted to pulses in the western zone, while fava bean is more important in the other zones.

Table 3.5: Three Widely Grown Cereal Crops in Tigray, by Zone (1993-1995 average)

Zone	Rank		
	1st	2nd	3rd
Southern	barley	wheat	teff
Eastern	barley	wheat	barley/wheat mix
Central	sorghum	teff	barley
Western	sorghum	finger millet	teff
Region	sorghum	barley	teff

Source: Own computation based on Abraha et. al.,(1996, p.4)

Under normal conditions, the first crops to be planted are finger millet, maize and sorghum, followed by barley, barley/wheat mix, wheat and teff. Oil seeds and pulses are planted late in the season, generally only when the early crops fail. This planting pattern may be disrupted if the small rains fail. Perennial crop production is very limited. Due to the variety of agroecological conditions in the region, different perennial crops including orange, lemon, guava, papaya, banana and grapes can be grown and the reason for the limited production of these crops is not obvious. However, farmers' interest in perennial crops appears to be growing.

Crop yields

Due to moisture stress, crop pests, and low soil fertility, crop yields in the region are low. The factors for low crop yield are direct consequences of the challenge that the dryland environment poses for development. The regional average yield for cereals is 6.93 meteric quintals (100 kg) per hectare (qt/ha), while the corresponding figures for oil seeds and pulses respectively are 5.66 and 4.59 (Table 3.6).

Table 3.6: Yield (100kg/ha) of Cereal Crops, Oil Seeds and Pulses in Tigray (1993-95 average)

Cereals		Oil Seeds		Pulses	
Crop	Yield	Crop	Yield	Crop	Yield
Barley	6.82	Noug	3.12	Field pea	4.23
Wheat	5.40	Linseed	2.50	Chick pea	4.45
Barley/wheat mix	5.95	Sesame	6.26	Lentils	3.68
Finger millet	5.88			Haricot bean	4.50
Maize	8.69			Lathyrus	5.67
Sorghum	9.15			Fava beans	5.06
Teff	4.06				
Region	6.93		5.66		4.59

Source: Abraha et. al., 1995

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Use of improved seeds in the region is very limited and farmers grow local seeds. In addition, farmers prefer to use their own seeds rather than seeds obtained from other sources. However, seed selection from among the local varieties is widely practiced. Farmers select seed based on several criteria including time required for maturity; soil and moisture requirements; weed, pests and disease tolerance; baking quality, suitability for different food products, color of food product; grain and fodder yield; and size of grain. Among these the most important factors considered by farmers are time required for maturity, drought tolerance and grain yield (Haile, 1995). Plant breeders may need to take these factors into consideration in designing research programs.

Seed selection is done both pre-harvest and post-harvest. In the former method, which is more widespread, farmers mark and harvest separately those plants which showed better performance from germination to fruition. In post-harvest selection, better seeds are selected from harvested heads. Seed exchange among neighboring plot owners is practiced when one of the plots has better crop stand or patches of crop stands. Farmers residing in different villages also exchange seed. In addition to seed selection, intercropping is also practiced by farmers in Tigray, the most common intercropping practices being cereals with oil seeds or pulses. Seed selection is accompanied by seed multiplication. This is done in two ways. One way is by sowing the selected seeds in part of a plot designated for multiplication during planting season. In the second method, farmers plant the seeds on catchments during dry periods.

Despite efforts by farmers to preserve their own seed, in practice, farmers use seeds from different sources. This is a direct result of the inability of most farmers to be selfsuffic

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sufficient in their production. A study in central Tigray indicates that seed sources other than own production were mentioned more than sixty per cent of the time. The most frequently used alternative sources being market and relatives.

Community seed banks aimed at providing seed to the needy farmers are now operational in some woredas of Tigray. They are organized at the woreda level and operate at the village level. Their purpose is to store good quality seed varieties. Each seed bank is administered by a committee comprised of agricultural experts, contact farmers, and selected farmers. Seeds are purchased from local farmers who multiply better performing varieties or have field of better crop stand in the area.

Oxen ownership and use

The current land disribution system, assigning land to individuals rather than to households, resulted in remarkable equity in land distribution. With this equity in land distribution in the region, agricultural capital and inputs have become the major factors of social differentiation. The most important factor, perhaps, is oxen ownership. A study in central Tigray indicates that 38.5 per cent of farmers in the survey area were without any ox, only 16.6% of them reported being self-sufficient in draft power, and average oxen ownership was 0.83 per household (REST, 1995). Shortage of draft power is even more acute to female headed households. In addition to oxen losses from recurrent droughts, the availability of fodder in normal weather years is another reason for households' inability to keep the required amount of oxen. The problem of fodder is particularly pressing before the beginning of the rainy season when most of the grazing pasture is depleted. It is common

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common to supplement this dry period feeding with straw and stovers. However, the yield of such products does decline from year to year together with the decline of grain output. The situation is compounded with the decreasing land holding size due to population growth. The consequences of inadequate draft power include late and reduced frequency of land preparation, and late planting with a major depressing effect on crop yield. The most important source of additional draft power is oxen exchange. Oxen rent for cash has very recently been started. In the eastern zone a pair of oxen including labor and implements is rented for 25-30 Birr[3]/day. In the central and southern zones, the rate is about 36 Birr/day.

Agricultural implements

Although less serious than the shortage of draft power, some households also lack adequate farm implements. Agricultural villages in Tigray used to be self sufficient in agricultural tools and implements. Iron parts of the oxen-drawn plow were made by local black-smith and wooden parts by the farmers themselves. There would be at least one black-smith workshop in each village for producing and sharpening metallic tools.

The oxen-drawn traditional plow in use in Tigray, and indeed in many parts of Ethiopia, only turns the soil without breaking it. It is possible that unploughed strips may be left between consecutive passes. As a result, ploughing of three to four times[4] is normally required before the soil is ready for sowing. At first plowing, plow depth ranges

[3] In 1995/96, US $1 =6.30 Birr.

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from five to ten centimeters depending on the soil type and moisture content. At final cultivation, ploughing can be as deep as twenty centimeters (Salih and Morris, 1996). Post-planting plowing is commonly done in fields sown with maize, sorghum and millet, the purpose of which is to increase water percolation and reduce weeds.

The reasons for the widespread use of the traditional plow include its versatility for different operations and soil types, simplicity in operation and maintenance, light weight and ease of transportation, low draft power requirement, and the possibility that most of the parts can be made by the farmer himself. Its drawbacks include its being primarily a cultivation rather than a plowing implement, low pulverizing effect, and inability to turn the soil. The efforts currently underway by the Rural Technology Promotion Department (RTPD) of the region to introduce improved farm implements need to take these points into consideration. The regional RTPD has been trying since since 1992 to introduce the moldboard plow, chisel plow, broad bed maker, and tied-ridger to farmers in the region, depending on the specific needs of a particular environment. Broad bed maker is meant to reduce the problem of water logging in areas with predominantly clay soil, and tied-ridger is aimed at conserving soil moisture.

Fertilization and pests

The most widely used fertility maintenance practices of farmers in the region are manuring and crop rotation. Due to land scarcity and possibily tenure insecurity, fallowing has become a disappearing practice. Use of chemical fertilizer by farmers in the region is very limited. The proporition of farmers using commercial fertilizer was 11 percent in 1993 and 16 percent in 1995. Among the few farmers who use commercial fertilizer, the application rate is much lower than the rates recommended by the regional bureau of agriculture. A study conducted in 1995 in central Tigray indicated that the average rate of fertilizer application in the study area was 18 kg/ha (Haile, 1995). There is also zonal disparity in the use of commercial fertilizer. The eastern zone has the highest proportion of households that use commercial fertilizer while the southern zone has the least. The proportion of households in the central zone is slightly higher than those in the western zone. The most common reasons given by farmers for not using commercial fertilizer include high price, and inadequate and/or unreliable rainfall. Some farmers believe that application of fertilizer favors the development of the crop pest shoot fly which affects mainly teff. Due to its high value, most fertilizer is applied on teff.

The dry land environment of farming in Tigray provides favorable conditions for weeds, crop pests and diseases. However, the threat to agricultural production comes more from weeds and pests than plant diseases (Fitiwy et al., 1996). Broad leaved weeds, grasses and parasitic weeds are economically important. The parasitic weed, striga, favored by the regional ecological conditions of erratic rainfall, low soil fertility, and mono-cropping practices, causes substantial loss in sorghum, finger millet, and maize fields. Important crop pests in the region include barley shootfly, termites, stalk borer, weevils and beetles. Rodents also cause significant problem both pre- and post-harvest.

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3.2.4 Livestock production

Livestock population and use

Livestock play an important role in the rural economy of Tigray. Oxen are the only sources of draft power for plowing. As such, oxen ownership is major indicator of wealth and food security status of farm households. Livestock products such as milk, meat, and eggs are important food items for rural households in addition to being a source of cash. Hides and skins are used for storing agricultural products and for sale. Even though dung cakes are increasingly becoming used for fuel, animal manure is still used as fertilizer. Moreover, livestock are used as dowry and source of prestige for many rural families. Some rural households consider investment in livestock as a risk spreading strategy- a source of cash income from sale in case of crop failures due to drought.

Estimates of livestock population in the region vary considerably. The regional bureau of agriculture's 1992 livestock survey report estimated that Tigray had 2.1 million cattle, 5.6 million sheep and goats, 0.5 million horses, mules and donkeys, 1 million poultry, and 0.1 million beehives. As such, the region accounts for about eleven per cent of the total livestock population in the country (Berhane, 1995). While cattle dominate in the highlands, sheep and goats are more prevalent in the low altitude zones.

Livestock management and feed

The most important problems of livestock production in Tigray is shortage of feed, particularly in the southern, eastern and central zones. Livestock population is much higher than the carrying capacity of the region as a whole. Animal feed in the region include

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straw, maize and sorghum stover, hay, pasture and browse trees. More than forty-six percent of the feed comes from crop residues, the most important of which are teff, wheat and barley straw, and pulse halms. During the dry season animals graze freely on cultivated and communal pasture areas while during planting time they would be restricted to pasture areas and areas bordering the cultivated plots. After the 1984/85 drought, prickly pear is becoming popular as animal feed in the region. Although the crop is not a traditional fodder crop, recurrent drought and coping efforts of farmers is making the crop an important fodder crop. My discussion with farmers in the field regarding the reason for the growing popularity of prickly pear as a fodder crop indicates that its resistance to drought and its moisture conserving ability make the crop suitable as a fodder crop during dry season. Its cultivation which was limited to the eastern zone is now spreading to all over the region. Many farmers are planting their gardens permanently with the crop. Farmers who live in areas with relatively more livestock feed take custodianship for raising cattle, sheep, and goats owned by those who live in areas of more serious feed shortage. Custodians get 25 to 50 percent of goat and sheep offsprings, and all the milk from cows.

Poor management is another major problem of livestock production. Most farmers devote minimal managerial care only to oxen and cows. Sheep and goats are believed to need no managerial care. Moreover, quantity of animals is preferred to quality and productivity. As a result, livestock production in the region is characterized by late maturity, late first calving, low milk yield, and long calving interval. First calving in cattle is at about five years and average calving interval is three years (Berhane, 1996). Animal diseases are prevalent.

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The extension service provides demonstrations and farmer training on improved livestock production techniques. In addition to expanding the provision of veterinary services, the regional bureau of agriculture is trying to introduce an improved feeding system including restricted grazing, improved hay making, stall feeding, and forage development. The shift towards stall feeding needs to be seen within the overall context of agricultural production in the region. Stall feeding can increase availability of manure and reduce the energy loss of livestock due to walking in search of fodder where there usually is little. On the other hand, stall feeding requires more labor for watering, housing and breeding. Moreover, oxen and pack animals need the physical exercise required for plowing and transporting.

Overpopulation of livestock is one major cause of land degradation in the region. Improvement of the quality and productivity of livestock could facilitate destocking thus reducing the pressure on grazing land, and better opportunity for stall feeding. This would, however, require farmers to change their attitude towards livestock ownership. Strategies for natural resource conservation and development in the region need to explicitly consider livestock production. Failure to do so may mean ineffective use of human and capital resources for natural resource conservation and even more land degradation.

3.2.5 Natural Resource Degradation and Conservation

Soil erosion

Land degradation in Tigray, mostly in the form of soil erosion and deforestation is very severe, particularly in the southern, eastern and central zones. The western zone, due

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to relative low population density and adequate grazing area for livestock, exhibits less severe land degradation. The severity of land degradation in the region is manifested by gullies cutting arable lands, exposure of stones and rocks in cultivated and grazing areas, destruction of grazing land and declining crop yield. REST's study (REST, 1995) in central Tigray indicate that about 50 per cent of the cultivated land in the study area was severely eroded. This result confirms the findings of a study conducted in 1975 (Virgo and munro, 1978). Michael Stahl succinctly described the land degradation situation in Tigray as follows: " If any region [in Ethiopia] would need environmental first aid, that would be Tigray" (Ornas and Salih, 1989, p.192).

The main causes of soil loss is in appropriate land use coupled with erosive rainfall, steep slopes. There has never been a policy that delineates arable from nonarable areas. As a result, although most arable lands are found on the plateau and undulated terrain, steep slopes are also widely cultivated. Except in the northwestern part of the region, almost all land that is physically cultivable is currently under cultivation. Areas that are not cultivated are in most cases drainage-line depressions used for grazing livestock and steep rocky lands which are the only places for browsing.

The seemingly paradoxical combination of lack of adequate soil moisture and excessive run-off are among the major contributors to the severity of soil erosion. Due to the concentration of rainfall in the months of June to August, shallow soils, removal of fine soil particles by soil erosion and lack of soil organic matter, soil moisture is in the available range for less than three months in a year. Lack of adequate soil moisture reduces the vegetative cover of the land exposing the soil for further erosion. Moreover, crop residue t

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is grazed right after harvest after which the land is ploughed repeatedly to combat weeds. When the rainy season begins, cultivated land remains without cover. According to Virgo and munro (1978), even during the growing season, vegetative cover in the grazing and browse areas does not exceed 30 percent, the rate below which accelerated soil erosion could occur; and that the highest rate of soil erosion occurs in marginal cultivated lands of a middle slope of up to 15 percent gradient.

Quantitative soil loss studies are rare in Tigray. The first attempt in this regard was the study conducted by Virgo and Munro in 1975. Based on a combination of empirical and suspended sediment measurements, the study estimated soil loss for the central part of the region to be 17-33 metric tons per hectare. The same study applied the Universal Soil Loss Equation (USLE) on cultivated lands and concluded that potential soil loss rates for the region could range from 200 tons /ha to 400 tons/ha, the difference being principally accounted for by sowing date, which affects the level of vegetative cover. Moreover, a comparison of photographs of 1965 and 1974 indicated that gullies expand at an average rate of 5-10 meters per year and that gullies which were as recent phenomena as since 1943 are now a major erosion feature in most parts of the region.

The USLE could have been applied to assess soil loss and indicate the relative importance of the causative factors of soil erosion in the region thereby providing guidance for conservation programs. However, I have not come across any other quantitative soil loss study. The Soil Conservation Research Project (SCRP), funded by the government of Switherland since 1981, and aimed at providing applied research findings to support the soil and water conservation efforts in Ethiopia did not have a research station in Tigray.

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Deforestation

Several areas in Tigray are said to have been covered with forests only about 40 years ago (Wolde-Giorgis, 1993). There is virtually no forest area left at present except for a few remnants at places such as Desa and Hugumburda, and church yards. Cutting trees for fuelwood, timber and agricultural implements, and clearing forests to expand agricultural land have exhausted the forest cover of the area. Use of oxen for plowing particularly needed clear land. While cultivated land was operated under individual households, forest areas were either communally utilized or open access resources. The resulting deforestation has caused a shortage of fuelwood forcing households to use animal dung and crop residues for fuel thereby reducing the organic matter and nutrients returned to the soil.

There has not been any formal policy that defines ownership or use rights of trees that grow on cultivated land, communal forests, gullies, wasteland and closed areas. There is only an informal institution that allocates ownership and user rights to households when trees are grown on plots adjacent to the homestead. The price of a load of fuel wood depends only on the consideration of transportation and labor costs with no value accorded to the trees themselves. Currently, cutting trees from cultivated land or forest area is prohibited without obtaining permission from the concerned administrative body.

The development of forest resources in the region requires assurance of ownership and use rights of trees, an appropriate organizational and legal framework for tree planting and forest management on communal lands, and/or allocation of communal lands to individuals for tree planting and grazing purposes. Area closures may result in increased

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pressure on productive land due to grazing requirements unless products from the closed area are used systematically to feed animals in a cut-and-curry system. This requires an appropriate policy for the utilization of products from the closed areas as well.

Livestock management and grazing systems need to be accorded serious consideration in addressing the problem of land degradation. Solving the problem of land degradation in a significant way may be impossible without appropriate policies pertaining to livestock population and utilization of pasture land. Expansion of the provision of veterinary services which has been the main focus of livestock development all over Ethiopia may actually have contributed to land degradation by emphasizing the quantity rather than the quality of livestock.

Community involvement in soil and water conservation

Farmers in the region apperar to be aware of the problem of land degradation (REST, 1995). However, pressed by short-term needs, they continue to use cultural practices that induce land degradation. Several local expressions indicate how farmers perceive the problem. Expressions such as 'flat lands are converted into gullies that could not even be crossed by small animals' and 'small streams we used to cross on foot have widened by erosion to become larger than a stone's throw' indicate the extent of land degradation (Wolde-Giorgis, 1993). Farmers also praise households that protect their land from soil erosion. Hence there is a favorable condition for mobilizing local communities to combat land degradation and develop natural resources.

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Farmers in the region have used terracing for soil and water conservation since as back in history as the Axumite empire, around 700 A.D (Oyhus, 1995). Check dams, grass strips, agroforestry and contour plowing were also used traditionally by farmers in many parts of the region. The conservation practices currently recommended for use by farmers are in effect improved versions of the traditional practices.

Soil and water conservation efforts supported by government or foreign aid donors are very recent. The United States Agency for International Development (USAID) supported the first afforestation and terracing program in Tigray during 1971-1974 (Hunting Technical Service, 1976, as cited in Tilahun, 1996). Under this program about 4400 km of bunds were constructed and 3.4 million seedlings planted. After 1974, the environmental rehabilitation efforts in the region were supported by the UN/FAO FFW program. During the period between 1983 to 1988, more than 94,000 km of hillside terraces, 18,000 km bunds and 500 km check dams were constructed (Tilahun, 1996). On the other hand, the Tigray People Liberation Front (TPLF) was organizing soil and water conservation programs since 1988 in areas it had controlled. The prominent features of the TPLF-led programs were community participation in their planning and implementation, and emphasis on achieving food security through conservation based agricultural development. This was in contrast with the donor-led programs in the government controlled areas which did not involve local communities in their design and implementation.

Due to the highly degraded and barren sloppy areas, all soil and water conservation efforts focused on constructing physical conservation structures whether sponsored by the

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government, donors or rebels. No scientific or systematic study has examined the effectiveness and sustainability of the structures. But the urgency of reducing run-off and soil loss at least for the short term justifies use of the engineering practices. Some zonal experts in the regional Bureau of Natural Resource Development consider this movement as the first phase in the effort to combat land degradation, the second phase being supplementing the physical structures with biological measures.

Since the downfall of the military government in 1991, every able person in Tigray has been required to provide free labor for soil and water conservation efforts, nearly 50 percent of which is contributed by women. Initially, every able citizen was required to provide four months of free labor annually. This was reduced to twenty days in 1995. Such mass mobilization in campaign form has resulted in the construction of many different physical conservation structures. During 1992-1995, soil and stone bunds were constructed on more than 0.37 million hectares of land (Table 3.7). Lying the emphasis on physical structures may result in an immediate reduction of soil loss. However, the long term effectiveness and sustainability of the structures is uncertain. Hence there is a need to supplement and strengthen them with trees, shrubs, or grasses that have been selected locally using adaptive research.

Table 3.7: Soil and Water Conservation Accomplishments Through Public Campaign Work in Tigray, 1992-1995

Type of Work	Unit of measurement	Accomplishment
Soil and stone bund	hectare	370,432
Terrace maintenance	hectare	35,389
Afforestation	hectare	3,555
Area closure	hectare	125, 000
Diversion ditch	kilometer	1,618
Grass strip	kilometer	1,646
Check dam	kilometer	1,938
Pond construction	Unit	28

Source: Teka and Edwards, 1996, p.2

In addition to community involvement, an environmental rehabilitation project known as Sustainable Agriculture and Environmental Rehabilitation in Tigray (SAERT) is currently operational in the region. The main objective of the project is to develop small scale irrigation schemes. It incorporates the construction of small scale irrigation dams, conservation of the associated watershed, and where necessary, afforestation. The project emphasizes capacity building and participation of local beneficiaries.

Institutional aspect of soil and water conservation public campaign work

Since 1992, the soil and water conservation campaign works have been coordinated at different levels by committees composed of experts, administrators and local people. At the regional level, a soil and water conservation team composed of experts leads the effort by developing annual plans, and conducting monitoring and evaluation activities. At zonal and woreda levels, committees are constituted by a chairperson and other members of the respective administrative body, head of the bureau of natural resources, and representatives of farmer associations. The committees make detailed conservation plans, and facilitate and monitor their implementation. The expert from the bureau of natural resources is responsible for technical aspects. At tabia level, the local committee is made up of the chairperson and other members of the administration, a development agent, contact farmers and representatives of farmer associations. The tabia committee closely supervises the implementation of the plans at village level and reports results. At village level, where the soil and water conservation work is actually carried out, work is coordinated by a committee chaired by a development agent and constituted by contact and selected farmers.

Although annual plans for soil and water conservation activities are prepared at the regional level, they are approved at the village level before implementation. An annual plan drafted at the regional level will be passed to zonal committee for evaluation and modification. The revised version of the plan will again be evaluated and possibly modified by the woreda and tabia committees before it is passed to the village level. The village committee evaluates the plan in terms of feasibility before it finally approves it for implementation.

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Once a village approves its annual plan, implementation proceeds through several steps. First, development agents and contact farmers decide on which part of the village land should be conserved. Next, they estimate the number of person-days that able people in the village can contribute for the campaign work. Slope measurement, technique selection, and marking of contours will then follow. Three conservation techniques are commonly applied, namely, stone terrace, soil bund, and check dams. On hillsides stone terraces are used. On cultivated lands, either stone terraces or soil bunds are applied. The choice between stone terraces and soil bunds is made based on the avaialability of stones and slope degree. Generally, stone terraces are used as there is no shortage of stones for construction and steep slopes. Checkdams are used to control gullies.

Villagers are grouped into work teams of 7-10 individuals. Since 1995, a man or youth is required to construct 12 meters of soil bumd or 7 meters of stone terraces per day while a woman is required to construct 6 meters of soil bund and 3.5 meters of stone terraces. The village community imposes fines on those villagers who fail to contribute labor during the campaign work. Most fines take the form of a double work load.

3.2.6 Rural Institutions

Land tenure

Prior to the land reform of 1975, there existed private, state, church and communal based tenure systems. The private tenure system was based on inheritance through the family who first cleared the land or occupied it after the previous tenure rights lapsed. Under this system, which was locally called risti, a person who could prove his descent

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from the original tenure right holder was entitled for a share of the land. Under the state ownership system, locally called gulti , state officials at different administrative levels were entitled to collection of taxes from the tenants who operated the land. Part of the collected tax could be given to the regional or national government. The church-owned lands operated in the same way as the state owned lands except that the taxes collected from the land were used by the churches or else the land would be operated by church servicemen in exchange for their service. The communal tenure system evolved over time as a replacement for the other systems when the latter failed to fit the changing social and environmental conditions of villages. Under the communal system, land distribution was based on residency in a particular village. It was not uncommon for an individual to own holdings under different tenure systems.

Under the risti system, it was the discretion of the father to give land to his children, and parents had significant power over their children due to land inheritance expectations. The continuous subdivision of land resulted in considerable fragmentation of holdings (Bruce, 1976). Moreover proving blood relationships would usually end up in court, and conflicts among relatives based on land claims were common (Wolde-Giorgis, 1993).

Neither of the different land tenure systems that existed prior to 1975 gave tenure security to farmers. This may have discouraged investments in land development. The land reform of 1975 by the military government proclaimed that land was the collective property of the Ethiopian people. Land ownership was effectively abolished, giving farmers only usefruct rights. Coupled with the collectivization policy of the government, the land reform rendered farmer land tenure even more insecure. The reform could not be implemented in most parts of Tigray due to security reasons.

However, TPLF itself was an advocate of land reform in areas it controlled. The TPLF-pioneered land distribution also gave farmers usefruct rights to land. The system was based on two simple principles: (1) a farmer needs to reside as a farmer in a given tabia to get land from the tabia and (2) land will be allocated to individuals, not to households. Adults get equal shares and four underage children are counted as one adult. In most places, the minimum age for qualification as an adult for land distribution is 22 years for male and 15 years for a female. However, the minimum age requirement for entitlement to land can vary from district to district. It is the district congress, locally called woreda baito, that decides on the age limit. Since residence is one criterion for entitlement to land, the current land tenure system precludes 'ownership' of plots in different tabias. Moreover, the system has given legal land tenure rights to women; upon divorce, the husband and wife retain their individual shares.

Land is distributed by a committee elected by tabia farmers. The share allotted to an adult household member is referred to as one-half of a gibri. The sum of the shares of two adult household members, therefore, makes up one gibri. Two underage children receive one-fourth of a gibri. The size of a share of an adult, however, depends on the availability and fertility status of cultivated land in the tabia. For distribution purposes, cultivable land in a tabia is classified into three groups based on fertility status as fertile, medium and degraded. Mitiku (1995) found that the local land classification used for land distributuion purposes was consistent with modern scientific classification system.

Each household is allotted land from each category. A considerable variation may exist in the size of a share between different tabias. Usually the size of land allocated from the degraded category is larger in size. Land holding per household also varies between administrative zones. In the western zone, the land holding per household is 2.4 ha, while the corresponding figures in the central, eastern, and southern zones respectively are 1.06 ha, 0.9 ha, and 1.25 ha (Regional Bureau of Agriculture, 1995). The regional average of land holding size is 1.2 ha.

Land was redistributed in order to accommodate young families and returnees from settlement areas of the military government. This had resulted in further fragmentation of holdings. Although there is no policy that formally establishes that there would be no further land distribution, land distribution is temporarily halted in the region and several new families and returnees have not been allocated land.

Land leasing is also widely practiced in the region. Households who are unable to operate their own land may lease it for a share of the harvest. Lease agreements specify input contributions, including labor and seed, as well as the division of the harvest. The prevailing arrangement is to share output equally between the share cropper and the land owner. In some places, a renter may pay a lumpsum payment.

Like its predecessors, the current land tenure system does not guarantee farmers full security in their holding. In the absence of a law that prohibits further redistribution of land, farmers expect that land can be redistributed at any time. This uncertainty seems to have limited land development efforts mostly to plots that are adjacent to the homestead, because of the relative security farmers have on the nearer plots. In conclusion, the absence of tenure security for many generations in the region is likely to have contributed significantly to the land degradation process.

Agricultural credit

The predominant sources of agricultural credit in Tigray have been relatives, friends and merchants. Although the regional branches of government banks such as Commercial Bank of Ethiopia (CBE) and Development Bank of Ethiopia (DBE) are mandated to provide credit to farmers, the operational procedures of these formal financial institutions have not been suited to the credit needs of farm households, particularly the small farmers which constitute the bulk of the rural population. In most cases, collateral requirements have put the financial institutions out of farmers' reach. A study conducted in central Tigray (REST, 1995) indicated that relatives and friends made up for more than 65 per cent of the sources of credit in the study area.

After many years without a formal financial institution that meets the credit needs of farmers, REST initiated a rural credit scheme in 1994 designed to meet these needs. The scheme combines both credit and savings services. The organizational structure of the credit scheme stretches from the head office at Mekele to the mobile branch offices at the tabial level. Each branch office is staffed with a branch manager, an accountant and a cashier. Loans are processed and savings accepted at the branch level.

Priority in loan provision is accorded to women and the relatively poorer farmers where poverty is defined based on oxen ownership or equivalent wealth. For this purpose, beneficiaries are selected by the whole community. The selected individuals will then make

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up credit and saving groups, and a collection of groups will make up credit and saving centers. Group members approve loan requests by individuals. Groups and centers are collectively responsible for loans taken by individuals. Although no collateral in the form of physical capital is required, group pressure and group savings serve as indirect forces to facilitate repayment. Woreda and tabia congresses work in close collaboration with the branch offices and local community in the process of beneficiary selection, coordination of inter- and intra-group activities, monitoring of credit use, and repayment enforcement in case of potential default.

Although it is too early to evaluate the performance of this innovative credit scheme, results of the first few years of operation appear to indicate promising performance. Until late 1995, 14000 households in twenty different districts were served and 19 million Birr was disbursed. Out of this, 46 percent was received by women. A repayment rate of 93-98 per cent was recorded (Gebremedhin et al., 1996).

Agricultural extension and farmer cooperatives

Agricultural extension service in Ethiopa was first provided in 1951 under the then Alemaya College of Agriculture, where it was coordinated with the college's teaching and research activities. The extension organization has since gone through successive modifications. In 1961, the Ministry of Agriculture took the responsibility from Alemaya College. In order to generate technology for diffusion to farmers, the Institute of Agricultural Research (IAR) was established in 1966, administered by a board chaired by the minister of agriculture. Since this time, integrated rural development programs and/or

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extension programs aimed at diffusing package of technologies have pre-dominated. However, most of these agricultural extension efforts did not operate in Tigray for various reasons.

During the 1980's, TPLF provided extension service in areas it liberated, placing major emphasis on soil and water conservation. In the absence of modern technologies tested for use in the region, the extension program focused sound indigenous practices such as land preparation, timely operation of farm activities, seed selection and pest control. By 1991, on the eve of the downfall of the military government, the program was operating in almost all parts of Tigray.

Currently, a modified version of the training and visit (T&V) extension model is being used in the region. The whole region is classified into extension centers. Each extension center, which is a collection of villages, has three development agents, one each for agricultural production, natural resource development and home economics. Each village has seven contact farmers of which two each are for agricultural production, home economics, and natural resources development, and one for plant protection. Development agents receive two days training each month from woreda level agricultural experts. This is followed by a meeting of the development agents and contact farmers. The contact farmers then meet with the village community every two weeks. The focus of the extension services in the region are agronomic and crop protection demonstrations, distribution of improved seed, distribution of forage and horticultural seedlings, provision of modern inputs and associated credit, formation and development of farmer cooperatives. By late 1995, about 300 extension centers were operating, in which 65 half-hectare demonstration plots managed by the bureau of agriculture, 1 566 one-tenth hectare demonstration plots for cereals on farmers fields, and 104 fifty square meter farmer field demonstration plots for horticultural crops were used (Meles and Hagos, 1995).

Four types of farmer co-operatives function currently in the region viz., multipurpose cooperatives, handicrafts producers' cooperatives, fishers' cooperatives and water users' associations. Multipurpose cooperatives provide members with diverse services including agricultural inputs and consumer goods. Water users associations are aimed at coordinating the use of irrigation water that is being developed as a result of the SAERT project. In 1995, about 150 multipurpose cooperatives and 47 water users associations were functioning with total membership of 98,700 and 3,280 respectively.

3.3 Summary

Soil erosion is the most serious environmental problem in Ethiopia and cultivated land is the major contributor to soil loss. Steep slopes and erosive rainfall are the major physical factors of soil erosion. To these is added intensive cultivation of land due to increasing population pressure. The huge livestock population is another contributor to soil erosion due to overgrazing.

Agricultural policies of the previous governments had left small holder agriculture out of focus of development programs. Farmers lacked land tenure security. The marketing policies of the military government depressed the profitability of small holder agriculture. As a result, small holder investment in land improvement practices had been very low.

Public intervention in soil conservation started in the early 70's, mostly in the form of FFW projects. However, the interventions used technical packages that were not tested on-farm and which lacked adaptability to the diverse agroecological conditions. Involvement of local people was also minimal.

The Tigray region, which receives about 30 percent less rainfall than the national average, is one of the most severely degraded areas in Ethiopia. Moreover, the region was not a significant beneficiary of public interventions for natural resource conservation during the past regimes. Conservation and development of the natural resources and rehabilitation of the environment has been at the center of any development policy in the region since 1991, after the dawn fall of the military government.

CHAPTER 4

FARMING SYSTEMS CHARACTERISTICS OF THE STUDY AREA

This chapter characterizes the farming systems in the study area using the descriptive statistics from the household survey and econometric models of availability and use of farm inputs. Land tenure and crop production; availability and use of draft power, local and improved seed, commercial fertilizer; and household involvement in off-farm employment are described. Farmer ratings of development constraints and priorities for government intervention are also discussed.

4.1 General Characteristics of the Surveyed Villages

The study area, in south central Tigray, ranges in altitude from 1560 to 2510 meters above sea level. Areas between 1500 and 2500 meters above sea level are categorized as intermediate highlands and those above 2500 meters are in the highland zone. Three of the thirty villages included in the survey were in the highland zone. According to the villagers, the predominant soil textures were sand and clay and the predominant topography of twenty-three of the villages was hilly or intermediate hilly. The average walking time from the surveyed villages to the nearest market place and all weather road, respectively, were 1.6 and 1.5 hours.

Land degradation has forced villagers to depend more on animal dung as a source of cooking fuel. Seventy-five percent of the villages depended primarily on animal dung for fuel while the rest used fuel wood from forests and bushes. To fetch fuel wood (without considering the time spent to collect the wood), the average round trip walking time was 6.3 hours. In some villages, residents had to travel for as long as 12 hours. In the highland zone, the average walking distance was 5 hours while the corresponding figure for the intermediate highland zones was 7 hours. However, animal dung was reported as the only primary source of fuel in all the villages in the highland zone while twenty-eight percent of the villages in the intermediate highland zone depended primarily on forests and bushes for fuel. Eighty percent of the villages had closed areas (areas protected from human or livestock intrusion) with the duration of area closure ranging from 1 to 17 years. The benefits villagers get from the closed areas included feed and construction wood.

The number of households living in a village ranged from 59 to 610 with an average of 242 households per village. Male-headed households accounted for 83 percent of the total households. The average family size was 4.8, and the average female and male members per household were 2.4 and 2.6 respectively. The number of working age household members (15-64 years old) averaged 3 per household. Only twenty three percent of household heads were able to read and write. The age of household heads ranged from 20 to 78 with an average of 47 years. Twenty-five percent of the households reported sending a child to school. FFW projects were operational in seventeen of the villages during 1992-95.

4.2 Land Tenure

The national policy on land tenure stipulates that farmers have usufruct rights on land, but may not buy or sell it. In principle, a farmer is entitled to get land as long as his primary occupation is farming and he dwells in a village. In Tigray, redistribution of land has been halted for some time now. In the survey area, the time since last land distribution up to 1995, ranged from 2 to 12 years and the time of operation of a plot of land by a given household ranged from 1 to 38 years. During the 1995/96 crop season, the average area of cultivated land per household was 1.7 hectares, made up of 3.5 plots with an average plot size of half a hectare. Some farmers cultivated as many as 11 plots. The average cultivated land per capita was 0.4 hectares. Since farmers are entitled to land in their tabia, most plots cultivated were not far away from their villages. The average walking distance to a plot from homestead was half an hour. Plots with slopes as high as 23 degrees were cultivated by the surveyed households.

The average land share of a couple (husband and wife) was 1.3 hectares, and the average share of a child 0.2 hectares. The average share of a couple was lower in the highland zone (1.0 hectare) as compared to the intermediate highland zone (1.3 hectares). The minimum age for entitlement to land ranged from 12 to 17 years for females and from 20 to 26 years for males.

Land leasing is commonly practiced in the area. Twenty-six percent of surveyed farmers reported having leased land during the 1995/96 crop year. The average land size leased out was 0.7 hectares. The most common rental form for land lease is share cropping, the dominant ratios of share being 1:4 and 1:3 between the owner and the operator (Table 4.1). The most important reasons for leasing out land were lack of draft power, labor and seed in that order.

Table 4.1. Rental Form for Land Leasing and Share Crop Ratio

Rental form and share crop ratio		Percent of farmers	
		(n=61)	(n=64)
Share cropping	1:5	6.6	85.9
	1:4	36.1	
	1:3	32.8	
	1:2	24.6	
Share cropping and lumpsum payment			10.9
Fixed amount in kind			3.1

In addition to farmers responses about why they lease land out, a probit model was estimated to determine the factors associated with land lease practice after other factors were controlled for. Land leasing was expected to be determined by agroecological condition and village characteristics, land area owned, labor availability, and household demographic characteristics.

Location in a highland zone (HIGHLAND) was expected to reduce the likelihood of leasing out land due to the relative land scarcity compared to the intermediate highland zone. Distance of village from market place (MKTDIST) and all weather road (ROADDIST) were expected to encourage leasing out land due to their effect in reducing the return to agriculture. Use of animal dung as primary source of fuel in a village (FUELDUNG) was expected to encourage leasing out due to the relative severity of land degradation which could reduce agricultural productivity. Land area owned (LANDOWN) was expected to encourage land leasing. Number of working age family members (WORKERS) should discourage leasing out land due to the availability of labor for farm activities. Among the demographic variables, male household head (MALEHEAD) was hypothesized to reduce leasing out as male headed households would be expected to have higher access to resources and age of household head (AGEHSHED) to increase land lease for the opposite reason. The expected effect of literacy of household head (LITERACY) was ambiguous because literate households could have better access to resources or more likely to be involved in non-farm activities. Having access to credit (CREDITAC) should discourage leasing out since it eases liquidity problems. Explanatory variables are defined in Table 4.2 below.

Table 4.2: Definition and Measurement of Explanatory Variables

Variable code	Definition	Measurement	Level of observation Village=VILL Household= HD
HIGHLAND	Agroecological Zone	0=intermediate highland 1=highland	VILL
MKTDIST	Distance of village from nearest market	walking hours	VILL
ROADDIST	Distance of village from nearest all-weather road	Walking hours	VILL
FUELDUNG	Major source of cooking fuel	0=forest and bush 1=animal dung	VILL
AGEHSHED	Age of household head	years	HD
MALEHEAD	Sex of household head	0=female 1=male	HD
LITERACY	Literacy of household head	0=illiterate 1=literate	HD
SIZEHSHED	Size of household	number	HD
WORKERS	Number of working age household members	Number of people aged 15-64	HD
LANDOWN	Owned land	Hectares	HD
LANDSIZE	Size of cultivated land	Hectares	HD
CREDITAC	If household had access to formal or informal ag. Credit	0=no 1=yes	HD

The following probit specification was estimated to determine the characteristics of farmers who leased land out.

LEASEOUT = F(HIGHLAND, MKTDIST, ROADDIST, FUELDUNG, LANDOWN,

WORKERS, AGEHSHED, MALEHEAD, LITERACY, CREDITAC)

LEASEOUT refers to leasing land to others during the 1995-96 cropping year (0=no, 1=yes)., and all explanatory variables are as defined in Table 4.2 (page 84).

Eight of the ten explanatory variables had the expected signs. Highland zone and sex of household head significantly explained the leasing out of land (Table 4.3). Farm households residing in the highland zone had less probability of leasing land out as compared to households who lived in the intermediate highland zone. This may be due to the relative land scarcity that exists in the highland zone. Female headed households are more likely to lease land out because they possess inadequate labor and/or draft power. Male household head had the highest marginal effect (-0.39) on a the probability of leasing out land by a household, followed by highland zone (-0.21). An average farmer had 14 percent probability of leasing out land.

Table 4.3: Probit Model Predicting Land Leasing Practice of Farmers (robust standard errors)

Indep. Variable	Coefficient	Marginal effect (dF/dx)
HIGHLAND	-1.034 (.422)**	-.211
MRKTDIST	-.225 (.173)	-.061
ROADDIST	.038 (.089)	.010
FUELDUNG	-.258 (.250)	-.074
LANDOWN	.003 (.110)	.001
WORKERS	-.099 (.106)	-.026
MALEHEAD	-1.148 (.275)***	-.393
AGEHSHED	.010 (.008)	.003
LITERACY	.190 (.267)	.053
CREDITAC	-.257 (.229)	-.066
Constant	.688 (.541)	---
Chi-square	38.26	---
Prob. > chi-square	0.0000	---
Pseudo R-square	0.1912	---
Predicted prob. at x-bar	---	.136
N	215	---

***, ** significant at 1% and 5% respectively.

Farmers in the survey area feel more insecure about their holdings in the long run than in the medium term. Sixty percent of farmers responded that they felt certain that they would cultivate their plots five years from 1995 while only 41.7 percent felt sure of being able to leave their plots to their children (Table 4.4).

Table 4.4: Perceived Tenure Security Among 243 Interviewed Farmers, 1995-96

Security Type		Percent of farmers (N=243)
Will cultivate plot in five years	Yes	60.5
	No	6.2
	Am not sure	33.3
Will leave plot to children	Yes	41.7
	No	24.4
	Am not sure	33.9

Farmers' estimates of land area did not show strong correlation with actual measurements of field sizes. Farmers were asked to report the size of each plot of land they cultivated in the 1995/96 crop year in tsimdi, a local measure of land area equivalent to the area that could be ploughed using a pair of oxen in a day. Four tsimdi is approximately equivalent to one hectare. The farmers' estimates were converted into hectares using this equivalence. The size of each plot was again measured directly in hectares. A comparison of farmers' estimates and the direct measurement showed a correlation coefficient of 0.67. This result indicates that farmers' estimate of land size needs to be taken with caution.

4.3 Labor use

The primary activities involving adult males include land preparation, cultivation and harvesting, while adult females are involved primarily in household and cultivation activities. Fuelwood collection is done by all household members. Work prohibition on religious days is widely observed in the Tigray region. In the study area, the number of such days excluding weekends ranged from 0 to 11 per month. Weekends are not working days.

Farmers in the area experience labor shortage for farm operations. Fifty eight percent of surveyed farmers reported labor shortage for the 1995/96 cropping season of which only 30 percent used hired labor while 52 percent used exchange labor or help from friends and relatives to alleviate the problem. Casual hired labor is mainly male. While permanent hired labor was reported to be scarce throughout the year, casual hired labor was abundant except for the months of September to December (Table 4.5).

Table 4.5: Availability of Hired Labor as Rated by Respondents

Labor Type	Percent of farmers (N=243)		
	Abundant	Scarce	Seasonally scarce
Permanent	12.7	82.4	4.9
Casual	51.0	29.6	19.3

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Casual hired labor is mainly used for cultivation and harvesting. The crops for which labor shortage was more prevalent were teff, wheat and barley. Farmers reported the need for additional labor especially for weeding, harvesting and threshing during the months of July to November. In addition to agricultural activities, 29 percent of households reported participation in off-farm work, the most important being construction, trade and selling firewood (Table 4.6).

Table 4.6: Households' Off-farm Involvement by Type of Work

Type of work	Percent of households involved (N=71)
Trade	25.4
Construction	43.7
Food processing	2.8
Selling fuelwood	12.7
Fetching salt	1.4
Other*	14.0

* includes, among others, crafting, quarrying, spinning and hair dressing

In order to identify the factors associated with participation in off-farm activities a probit model was estimated. Off-farm work was expected to be determined by agroecological condition and village characteristics, land area owned, family labor availability, and household demographic characteristics.

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Farming in a highland zone (HIGHLAND) should reduce off-farm involvement due to higher land productivity. Distance of village from market place (MKTDIST) and all-weather road (ROADDIST) were expected to reduce participation due to possible lack of off-farm employment opportunities. Villages with more degraded soil proxied by use of dried dung for cooking fuel should encourage off-farm work due to lower land productivity. Age of household head (AGEHSHED) was expected to have an ambiguous effect because such households could have more experience in off-farm activities or less available family labor. Land area owned (LANDOWN) was hypothesized to reduce participation as wealthier households should have less need for off-farm income. The impacts of sex of household head (MALEHEAD) and availability of family labor (WORKERS) were ambigous. Male-headed households might have less need for additional income than female-headed households, but they are more likely to have off-farm skills. Availability of family labor could increase farm income but also encourage participation in off-farm activities due to the availability of labor. Literacy of household head (LITERACY) should increase involvement as literacy could result in skills for off-farm work. The impact of access to credit (CREDITAC) was ambiguous as credit can encourage investment in both farm and off-farm activities.

The following probit specification was estimated to identify the factors influencing household involvement in off-farm work:

OFF-FARM = F(HIGHLAND, MKTDIST, ROADDIST, FUELDUNG,
LANDOWN, WORKERS, AGEHSHED, MALEHEAD,
LITERACY, CREDITAC), where

OFF-FARM refers to household involvement in off-farm activities during the 1995-96 cropping year (0=no, 1=yes). All explanatory variables are as defined in Table 4.2 (page 84).

Participation in off-farm work was explained negatively by distance of village from market place and positively by major source of fuel (Table 4.7). Households living in remote villages were less likely to participate in off-farm employment perhaps due to limited employment opportunities. Those living in more degraded environments were more likely to participate in off-farm employment. Relative degradation of land had the highest marginal effect (0.17) on the probability of household participation in off-farm employment. An average farmer had 27 percent probability of participating in off-farm employment.

Table 4.7: Probit Model Predicting Participation in Off-farm Employment (robust standard errors)

Independent variable	Coefficient	Marginal effect (dF/dx)
HIGHLAND	-.133 (.304)	-.042
MKTDIST	-.357 (.161)**	-.118
ROADDIST	-.038 (.100)	-.013
FUELDUNG	.604 (.313)*	.172
LANDOWN	.178 (.112)	.058
WORKERS	-.091 (.099)	- .030
MALEHEAD	.223 (.320)	.069
AGEHSHED	.008 (.007)	.002
LITERACY	.238 (.220)	.081
CREDITAC	-.121 (.205)	-.039
Constant	-1.050 (.631)	---
Chi-square	21.73	---
Prob. > chi-square	0.016	---
Pseudo R-square	0.088	---
Predicted prob. at x-bar	---	.266
N	215	---

** ,* Significant at 5% and 10% respectively.

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(Table 4.8).

4.4 Crop and Livestock Production

Barley is the most widely grown crop in the study area, followed by wheat and teff. Pulses and oil seeds are also grown on limited areas. Some crop varieties have been disappearing due to environmental and agricultural conditions. Wheat varieties are the most commonly mentioned disappearing crop varieties followed by teff, barley and sorghum. Drought is the most important reason that induces abandonment of crop varieties. Other important reasons include water logging, plant diseases, decreasing yield and land scarcity. Farmers shift into growing different varieties notably ones that give high yield, tolerate drought, and resist water logging.

The majority of farmers surveyed used local seed with only 22 percent reporting use of some improved seed during the 1995/96 cropping year. Of those who used improved seed, 81 percent used wheat varieties and 17 percent used teff varieties. The most important source of improved seed for farmers was purchase on credit from the regional bureau of agriculture. Provision of improved seed on credit to farmers was consistent with the reason reported by farmers for not using improved seed. Lack of purchasing power was reported to be the primary reason for inability to use improved seed (Table 4.8).

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Table 4.8: Improved Seed: Sources and Reasons for Not Using

Source of and reason for not using improved seed		Percent of farmers
Source of seed (N=50)	Own production	14.0
	Market	14.0
	Purchase on credit	72.0
Reason for not using (N= 179)	Was not available	12.8
	Lack of purchasing power	49.7
	Did not want to use	22.0
	Did not know its benefit	15.6

The following probit model was estimated to study the factors associated with households' adoption of improved seed:

SEEDIMP = F(HIGHLAND, MKTDIST, ROADDIST, FUELDUNG,
AGEHSHED, MALEHEAD, LITERACY, WORKERS,
LANDSIZE, CREDITAC), where

SEEDIMP refers to household use of improved seed during the 1995-96 cropping year (0=no, 1=yes). All explanatory variables are as defined in Table 4.2 (page 84).

However, the regression was not significant, so results are not reported.

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Although farmers prefer to use local seed, not all surveyed farmers were self sufficient in seed; 44 percent of farmers did not have adequate local seed of their own during the 1995/96 cropping year. The shortage of local seed was equally spread among the important crops including barley, wheat, teff and sorghum. Farmers' main sources of additional seed were market and credit from local areas.

A probit model was estimated to identify the factors associated with farmer self-sufficiency in local seed. Self-sufficiency in local seed was hypothesised to be a product of agroecological and village characteristics, area of cultivated land, availability of family labor and household demographic charateristics.

Location in a highland zone (HIGHLAND), male-headed households (MALEHEAD), higher family labor (WORKER), and larger cultivated land area (LANDSIZE) were expected to increase households' likelihood of being self-sufficient in local seed through their impact on increasing production. Villages that are more distant from roads (ROADDIST) and markets (MKTDIST) should increase probability of self-sufficiency due less integration into market. Villages that are more degraded (FUELDUNG) should decrease self-sufficiency through reduced production. Larger family size (SIZEHSHD) was expected to reduce self-sufficiency as it would mean more mouths to feed. The effect of age (AGEHSHED) and literacy (LITERACY) of household head were ambiguous. Old age could mean more experience but also less family labor. Access to agricultural credit (CREDITAC) was expected to reduce self-sufficiency as farmers would rely on credit for additional seed.

The following probit specification was estimated:

LOCALSEED = F(HIGHLAND, MKTDIST, ROADDIST, FUELDUNG, AGEHSHED, MALEHEAD, LITERACY, SIZEHSHD, WORKERS, LANDSIZE, CREDITAC), where

LOCALSEED refers to farmer self-sufficiency in local seed during the 1992-95 cropping year (0=no, 1=yes). Explanatory variables are as defined in Table 4.2 (page 84).

Farming in a highland zone, male household head and more family labor all increased a household's likelihood of being self-sufficient in local seed as expected (Table 4.9). Distance to market also increased the likelihood, perhaps because less market access forces households to reserve their own seed. Age of household head reduced self-sufficiency, perhaps due to less access to resources. Larger households were less likely to be self-sufficient in local seed. Seed reserves may be consumed during planting time by larger households who have more mouths to feed. An average farmer had 57 percent probability of being self sufficient in local seed. Highland zone had the highest marginal effect (0.35) on the likelihood of a household's self-sufficiency in local seed, followed by male household head (.29), and distance of villages from market place (0.17).

Table 4.9: Probit Model Predicting Household Self-Sufficiency in Local Seed (robust standard errors)

Independent variable	Coefficient	Marginal effect (dF/dx)
HIGHLAND	1.002 (.292)***	.350
MRKTDIST	.443 (.149)***	.174
ROADDIST	-.081 (.090)	-.032
FUELDUNG	.192 (.237)	.076
AGEHSHED	-.014 (.008)*	-.006
MALEHEAD	.747 (.300)**	.289
LITERACY	-.169 (.223)	-.067
SIZEHSHD	-.211 (.069)***	-.083
WORKERS	.246 (.125)**	.097
LANDSIZE	.054 (.106)	0.021
CREDITAC	-.008 (.208)	-.003
constant	-.543 (.554)	---
chi-square	36.06	---
prob. > chi-square	0.0002	---
pseudo R-square	0.1229	---
predicted prob. at x-bar	---	.568
N	214	---

*, **, *** significant at 10%, 5% and 1% respectively.

Fertilizer use by farmers is limited. Only 28 percent of surveyed farmers reported having used fertilizer during the 1995/96 crop year, and not all of them apply it at the recommended rate. Most fertilizer was applied on teff fields due to the high cash value of the crop. As in the case of the use of improved seed, the most important source of fertilizer for farmers was purchase on credit from the regional bureau of agriculture. The most common reason for not using fertilizer was lack of purchasing power. Manuring was reported to have been practiced by 40 percent of the farmers, although use of animal dung for fuel is rendering the practice less frequent.

A probit model was estimated to determine the factors associated with farmer use of commercial fertilizer. Use of commercial fertilizer was hypothesized to depend on agroecological and village and village characteristics, area of cultivated land, availability of family labor and household demographic charateristics.

Location in a highland zone (HIGHLAND), male household head (MALEHEAD), more family labor (WORKERS), larger size of cultivated land (LANDSIZE), and access to credit (CREDITAC) were expected to increase probability of fertilizer use through their impact on increasing production. Literacy of household head (LITERACY) was expected to increase fertilizer adoption due to its impact on access to information. Age of household head (AGEHSHED) was expected to reduce the likelihood of fertilizer use. Villages that are more degraded (FUELDUNG), and more distant from roads (ROADDIST) and market places (MKTDIST) should reduce fertilizer adoption as they reduce productivity or the return to agriculture.

FTZEUSE = F(HIGHLAND, MKTDIST, ROADDIST, FUELDUNG,
AGEHSHED, MALEHEAD, LITERACY, SIZEHSHD,
WORKERS, LANDSIZE, CREDITAC), where

FTZEUSE refers to household's use of commercial fertilizer during the 1992-95 cropping year (0=no, 1=yes). Explanatory variables are as defined in Table 4.2 (page 84).

Farming in a highland zone, distance of village from an all weather road, cultivated land area were the significant variables (Table 4.10). Highland zone reduces the likelihood of fertilizer use, contrary to expectation. Farmers who cultivated more land were more likely to use commercial fertilizer. Distance of villages from all weather road discouraged fertizer use perhaps by reducing the return to agriculture or adding to fertilizer transport costs and delays. The probability that an average farmer adopts commercial fertilizer was 27 percent. Highland zone had the highest marginal effect (-0.16) followed by cultivated land area (0.09).

Table 4.10: Probit Model Predicting Household use of Commercial Fertilizer (robust standard errors)

Independent variable	Coefficient	Marginal effect (dF/dx)
HIGHLAND	-.544 (.298)*	-.161
MRKTDIST	.194 (.162)	.064
ROADDIST	-.231 (.107)**	-.076
FUELDUNG	.159 (.261)	.051
AGEHSHED	.001 (.008)	.000
MALEHEAD	.219 (.342)	.068
LITERACY	.338 (.226)	.117
WORKERS	-.045 (.089)	-.015
LANDSIZE	.289 (.106)***	.095
CREDITAC	.-055 (.219)	-.018
Constant	-1.50 (.586)	---
Chi-square	28.40	---
Prob. > chi-square	0.0016	---
Pseudo R-square	0.114	---
Predicted prob. at x-bar	---	.269
N	213	---

***,**, * significant at 1%, 5% and 10% respectively.

The most important livestock reared in the area are cattle, followed by goats and sheep. The major reason for raising cattle is to obtain draft power for plowing. Goats and sheep are primarily used as source of cash for the household. Most of the villages had a delineated grazing area. However, 71 percent of them reported inadequacy of grazing area during the rainy season while 58 percent reported shortage during dry season. The major reasons mentioned by farmers for shortage of grazing land during rainy season were extensive cultivation and reservation for the dry season, while the corresponding reasons for the dry season were land degradation and area closure. Farmers supplement pasture with straw and hay. Some farmers also send their livestock temporarily to places which have more livestock feed.

With remarkable equity in land distribution in the study zone, the availability of draft power and labor are becoming important factors of social differentiation. Forty-one percent of the households had no ox and the percentage of households who had one ox and a pair of oxen were 31 and 25 respectively. Only 3.5 percent of households had three or more oxen. Oxen ownership appears to show different patterns between the highland and intermediate highland zones. The proportions of households with no ox at all or a single ox is higher in the highland zone than in the intermediate highland zone. The proportion of households who have two or more oxen is higher in the intermediate highland zone.

Sixty-two percent of farmers reported a shortage of draft power for the 1995/96 cropping season. The most common solution used by farmers for inadequate draft power is to arrange an exchange of ox among households; 64 percent reported using this system.

A probit model was estimated to determine the factors associated with household self-sufficiency in draft power. Self-suffiency in draft power was hypothesized to depend on agroecological and village characteristics, cultivated land area, availability of family labor, and household demographic charateristics. Farm location in a highland zone (HIGHLAND), male household head (MALEHEAD), availability of family labor (WORKERS), area of cultivated land (LANDSIZE) and access to credit (CREDITAC) were expected to increase the likelihood of self sufficiency in draft power due to their impact on increasing production or access to financial resources. On the other hand, distance from market (MKTDIST) and roads (ROADDIST), relative degradation of village lands (FUELDUNG) were expected to decrease the probability of a household's being self-sufficient in draft power due to their impact on reducing agricultural productivity or return to agriculture. Age of household head (AGEHSHED) was expected to reduce self-sufficiency as older people could be expected to have less farm resources. The impact of literacy of household head (LITERACY) was considered ambiguous.

The following probit specification was estimated:

DRFTPOWER = F(HIGHLAND, MKTDIST, ROADDIST, FUELDUNG,
AGEHSHED, MALEHEAD, LITERACY, WORKERS,
LANDSIZE, CREDITAC), where

DRFTPOWER refers to households self-sufficiency in draft power during the 1995-96 cropping year (0=no, 1=yes). Explanatory variables are defined in Table 4.2 (page 84).

Agroecological zone, age, sex and literacy of household head, availability of family labor and area of cultivated land explained self-sufficiency in draft power significantly (Table 4.11). Households in the highland zone were more likely to be self-sufficient in draft power probably due to higher land productivity. Male-headed households had higher chance of bein

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chance of being self-sufficient due to better access to resources while older age of household head reduced the likelihood perhaps for the opposite reason. More cultivated land was positively associated with having adequate draft power. Family labor increased draft power self-sufficiency, perhaps due its impact on production. Literacy of heads was inversely related to self-sufficiency. The probability of an average household being self sufficient in draft power (34 percent) was much less than the probability of being self-sufficient in local seed. Male head of household had the highest marginal effect (0.37) followed by highland zone (0.29).

Table 4.11: Probit Model Predicting Household Self-Sufficiency in Draft Power (robust standard errors)

Indep. variable	Coefficient	Marginal effect (dF/dx)
HIGHLAND	.756 (.289)***	0.289
MRKTDIST	.191 (.167)	0.070
ROADDIST	.057 (.098)	0.021
FUELDUNG	.251 (.256)	0.089
AGEHSHED	-.014 (.008)*	-0.005
MALEHEAD	1.553 (.506)***	0.367
LITERACY	-.418 (.220)*	-0.145
WORKERS	.232 (.092)**	0.084
LANDSIZE	.435 (.125)***	0.159
CREDITAC	-.080 (.212)	-0.029
Constant	-3.22 (.705)	---
Chi-square	43.06	---
Prob. > chi-square	0.0000	---
Pseudo R-square	0.192	---
Predicted prob. at x-bar	---	.338
N	214	---

***, * significant at 1% and 10% respectively

Although less serious than the shortage of draft power, a lack of adequate agricultural implements is also experienced by farmers. In the study area, this was reported by 30 percent of the farmers. Unlike the case with draft animals, farmers can easily borrow additional implements from friends and relatives. Of the farmers who faced shortage of agricultural implements, 39 percent reported that they did not have enough plow shares.

4.5 Farmers' Perceptions of Development Constraints and Areas of Institutional Intervention

Farmers in the study area perceive that the most important development constraints for agriculture are, in order of importance, drought, pests and land scarcity (Table 4.12). Despite these perceived constraints, farming was rated the highest among investment priorities of farmers. Sixty-four percent of surveyed farmers reported that agriculture was their highest priority for investment, followed by household investment (20 percent), off-farm work (15 percent), and education of children (1 percent).

Table 4.12: Development Constraints and Priorities for Government Assistance in Agriculture (farmers' rating)

Development constraint	Percent of response (N=401)*	Priority for intervention	Percent of response (N=621)*
Drought	32.4	Credit for oxen	27.5
Pests	18.5	Credit for seed	22.9
Land scarcity	16.2	Supply of inputs	20.5
Water logging	10.2	Development of irrigation	11.4

* Percentages do not add up to 100 because only the top four categories are included.

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In their priorities for government support, the surveyed farmers put credit for draft power at the top, followed by credit for seed, supply of farm inputs and development of irrigation water supply (Table 4.12). Twenty-nine percent of surveyed farmers reported having access to agricultural credit during the 1995/96 cropping season.

4.6 Farmer Involvement in Soil and Water Conservation

Currently the government and non-government organizations are implementing a wide array of soil and water conservation efforts in the region, mainly in the form of extension services, and assisting and organizing community work. Communities contribute free labor for conservation activities in the form of campaign work. Government and nongovernment organizations supply technical services and provide tools. Community campaign works construct conservation structures on communal as well as private lands. Out of the surveyed farmers, 70 percent had conservation work done on their plots through community campaign labor by 1995. Alongside the campaign work, extension service is assisting farmers to invest in soil conservation practices on their own. Fifty-seven percent of surveyed farmers had contact with extension service related with soil conservation during 1992-95. Moreover, 34 percent of surveyed farmers made private investment in physical conservation practices and 60 percent reported having used biological soil conservation practices during 1992-1995.

Of those who invested in physical practices, 95 percent used stone terraces, 19 percent used soil bunds and 9 percent invested in check dams. About 23 percent invested in more than one practice. Among the biological practices, crop rotation was the most widely used practice (80% of cases), followed by contour plowing (60.3% of cases) and grass strips (31.5% of cases) (Table 4.13). About 82 percent of households used more than one biological practice.

Table 4.13: Farmer Investment in Conservation Practices

		Percent of cases (N1=98, N2=265)*
Physical practices	stone terrace	95
	soil bund	18.8
	check dam	8.8
Biological practices	grass strip	31.5
	contour plowing	60.3
	crop rotation	80.1
	tree planting	9.6

* N1 and N2 refer to number of cases in physical and biological practices respectively.

More than 60 percent of farmers reported having maintained physical conservation practices. The most important reason given by farmers for not maintaining conservation structures is labor shortage. Most of the maintenance work was done on stone terraces. Regarding preference between own and campaign work for soil conservation, 57 percent of farmers preferred campaign to private work. When asked if they would have constructed the conservation structures built on their plots through campaign work by themselves, 61 percent replied negatively. Labor shortage was given as the reason by more than 90 percent of them.

In some cases, farmers are involved in soil and water conservation activities including afforestation, area closure, dam construction, and soil conservation structures through food-for-work programs. Forty-four percent of farmers surveyed participated in such programs over the 1992-95 period. In addition to augmenting the conservation efforts in the region, the food-for-work programs were fairly effective in isolating the poorer from the better of households thus contributing to food security of the most needy households (Gebremedhin et al., 1997).

Almost all participants were of the opinion that such projects would increase yields benefiting the community as a whole, apart from the wage payment. The same opinion was held regarding conservation work done privately or through community work. When asked by how much conservation would increase crop yields, seventy-five percent of them replied that yield would increase by one-fifth to one-third of the yield level without conservation. Surveyed farmers considered that the major causes of soil erosion were deforestation (51%), over cultivation (22%), poor agricultural practices (17%), and overgrazing (5%). Only five percent reported that intensity of rain and steep slopes were the major causes of soil erosion.

Risk has been identified as one factor affecting farmers' conservation decisions. Farmers' risk attitudes towards conservation practices were measured through farmers' perception of the effect of conservation on stability of yield. More than 63 percent of farmers surveyed thought that conservation practices increased the stability of crop yields

(Table 4.14). Moreover, more than 90 percent believed that investment in conservation practices is profitable. Such subjective evaluation of profitability may determine investment decisions more strongly than actual profitability during the initial adoption of conservation practices. Once the household adopted the practice, actual profitability may be more important.

Table 4.14: Risk Attitude of Farmers Towards Conservation Practices

Conservation practice	Percent of farmers (N=196 to 214)			
	Increases stability	Decreases stability	Has no effect	Can not determine
Stone terrace	66.7	17.4	15.1	1.3
Soil bund	63.3	16.3	18.9	1.5
Biological practice	67.8	12.0	18.9	1.3

Despite farmers' overall favorable evaluation of conservation practices, many farmers have encountered operational problems with stone terraces. Fifty seven percent of farmers surveyed reported that stone terraces harbor pests such as rats while 14 percent and 8 percent complained of land reduction and difficulty in farm operation respectively. About 60 percent of farmers received extension education related to soil and water conservation during 1992-95.

4.7 Summary

Farmers have usufruct rights on land and they feel more insecure about their holdings in the long run than in the medium term. Population pressure has rendered fallowing obsolete. Land lease, mainly on share cropping, is widely used in the area and female-headed households are more likely to lease land out. Cultivated land during the 1995/96 crop year averaged 1.7 hectares. Farmers in the study area experience labor shortage for farm operation and exchange labor is the major source of additional labor. Twenty-nine percent of the surveyed farmers reported participation in off-farm activities, mainly construction, petty trade and selling firewood.

Barley, wheat and teff are the most widely grown crops in the study area in that order. Several crop varieties had been abandoned due to environmental and agricultural conditions. Farmers could obtain improved seed on credit from the regional bureau of agriculture, but use of improved seed is very limited and farmers use local seeds. However, not all farmers are self-sufficient in local seed. Use of commercial fertilizer is very limited and those who use it do not apply at the recommended rate. Most of the commercial fertilizer is applied on teff due to the high cash value of the crop. Farmers reported lack of purchasing power as the major reason for not using fertilizer. However, farmers could obtain fertilizer on credit from the regional bureau of agriculture. Sixty-two percent of surveyed farmers experienced shortage of draft power during the 1995/96 crop season. The most common solution for inadequate draft power is exchange oxen between households.

The most important development constraints as perceived by farmers are, in order of importance, drought, pests, and land scarcity. However, farmers rated agriculture as their top priority for investment. Regarding priorities for public support of agriculture, surveyed farmers put credit for draft power at the top.

Thirty-two percent of surveyed farmers invested in physical soil conservation practices and another 60 percent in biological practices during 1992-95. Seventy percent of farmers had conservation done on their plots through public campaign work. Farmers showed slight preference for public campaign conservation work than private work. Farmers perceive that soil conservation enhances crop yield stability.

CHAPTER 5

THEORETICAL MODEL, EMPIRICAL MODELS AND RESEARCH DESIGN

5.1 Investment in Soil Conservation

When soil erosion occurs, productivity of the land may decrease and less output will be produced from a given level of inputs than would be obtained without soil erosion, using the same technology and under similar climatic conditions. This results in a downward shift of the production function. Soil conservation can be defined as the effort that goes into preventing the diminution of the productive capacity of land, while holding inputs, technology, and climate constant. In other words, conservation refers to the effort directed at maintaining a given production function over time. An input is a conservation input if it prevents such a downward shift of a production function. On the other hand, an input that causes a movement on the same production function is not a conservation input.

Soil conservation need not be the same as soil erosion control although soil erosion control may be the major aim of soil conservation (Ervin and Ervin, 1982). Measures aimed at improving soil structure such as incorporation of organic matter into the soil are soil conservation practices but may not necessarily reduce soil erosion.

Conservation investment can be analyzed using economic principles that deal with allocation of scarce resources among competing alternatives over time. From an economic efficiency point of view, investment on conservation practices should proceed as long as the marginal productivity of resources invested is not less than it would be in other competitive uses of the same resources. The benefits of soil conservation occur over time.

Under certainty and lack of capital rationing, investment in soil conservation practices is justifiable as long as the discounted net benefits are greater than the investment cost. Under uncertainty, the expected discounted benefits may need to be higher than the investment cost by a risk premium.

Conservation practices can be profitable to both individuals and society, but they can also be profitable to society but not to individuals (Heady, 1952; Cary and Wilkinson, 1977). The reasons why conservation practices can be profitable to society but not to individuals include tenure security problems, capital scarcity and risk, which make private discount factors higher than social discount factors. Tenure insecurity shortens the planning horizon of farmers while capital scarcity raises the opportunity cost of investment in conservation practices. Net returns to conservation practices depend on the discount factor used and time horizon considered. Net returns without conservation are likely to exceed those with conservation for shorter time horizons and higher discount rates. Moreover, market failure and the existence of externalities make farmers' conservation investments differ from the socially optimal level (McConnel, 1983). Market failure refers to inefficient outcome of existing markets due to market imperfection or the absence of markets. Controlled crop prices aimed at lowering food prices to urban consumers lowers the opportunity cost of lost topsoil thus inducing soil erosion. An externality exists when the action of one agent affects the welfare of another agent. An externality can be positive or negative. A positive externality occurs when the action of an agent increases the welfare of the affected agent while a negative externality occurs when the welfare of the affected agent is decreased. For example, soil erosion on poorly conserved farm land uphill may damage crops downhill due to sediment deposition or higher runoff, causing a negative externality. The upland farmer does not consider this cost and the benefit to the downhill farmer from conservation uphill in his/her decision of conservation investment. This will understate both the social costs of erosion and the benefits from conservation making the social and private profitability of conservation investment different.

5.2 Conceptual Model

Soil erosion is an insidious process and its yield reduction impact can be negligible when top soil is deep. The economic impact of soil erosion needs to be felt by farmers before any consideration of conservation investment will be made. Hence, farmer perception of the problem of soil erosion needs to be incorporated into the analysis of conservation investment decision making.

Since investment in conservation practices is a medium- or long-term investment with payoffs distributed over several years in the future, a farmer's conservation investment decision can be modeled as a present value maximization problem. The choice of whether or not Ethiopian farmers should invest in soil conservation is modeled as a problem of maximizing the present value of resulting benefits. The choice model developed below is adapted from the one developed by Barbier (1990).

The production of multiple crops by a farm household is assumed to be explained by a single crop production function. Livestock production is assumed to be subsidiary to crop production. This is because the analysis is concerned with farmer investment in conservation practices on cultivated lands and the major impact of soil erosion on cultivated lands is crop yield reduction rather than deterioration of grazing land. The production function is

$$q(t) = f\,(z_1(t), x\,(t))$$

$$f^1 > 0, f^{11} < 0,$$

$$f^2 > 0, f^{22} < 0,$$

$$f^{12} = f^{21} \geq 0,$$

where q(t) is output, x(t) is soil depth, and $z_1(t)$ is a vector of non-conservation (traditional) input package comprised of production inputs, crop varieties, cropping patterns and techniques. z_1 increases crop output at a decreasing rate as does soil depth, x. Increased soil depth raises the productivity of the traditional inputs and increased use of traditional inputs enhances the effect of soil depth on crop productivity as indicated by the positive cross partial derivatives.

Soil depth is assumed to be a function of management practices and agroclimatic factors. Use of z_1, the traditional input, induces soil erosion at an accelerating rate. The household has a choice of using conservation inputs, z_2. Thus, algebraically,

$$x(t) = h\,(z_1(t)\,,\,z_2(t)), \text{ and}$$

$$h^1 \leq 0, h^{11} \leq 0,$$

$$h^2 > 0, h^{22} \leq 0,$$

$$h^{12} = h^{21} < 0.$$

Let p(t) be the price of the crop output normalized by the price of any crop that might be associated with z_2, and $c_1(t)$ and $c_2(t)$ be the costs of z_1 and z_2 respectively. The conservation behavior of farm household can be modeled by the impact of soil depth on profits through the following present value maximization problem over a given time horizon:

$$\max_{z_1, z_2} PV = \int e^{-rt} [pf(z_1 , x) - c_1 z_1 - c_2 z_2] \, dt$$

s.t. $x^1 = h(z_1 , z_2)$

$x(0) = x_0$,

Where PV is present value

r is the farmer's discount factor

x^1 is rate of change of soil depth

x(0) is initial soil depth.

Since farmers in Tigray have only usufruct rights for land the terminal value of land is not included in the PV model. Assuming that the marginal value of soil lost to be a continuous function, u(t), the first order conditions from the Hamiltonian (H) are as follows:

$$dH/dz_1 = pf^1 - c_1 - uh^1 = 0, \quad (1)$$

$$dH/dz_2 = -c_2 + uh^2 = 0 \quad (2)$$

$$u^1 = ru - dH/dx = ru - pf^2 \quad (3)$$

$$x^1 = h(z_1, z_2) \quad (4)$$

$$x(0) = x_0 \quad (5)$$

Condition (1) implies that, for the traditional productive inputs, the marginal value product, pf^1, must equal the sum of input costs, c_1, and the opportunity cost of soil erosion, uh^1. Condition (2) implies that the total cost of soil conservation must equal the marginal value it generates by controlling soil erosion. The costate variable, u(t), is the shadow price of soil. Hence, the implicit cost of soil loss grows by the discount rate less the soil's contribution to current profits, pf^2 (condition 3).

The comparative static analysis of the temporal equilibrium of the optimization problem provides the following results:

$z_1 = z_1(u, p, c_1, c_2, x)$

$z_2 = z_2(u, p, c_1, c_2, x)$,

where u and c_1 decrease the probability of use of z_1 but increase that of z_2,

and

p, c_2 and x increase the probability of use of z_1 but decrease that of z_2.

As the implicit cost of soil loss increases, optimizing farmers would choose to use conservation input. Also, when the cost of the traditional input increases, conservation inputs would be preferred. On the other hand, an increase in the relative price of the traditional crop and in the cost of conservation input, and increased soil depth would make z_1 preferred over z_2. Hence, the farm household's choice of z_2 over z_1 is influenced by the factors that increase the profitability of the conservation input relative to that of the traditional input.

5.3 Empirical Models and Hypotheses

5.3.1 Effect of Stone Terraces on Crop Yields

Conservation practices are expected to raise crop yields. The profitability of conservation investments is another important consideration. To determine the effect of stone terraces (the most widely applied conservation practice in Tigray) on crop yields and farm profitability, an on-farm quasi-experimental study was conducted. Analysis of variance (ANOVA) is applied on crop yields from conserved and non-conserved plots. Investment profitability analysis using Net Present Value (NPV) criteria is conducted to determine the profitability of investment on stone terraces.

5.3.2 Adoption of Conservation Practices

Farmers need to perceive the problem of soil erosion before they will invest in preventing it. Hence, it is important to study the determinants and level of farmer perception of soil erosion in an adoption study of soil conservation techniques. Models of determinants of farmer perception of soil erosion and adoption of conservation practices are presented below.

Erosion Perception Models

In the present study, we examine perceptions of farmers regarding (1) the severity and productivity effect of soil erosion, (2) effectiveness of conservation in reducing soil erosion and (3) farmers' preference between own and campaign conservation work. Farmer perceptions were hypothesized to be the product of the topographic and ecological characteristics of the village in which a farm household lives, physical characteristics of the land holding of a household, socio-institutional factors, and demographic characteristics of the household. Village level factors include agroecological zone, predominant topography of village and indicators of land degradation. Villages situated in the highland zone were hypothesized to be associated with higher perception of soil erosion problem because of higher rainfall. Hilly villages and villages more degraded land were expected to raise erosion perception.

Physical characteristics of the land include plot size, degree and shape of slope, distance from homestead, soil type, location of plot and length of time operated by household. Slope degree, and duration of time of operation were expected to raise perception while distance from homestead was expected to lower it as more distant plots are likely to be less frequently observed. More erodible soils, location at upper slope, and convex-like shape of slope were expected to raise erosion perception due to their tendency to increase erosion.

Institutional variables include extension service, availability of food-for-work (FFW) projects for resource conservation, community campaign work on individual plots, and land tenure. All institutional variables except land tenure were expected to raise erosion perception either through information access or technical service. The effect of land tenure (owned versus leased in) is ambiguous. On one hand, research results indicate that farmers perceive more erosion on other people's land than on their own. On the other hand, owned land is typically operated longer than leased in land, as lease terms in Tigray last only for a few years.

Demographic characteristics of the household include age, sex and literacy of household head. Age was expected to raise erosion perception through experience, literacy to raise it through access to information, and male sex to raise it through higher involvement in the agricultural production process. The effect of the explanatory variables on farmer perceptions of the productivity effects of soil erosion and effectiveness of conservation in reducing soil erosion were expected to be the same as in the perception of severity of erosion model.

Farmers' preference between own and campaign work was hypothesized to be a function of the factors affecting capacity to invest, in addition to the factors affecting perceptions. Village location in highland zone and severity of land degradation were expected to favor own work, as were plot characteristics that cause higher erosion, contact with extension service and duration under owner's operation. Distance of plots from homestead should favor campaign work because of the travel time required to conserve distant plots. The effect of availability of FFW projects is ambiguous because FFW projects can be sources of information and/or technical support but can also compete for time with own conservation investments.

Conservation Adoption Models

The adoption of soil conservation practices was hypothesized to be a function of the financial and physical incentives to invest, the capacity to invest, risk of investment, and socio-institutional factors. Village location in a highland zone and indicators of the severity of degradation were expected to encourage adoption due to higher need for conservation. Plot characteristics that induce more erosion and thus possibly higher returns to conservation were expected to encourage adoption. Duration of cultivation by owner should encourage adoption. Family labor supply and area of cultivated land were hypothesized to increase adoption since they increase the capacity to invest. Access to credit and contact with extension service were hypothesized to encourage adoption by augmenting the capacity to invest through easing liquidity problem and provision of technical knowledge respectively. The effects of distance of village from market place and all-weather road were ambiguous. These variables could reduce the return to agriculture thus reduce the probability of adoption; on the other hand they could lower the opportunity cost of labor thus increase adoption. Distance of plot from homestead was expected to reduce the probability of adoption. Leased in land, and short- and long-term land tenure insecurity were expected to lower the probability of adoption due to their effect on the riskiness of the investment. The effect of FFW project availability was considered ambiguous as FFW projects can serve as sources of technical information but also compete for labor with conservation investments. The effect of campaign conservation work on own land was also considered ambiguous because campaign work can be a substitute for own investment but can also be a source of technical knowledge. Several groups were expected to have a lower propensity to adopt: older people due to shorter time horizon, female headed households due to less access to resources, and illiterate people due to less access to information.

Intensity of Adoption Models

The decision to take an action and the degree of action taken need not be joint decisions (Cragg, 1971). Unlike the Tobit model (Tobin, 1958), where the two decisions are assumed to be made simultaneously and so influenced by the same set of variables, technology adoption and intensity of adoption may be viewed as a two-step process requiring examination of the two decisions separately. This can be done using a double-hurdle model where the decision to take an action is modeled as a probit model and the decision on the intensity of the action modeled as a truncated regression, the distribution truncated at zero for decisions that have only positive action outcomes (Cragg, 1971).

In this study, adoption and intensity of use of conservation practices are modeled as separate decisions. A farm-household first makes a decision on adopting a conservation practice and then on how much to invest in it. While the decision on adoption can be a one-period decision, investment on the intensity of conservation practices is necessarily a multi-period decision as time will be required to implement most practices, physical conservation practices in particular. Intensity of conservation practiced was hypothesized to be a function of the same variables as adoption. Although it is difficult to predict how the effect of the explanatory variables would differ between the adoption and intensity models, it was hypothesized that some of the effects would differ either in direction or magnitude, or both.

5.4 Explanatory Variables

Production inputs, crop varieties, cropping patterns and techniques and cost of conservation investment did not vary in the study area. Information on soil depth and cost of soil loss were not available. Hence, the variables included in the empirical models were selected following the literature on farm-level investment theory (Christensen, 1989; Feder et al., 1992; Clay and Reardon, 1996). Following this literature, farm investment can be modeled as a function of financial and physical factors that affect the profitability of investment, risk of investment, capacity to invest, household demographic characteristics and socio-institutional variables.

Financial factors of investment refer to the price and cost variables that affect, directly or indirectly, the relative profitability of investment in conservation practices. Ideally such factors would include crop prices, cost of labor and materials used for conservation and the yield effect of conservation practices. Data on crop prices could not be collected, nor were they available from secondary sources. Cost of conservation did not vary across farms in the study area. Information on the effect of conservation on yield was not available. Distance from market place and access to all weather road was expected to affect farmers' revenue from sale of crop output in addition to prices. Each of these variables was measured as walking distance from village of residence.

Physical incentives to invest in conservation practices include the village level ecological factors and physical characteristics of plots. The more environmental degradation in a village, the more likely resident farmers would be to invest on conservation practices. One such measure is what the major source of cooking and heating fuel is. As degradation gets severe, farmers depend more on animal dung for fuel than fuelwood. The distance villagers need to travel to fetch fuelwood is another indicator of the extent of degradation. Hilly villages induce soil erosion thus should encourage conservation. Highland zones have higher rainfall than the intermediate highland zones and should induce greater soil erosion with more incentive for conservation practices to reduce runoff. Physical characteristics of plots include slope degree and slope shape, soil type, plot location, plot size, distance from homestead, plot fragmentation and period in years since operated by current operator.

Three different measures were used to capture the risk of investment, one each for the "immediate period", the short-term and the long-term. In the immediate period, risk was measured in terms of whether or not the land was owned or leased in. For the short-term, farmer tenure security was measured in terms of whether or not farmers believed that they would cultivate the same plots five years from the time of the survey. Long-term tenure security was gauged by whether farmers believed they would bequeath plots to their was solicited. At the village level, time elapsed since last land distribution was used as measure of the stability of land tenure.

The factors that affect the capacity to invest include cash income, wealth, land area and family labor. The cash income and wealth data were unusable due to under-reporting. Land area was measured as hectares of cultivated and cultivated land per capita. Family labor was measured as number of household members aged 15-64.

Household demographic variables include age, sex and literacy of household head. Age was measured in years. Literacy was measured in terms of the head's ability to read and write.

Relevant socio-institutional variables include the pressure village communities would have on households to conserve soil, access to formal or informal agricultural credit, contact with the agricultural extension service, availability of FFW projects in a village, and whether a household benefited from soil conservation campaign works. Pressure from community to conserve soil was measured in terms of whether a households felt that the community expects him to conserve his land.

Definitions and measurements of dependent and independent variables are given in Table 5.1 and Table 5.2 respectively.

Table 5.1: Definition and Measurement of Dependent Variables

Variable code	Definition	measurement	Level of Observation: Village = VILL, Household=HD, Plot=PT
1.Farmer Perceptions of Soil Erosion and Conservation			
ERSEV	Farmer perception of the severity of soil erosion before conservation was applied	0=no problem 1=slight 2=moderate 3=severe	PT
ERSEV1	Farmer perception of the severity of soil erosion before conservation was applied	0= no problem or slight 1=moderate or severe	PT
EFFECTCN	Farmer perception of the effectiveness of conservation in reducing erosion	1=aggravated 2=same 3=reduced	PT
ERSPRD	Farmer perception of the effect of erosion on productivity	0=no reduction 1=one-fifth 2=one-fourth 3=one-third 4=one-half	PT
ERSPRD1	Farmer perception of the effect of erosion on productivity	1=0 2=0.20 3=0.25 4=0.33 4=0.5	PT
OWNCGPRF	Farmer preference between own and campaign conservation work	0=campaign 1=own	HD
OWNFORCG	Willingness to substitute own work for campaign conservation work by farmers who already had public campaign conservation work on private land	0=no 1=yes	HD

Table 5.1 (Cont'd)

2. **Adoption and intensity** of use of conservation practices			
ADOPTTER	Adoption of stone terrace	0=no 1=yes	PT
ADOPTBUN	Adoption of soil bund	0=yes 1=no	PT
ADOPTBIO	Adoption of biological conservation practices	0=no 1=yes	HD
MNTNTER	If household maintained stone terraces	0=no 1=yes	HD
TERACEHA	Terraces per hectare	meters	PT
BUNDHA	Bunds per hectare	meters	PT

Table 5.2: Definition and Measurement of Explanatory Variables[5]

Variable Code	Definition	Measurement	Level of observation Village=VILL Household=HD, Plot=PT
1. Financial factors			
MKTDIST	Distance of village from nearest market	walking hours	VILL
ROADDIST	Distance of village from all weather road	walking hours	VILL
2. Physical factors			
FUELDIST	Average round trip distance to fetch fuel wood	walking hours	VILL
FUELDUNG	Major source of cooking fuel	0=forest and bush 1=animal dung	VILL
HIGHLAND	Agroecological zone	0=intermediate highland 1=highland	VILL
HILLYVIL	predominant topography of village	0=plain 1=hilly	VILL
PLOTCVT	Fragmentation of plots	number of plots cultivated	HD
SLOPEDGR	Slope of plot	degrees	PT
SLOPEAVE	Average slope of plots	degrees	HD
SOILSAND[6]	Predominant soil type of plot	1=sand 0=otherwise	PT
SOILSILT	Predominant soil type of plot	1=silt 0=otherwise	PT
SOILLOAM	Predominant soil type of plot	1=loam 0=otherwise	PT

[5] Some variables could be categorized differently. This classification is based on the adoption and intensity of use models.

[6] Clay soil was the base for comparison among all soil dummies

Table 5.2 (Cont'd)

SLOPCNVX[7]	Plot slope shape	1=convex 0=otherwise	PT
SLOPCNCV	Plot slope shape	1=concave 0=otherwise	PT
SLOPMIX	Plot slope shape	1=convex-concave 0=otherwise	PT
PLOTUP[8]	Location of plot	1= upper slope 0=otherwise	PT
PLOTMID	Location of plot	1= middle slope 0=otherwise	PT
PLOTLOW	Location of plot	1= lower slope 0=otherwise	PT
PLOTAREA	Size of plot	hectare	PT
DISTHOME	Distance of plot from home	walking hours	PT
DISTHMAV	Average distance of plots from home	walking hours	HD
PLOTAGE	Duration plot operated by owner	years	PT
PLOTAGAV	Average duration plots operated by owner	years	HD
3. Capacity factors			
WORKERS	Number of working age household members	number of people aged 15-64	HD
AREAPCAP	Size of cultivated land per capita	hectare	HD
LANDSIZE	Size of cultivated land	hectare	HD
4. Risk factors			
OWNNOW	If plot is owned or leased in	0=leased in 1=owned	PT

[7] Rectilinear shape of plot was the base of comparison for all slope dummies.

[8] Plain or Plateau was the base of comparison for all plot location dummies.

Table 5.2 (Cont'd)

OWN5YRS	If owner feels certain to cultivate the same plots after five years	0= no/not sure 1=yes	HD
OWNINHRT	If owner feels certain to leave plots to children	0= no/not sure 1=yes	HD
5. Socio-institutional factors			
LANDDSTR	Time in years since last land distribution in village	years	VILL
PRESSURE	If household feels pressure from cummunity to conserve soil	0=no 1=yes	HD
CREDITAC	If household had access to formal or informal ag. credit	0=no 1=yes	HD
EXTCONS	If household had contact with extension conservation service	0=no 1=yes	HD
FFWAVAIL	If food-for-work was available in village	0=no 1=yes	VILL
CAMPAIGN	If household had conservation work done on his plots by public campaign work	0=no 1=yes	HD
HOLIDAYS	Number of holidays household observes per month excluding week ends	days	HD
6. Household demographic characteristics			
AGEHSHED	Age of household head	years	HD
MALEHEAD	Sex of household head	0=female 1=male	HD
LITERACY	Literacy of household head	0=illiterate 1=literate	HD
SIZEHSHD	Size of household	number	HD

5.5 Sampling and Data Collection

The study area, approximately 400 km^2, covered 30 villages in six districts in the Tigray region. Five districts were in southern Tigray and one district in central Tigray. For sampling purposes, the area was classified into four topographic zones: steep, moderately steep, moderately steep and hilly, and plain. Representative villages were purposively selected in each topographical class. The number of villages selected was proportional to the land area covered by each class. A sampling frame of household heads in each village was then prepared in cooperation with extension agents and village leaders. A random sample of 250 households was drawn. The number of households sampled from each village was proportional to the number of households in the village.

Data were collected at village, household and plot levels. Observation, measurement and interviews with farmers were used to collect the data. First, a rapid rural appraisal (RRA) study was conducted using semi-structured questionnaires. Discussions were made with experts at the Ministry of Natural Resource Development and Environmental Protection (MoNRDEP) in Addis Ababa, and the regional branch offices of the same ministry, Ministry of Agriculture (MOA), the Institute of Agricultural Research (IAR), and several NGO's (local and foreign) in Mekelle, Tigray. Meetings were also held with subject matter specialists, extension workers, contact farmers, and elderly farmers in Tigray. Available secondary data were reviewed.

The results of the RRA study were used in developing the survey instrument which was later tested at two representative locations in the study area, one in the highland zone and another in the intermediate highland zone. Enumerators were

selected and trained on interview techniques, slope measurement, determination of slope shape and location of plot, identification of soil texture using the 'finger assessment' method, and plot size measurement using the 'rectangularization' approximation[9] method. A soil scientist from Mekelle University College participated in the training.

Most of the village level data were collected by observation and interview with village leaders. Data related to household characteristics and agricultural activities were collected by interview with household heads. Data on physical characteristics of plots were collected by observation and measurement. Soil samples were taken from each plot operated by a sample household and soil texture determined by the 'finger assessment' method. The finger assessment method is a method of soil texture determination by manipulating the soil sample to determine the predominant feel and creating balls and threads of soil to determine its elasticity. Physical conservation practices constructed on each plot operated by the sampled households were measured using measuring tapes. Plot sizes were measured by 'rectangularization'.

An on-farm quasi-experimental study was conducted to determine the effects of stone terraces on crop yields. 8 m^2 quadrats were marked on conserved and non-conserved farmers' fields sown with wheat and fava beans. Enumerators supervised the maintenance of the plot markings while crop management was left to farmers. Crops on the quadrats were harvested separately and grain and straw/hay yields recorded.

[9]Using this method, a plot was first approximated to have rectangular shape with the opposite sides not necessarily equal. Then the average of the two lengths and the two widths were taken as measures of the width and length of the plot respectively.

CHAPTER 6

EFFECTS OF STONE TERRACES ON CROP YIELDS AND FARM PROFITABILITY: A CASE STUDY IN DEGUA TEMBEN, CENTRAL TIGRAY

Stone terraces are the most common soil conservation structures used on cultivated fields in Tigray. However, no published evidence exists that quantifies the effect of terraces on crop yields in the region. This study was conducted during the 1995-96 cropping season in order to evaluate the effect of stone terraces on crop yields and farm profitability. [10]

6.1 An Overview of Research on the Effects of Conservation Practices on Crop Yields

Soil erosion reduces crop yield through nutrient loss, shallower rooting zone, reduced organic matter and water holding capacity, and changes in soil structure and clay content (Weesies et al., 1994). These effects can be represented by soil loss or reduction in the depth of top soil. Soil type and climatic factors, particularly rainfall, condition the effect of soil erosion on productivity. Gantzer and McCarty (1987) as cited in Weesies et al. (1994) found that on Mexico silt loam soils in the United States yield reduction due to topsoil loss was higher in drought years than in normal years. The major benefits from soil conservation are increases in crop and fodder yields (Tjernstrom, 1992).

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[10]The study was conducted in collaboration with Mr. Yibabe Tilahun, a masters student in management of natural resources and sustainable agriculture at the Agricultural University of Norway, who was doing field work for his thesis.

Very few studies have been conducted on the effects of soil erosion and soil conservation on productivity in Ethiopia. Kejela (1992) studied the costs of soil erosion in central Ethiopia and found a strong correlation between nutrient loss and soil loss. From experimental plots, he estimated that the cost of the two major nutrients , nitrogen and phosphorus, lost due to soil erosion, could be as high as 2,500 Birr/ha or US$ 1,208/ha at 1985-86 fertilizer prices[11] (Kejela, 1992, p.227).

Gebremichael (1992) conducted a survey in central Ethiopia to analyze the effects of soil conservation on crop yields in the 1986/87 production year. Based on 603 harvest samples from 4 m^2 quadrats, he found that (1) grain and straw yields from graded *Fanya juu*[12] terraced fields were 15-47 percent higher, and were more stable than yields from non-conserved plots; (2) within the *Fanya juu* terraced fields, grain and straw yields from above the terraces were higher than yields from below or the middle of the terraces; (3) grain and straw yields from fields under graded Fanya juu were higher by 31 percent and 26 percent respectively than those from level bunds.

Tegene (1992) studied the impacts of erosion on the properties and productivity of soils in southern Ethiopia based on data obtained from 17 experimental plots. By classifying the study area into three categories as severely, slightly, and moderately eroded, he analyzed the effect of erosion on the grain and straw yields of maize and haricot bean, the two most important crops in the area. He found that maize yields on the slightly eroded

[11] The prices of urea and diammonium phosphate (DAP) considered in the study were 88 Birr and 58 Birr per 100 kg respectively. In 1985/86 US $1= 2.07 Birr.

[12] Fanja Juu terraces are embankments along the countour, made of soil and/or stones, with a basin at its lower side, graded sideways towards a waterway.

fields were 3.2-3.6 metric tons/ha compared with 0.6-1.0 metric tons/ha on the severely eroded fields. The average haricot bean yield on the slightly eroded fields was 0.4 metric tons/ha while the yield from the severely eroded fields was 0.15 metric tons/ha. The average straw yield was 1.1 and 0.4 metric tons /ha for the slightly and severely eroded fields respectively.

The results of these studies cannot be extrapolated to the farming systems in Tigray region because of the differences in agro-climatic, socioeconomic and extent of land degradation between the farming systems in central and southern Ethiopia and those in the Tigray region. In fact, there may be a lot of variation in the characteristics of the farming systems within central or southern Ethiopia alone due to differences in altitude, cultivation practices and culture.

6.2 The Study Area

The study area was located in the highland zone of central Tigray with an altitude of over 2500 meters above sea level. The major crops grown include wheat , teff, barley and fava beans. Average annual rainfall for the 1992/93 to 1995/96 cropping years was 848 mm. During the 1995/96 cropping year, when the study was conducted, annual rainfall was particularly good at 1004 mm. Moreover, the rainfall distribution during the cropping season was also relatively good, with 56 days of rain out of 90 during the months of June, July and August. Atmospheric temperature can fall below freezing and frost incidences can occur during the harvest season of October to January. Depending on the intensity of rainfall, water logging can be a problem in some fields. Moreover, hail storms are common occurrence in the area.

6.3 Data and Research Design

The selection of plots for the study was based on (1) similar soil and geological formation, (2) slope gradient range of 20-30%, and (3) availability of terraces at least three years of age. Based on these criteria, a watershed was selected and in it 70 terraced plots divided equally between wheat and fava beans, and 70 non-conserved plots were also divided equally between same two crops.

Two quadrats of 8 m^2 (2m * 4m) were marked on each of the terraced plots sown with each crop; one just above the terrace and another one parallel to this but below the next upper terrace. Only one quadrat was marked on each of the non-conserved plots, for a total of 210 quadrats included in the study. The 4m side lay laterally across the slope (along the contour). The quadrats above the terraces were designated as Soil Accumulation Zone (Accum Zone) and those under the upper terrace, Soil Loss Zone (Loss Zone). The quadrats on the non-conserved plots were designated as Control Zone (Control). Crop management was totally left to farmers except for monitoring to ensure that the quadrat markings were preserved. Fava bean fields which were heavily affected by hail around mid-August were replaced by other fields in the same watershed. Crops from the quadrats were harvested and threshed separately from the rest of the plots. Grain and straw yields were then weighed and recorded.

The on-farm research was quai-experimental in the sense that farmers decided on which plots to use stone terraces. If farmers used stone terraces only on plots of that had some common characteristics, systematic bias might have been incorporated into the yield data. However, the magnitude of the bias is likely to be very small because there is no wide difference in the severity of erosion between fields in the study area.

6.4 Analytical Methods

6.4.1 Analysis of variance (ANOVA)

ANOVA is used to test the null hypothesis that several population means are equal (Watson et. al., 1990). Comparing the within-group variabilities of observations and the variability between group means, inference is drawn about the differences in the underlying population means. When only one variable is used to classify the cases, one-way ANOVA is used. The purpose of the on-farm experiment was to determine if terraces result in significant difference in crop yields. Hence, one-way ANOVA was primarily used for analysis with the treatment category as the classifying variable.

Terrace construction takes some land out of cultivation. To determine the net effect of stone terraces on yields and profitability, the production loss due to land occupied by terraces was considered. The minimum and maximum amount of land that could be lost to terraces were computed based on the terrace construction guidelines used in extension work in the region.

(1) Determining the minimum:

Terrace width averages 0.75 meter. Assuming that a terrace is constructed every 15 meters, there would be 6.67 terraces in a square one-hectare plot laid out across the slope contour, occupying 6.67 * 0.75m * 100m = 500.25 m^2 of land. This is 5 percent of a hectare.

(2) Determining the maximum:

If terraces are constructed every five meters and the terrace width remains the same as above, 20 terraces will be constructed on a hectare of land, occupying 20 * 0.75m * 100m = 1500 m^2, or 15 percent of a hectare of land.

The yields from the two terraced treatments were adjusted to a per-hectare basis under the two assumptions regarding land lost to terraces. Yields from the control plots were not adjusted. One-way ANOVA was conducted on both sets of yields. This allowed testing the sensitivity of yield results to assumptions regarding land loss.

6.4.2 Regression analysis

On-farm research ensures that technologies are evaluated under farmers' own management practices, and environmental and agricultural conditions (CIMMYT, 1980). But the heterogenous management of farmer-managed on-farm trials may confound experimental results. In this study, different frequency of tillage and weeding were observed on the experimental plots. Hence it was necessary to determine whether the management differences affected the results of the ANOVA analysis. Linear regression analysis was used for this purpose. Differences in yield, frequency of tillage, and frequency of weeding were computed between treatment groups. The differences in yield were regressed on a constant, differences in tillage and differences in weeding. The constant term captures the treatment effect of stone terraces.

6.4.3 T-test for difference in means

Terrace ages varied among the fava bean fields. Seventeen plots had terraces 3 years old and eighteen had terraces 4 years old. This raised the question of whether or not crop yield differences could be observed due to differences in terrace age. T-test was conducted to test whether or not mean fava bean yields were equal in Accum Zone and Loss zone.

6.4.4 Profitability analysis

Partial budgeting was used to evaluate the profitability of investment in stone terraces. Since the benefits from soil conservation accrue over time, the net returns were discounted and net present values (NPV) computed over time horizon of thirty years (Gittinger, 1982). A wheat-wheat-fava bean rotation is considered to represent the dominant cropping system in the area.

6.5 Results and Discussion

6.5.1 Effects on Crop Yields

Wheat

The unadjusted mean grain yield of wheat from the Accum Zone was significantly higher than those of the Loss Zone and the Control respectively at 5 percent level as were the adjusted yields at 5 and 15 percent land reduction levels (Table 6.1). After adjustment for 5 percent land loss, the mean wheat yield from Accum Zone was more than twice the mean yield from Control and about twice that from Loss Zone. Moreover, the yields from Accum Zone were much more stable than the yields from Control with coefficients of variation respectively of 38 and 61 percent. The coefficient of variation of the yields from Loss Zone was 40 percent.

The mean straw yield from Accum Zone was also significantly higher than the straw yields from Loss Zone and Control respectively, with and without adjustment at the two levels of land loss. At the 5 percent adjustment, straw yields from Accum Zone were twice the yields from Loss Zone and Control. The straw yields from Accum Zone were more stable than the yields from Control with coefficients of variation, respectively, of 35 and 50 percent. The coefficient of variation of straw yields from Loss Zone was 37 percent. On the other hand, neither the mean wheat grain nor straw yield from Loss Zone was higher than those from Control with and without adjustment. Mean wheat grain and straw yields are given in Table 6.1.

Table 6.1: Mean Wheat Grain and Straw Yield Under the Differen Treatments, 100 kg/ha (standard deviation in parentheses)*

Output	Treatment	Unadjusted	Adjusted at 5 percent	Adjusted at 15 percent
Grain	Accum Zone	16.10 (6.09)a	15.29 (5.79)a	13.68 (5.18)a
	Loss Zone	8.49 (3.35)b	8.07 (3.18)b	7.21 (2.85)b
	Control	6.64 (4.08)b	6.64 (4.08)b	6.64 (4.08)b
Straw	Accum Zone	27.87 (9.84)a	26.48 (9.35)a	23.68 (8.36)a
	Loss Zone	14.52 (5.42)b	13.79 (5.15)b	12.33 (4.61)b
	Control	12.03 (6.05)b	12.03 (6.05)b	12.03 (6.05)b

* Figures followed by different letters were significantly different at 5 percent level, using Bonferroni multiple range test (Watson et al., 1990).

In order to control for the effect of the differences in management practices of farmers on comparison of mean yields, yield differences at 5 percent adjustment were regressed on differences in frequencies of weeding and tillage. Tillage and weeding frequencies were the principal management differences exhibited by the farmers. Wheat grain and straw yield differences between each treatment pair were regressed on a constant, differences in weeding frequency (rounds of weeding), and differences in Tillage frequency (rounds of tillage). The sign and significance of the coefficients of the constant term in each regression were evaluated to see if the differences in means were affected by the management differences.

Except for the wheat grain yield differences between Accum Zone and Loss Zone, all other regressions were insignificant at the 5 % threshold level (Table 6.2). These results show that the grain and straw yield differences between treatment pairs are generally not significantly related to differences in management practices. Since the constant term shows the mean yield differences adjusted for farmer tillage and weeding frequency, results are reported even though most of the regressions were insignificant. In the one instance where wheat grain yield difference was affected by farmer management (Accum Zone - Loss Zone), the constant term is large (8 qt/ha) and over nine times its standard error.

Table 6.2: Regression Coefficients for Wheat Yield Differences at 5% Adjustment (stdandard errors)

	Wheat grain yield differences (100 kg/ha)*			Wheat straw yield differences (100 kg/ha)		
	T1-T2	T1-T3	T2-T3	T1-T2	T1-T3	T2-T3
Constant	8.06 (0.85)	10.57 (1.90)	1.67 (1.72)	13.27 (1.54)	15.25 (3.06)	0.65 (2.43)
Weeding frequency differences	3.29 (1.41)	1.28 (1.52)	-0.03 (1.18)	2.69 (2.55)	2.21 (2.45)	-1.96 (1.67)
Tillage frequency differences	3.10 (2.86)	-1.67 (1.43)	-0.24 (1.46)	-1.11 (5.17)	-0.25 (2.29)	1.09 (2.06)
R^2	0.15	0.05	0.01	0.05	0.03	0.04
Prob. > F	0.08	0.44	0.92	0.47	0.66	0.51

* T1, T2 and T3 represent Accum Zone, Loss Zone and control respectively.

<u>Fava Bean</u>

In the fava bean plots, the ANOVA's found grain yields from Accum Zone were significantly higher than the corresponding yields from Loss Zone and Control without adjustment and under 5 percent adjustment. When yields were adjusted for 15 percent land loss, mean yields from Accum Zone were significantly higher than mean yields from Loss Zone but not from Control. At the 5 percent adjustment, mean yield from Accum Zone were more than 40 percent higher than the mean yields from Loss Zone and Control. The grain yields from Accum Zone were also more stable than yields from Control with coefficients of variation, respectively, of 40 and 78 percent. The coefficient of variation of yields from Loss Zone was 43 percent.

Straw yields from Accum Zone were higher than yields from Loss Zone and Control with and without adjustment. At the 5 percent adjustment, straw yields from Accum Zone were 43 percent higher than the yields from Control. Straw yields from Accum Zone were more stable than those from Control with coefficients of variation respectively of 34 and 80 percent. Mean grain and straw yields from Loss Zone were not higher than mean yields from Control with or without adjustment. Mean grain and straw fava bean yields are given in Table 6.3.

Table 6.3: Mean Grain and Straw Yields of Fava Bean Under Different Treatments, 100 kg/ha (standard deviation)*

Out put	Treatment	Unadjusted	Adjusted at 5 percent	Adjusted at 15 percent
Grain	Accum Zone	8.04 (3.13)a	7.63 (2.97)a	6.83 (2.66)a
	Loss Zone	5.46 (2.37)b	5.19 (2.25)b	4.64 (2.01)b
	Control	5.35 (4.19)b	5.35 (4.19)b	5.35 (4.19)ab
Straw	Accum Zone	11.82 (4.07)a	11.23 (3.87)a	10.05 (3.46)a
	Loss Zone	7.46 (3.22)b	7.09 (3.05)b	6.34 (2.73)b
	Control	6.40 (5.09)b	6.40 (5.09)b	6.40 (5.09)b

* Figures followed by different letters were significantly different at 5 percent level using Bonferroni multiple range test (Watson, et al., 1990).

As in wheat, regressions were run on the differences in fava bean grain and hay yields between treatment pairs to determine whether differences in yields were caused by differences in crop management. The yield treatment differences with 5 percent land loss adjustment were regressed on differences in frequency of weeding, and differences in frequency of tillage. All treatment pairs were compared except for Accum Zone and Loss Zone where there were no management differences in fava beans.

The fava bean regressions show much less benefit from stone terraces than wheat did. Only for fava hay did the constant (yield difference) term show Accum Zone outyielding Control (Table 6.4). In the other regressions, the constant term was insignificant and weeding effort differences influenced yield more. The negative effect of differences in weeding frequency indicate that weeding has more yield effect on unconserved plots than on conserved plots. This is likely because the reduced availability of top soil as a nutrient source and water-holding resource makes weed competition more damaging to crop yield.

Table 6.4: Regression Coefficients for Fava Bean Yield Differences at 5% Adjustment (standard error)

	Fava bean grain yield difference (100 kg/ha)*		Fava bean hay yield difference (100 kg/ha)	
	T1-T3	T2-T3	T1-T3	T2-T3
constant	1.05 (0.89)	-1.2 (1.01)	3.57 (1.39)	-1.17 (1.23)
Weeding frequency difference	-2.71 (1.01)	-2.44 (1.05)	-2.29 (1.44)	-3.47 (1.27)
Tillage frequency difference	-1.69 (1.30)	-2.01 (1.36)	0.10 (1.87)	-0.17 (1.23)
R^2	0.25	0.22	0.07	0.20
prob. > F	0.01	0.01	0.29	0.03

* T1, T2 and T3 represent Accum Zone, Loss Zone and Control respectively.

The t-tests for the difference in mean grain and hay yields by terrace age showed that fava bean grain and straw yields under Accum Zone were higher under 4-year old terraces (mean, 0.73; std.dev., 0.21) than under the 3-year-old ones (mean, 0.55; std. dev., 0.26). However, straw and grain yields under Loss Zone showed no significant difference by terrace age. Apparently, the soil accumulation in the fourth year after terrace construction still enhanced yields, though the soil loss zone did not show a comparable yield loss reduction in fava grain and hay yield. This suggests that the terraces had not fully developed.

6.5.2 Profitability

Expected profitability can be a major consideration for farmers in deciding whether to adopt new agricultural practices. Profitability and income stability can be especially important to smallholders who live on the edge of subsistence and operate in an extremely risky agricultural environment. This section presents the results of profitability analysis of investments in stone terraces. It first develops cash flows based on partial budgeting, and then extends these into capital investment budgets.

The average length of terraces in the study area is estimated to be 700 m/ha. The regional campaign work for soil and water conservation assigns a target of preparing 7-8 m of stone terraces per adult man per day. At this rate 100 man days are required to construct stone terraces on one hectare of land. The terraces are expected to require annual maintenance equivalent of 5 man days per hectare. Construction and maintenance of stone terraces is done during dry season when there is little crop work.

An important ancillary cost of soil conservation is that more labor is required for harvest and threshing due to increased yield. The ANOVA results showed that wheat yields are doubled and fava bean yields increased by about 50 percent due to stone terraces. It is assumed that where conservation is practiced, higher crop yields will require additional 15 mandays per hectare in wheat fields and 5 mandays per hectare in fava bean fields as compared to fields without conservation. The daily wage rate in the area during the dry season ranged from 5 to 7 Birr, while during the agricultural season it ranged from 6 to 10 Birr. Hence the average wages of 6 and 8 Birr were used respectively for the two seasons.

Shovels, axes and spades are required to construct the terraces. It is assumed that one implement of each type is required, and each depreciates over a period of 20 man days. The market prices of the implements are 20 Birr, 15 Birr, and 15 Birr per unit respectively.

Yield differences between the soil accumulation and soil loss zones after adjustment for 5 percent land reduction were used for the profitability analysis. The 5 percent land reduction corresponds with the use of 700 m of terraces per hectare. The grain yield differences were 8.65 and 2.55 quintals/hectare respectively for wheat and fava bean. The corresponding straw yield differences were 14.45 and 5.15 quintals/hectare. Yield differences are conservatively assumed to be zero during the first three years of establishment because of the extent of degradation that has already occurred and the time needed for the terraces to stabilize. The yield differences observed on the fourth year of establishment are assumed to remain constant for the entire planning period.

The farm gate prices of 130 Birr/quintal for wheat and 100 Birr/quintal for fava beans were used, calculated at 1995-96 market prices during harvest season less transportation cost from farm to market. The prices of straw and hay were 25 Birr/quintal for both crops. A thirty-year farm planning horizon was assumed.

Two discount factors were used. First, a discount factor of 15 percent, the agricultural interest rate in the region was used. The 15 percent discount rate was used to evaluate the profitability of investment in stone terraces if farmers would have access to targeted credit for terrace construction at the current agricultural interest rate. Secondly, a discount factor of 50 percent, based on an estimated time preference rate (defined as the consumption rate of interest or intertemporal marginal rate of substitution) of Ethiopian farmers (Holden, S.T. et al., 1997) was used. Farmers would not be expected to invest unless the return to their investment is at least as high as their time preference rate.

Using the data and assumptions explained above, the incremental costs and benefits per hectare due to use of stone terraces were computed. The labor and implement cost of initial terrace establishment was 825 Birr and the subsequent maintenance costs amounted to 80 Birr annually for both crops. For wheat, the increased annual harvest and threshing labor cost amounts to 120 Birr and the market value of increased grain and straw output is 1,486 Birr. For fava bean, the increased annual labor cost is 40 Birr/hectare and the market value of increased grain and hay output is 384 Birr/hectare. The costs and benefits for wheat and fava beans are summarized in table 6.5

Table 6.5: Summary of Incremental Cost and Benefits of Stone Terraces on Wheat and Fava Bean Fields (in Birr)[13]

		Wheat	Fava bean
Increased Cost			
<u>Terrace establishment</u>			
Labor	(100 mandays @ 6 Birr/manday)	600.00	600.00
Materials	(5 shovels @ 20Birr + 5 axes @ 15 Birr + 5 spades @ 15 Birr)	250.00	250.00
		----------	---------
Total establishment Cost		850.00	850.00
<u>Annual cost</u>			
Terrace maintenance			
Labor	(5 mandays @ 6 Birr/manday)	30.00	30.00
Materials	(1 shovel @ 20 Birr + 1 axe @ 15 Birr + 1 spade @ 15 Birr)	50.00	50.00
Increased labor cost for agricultural operation (after year 3)			
wheat	(15 mandays @ 8 Birr/man day)	120.00	
fava beans	(5 mandays @ 8 Birr/manday)		40.00
		-----------	----------
Total annual cost		200.00	120.00
Increased Revenue (after year 3)			
Grain: wheat	(8.65 quintals @ 130 Birr/quintal)	1125.50	
fava beans	(2.55 quintals @ 100 Birr/quintal)		255.00
Straw/hay: wheat	(14.45 quintals @ 25 Birr/quintal)	361.25	
fava beans	(5.15 quintals @ 25 Birr/quintal)		128.75
Total annual revenue gain		1485.75	383.75

[13] US $1.00 = 6.30 Birr in 1995/96

Under the 15 percent discount rate the NPV of investment on terraces for the wheat-wheat-fava bean rotation over 30 years was 3, 907 Birr (Table 6.6). The discounted value of the incremental benefits exceeded the discounted sum of the incremental costs in the fifth year. The nominal pay back period was four years.

When the estimated time preference rate of 50 percent was used as the discount factor, the NPV was 12 Birr. Although profitability dropped to almost a break-even, investment in stone terraces remained profitable at the higher discount factor. The discounted value of the incremental costs exceeded the discounted value of the incremental benefits in the fourteenth year. The internal rate of return (IRR) of 50 percent suggests the severity of the impact of soil erosion on productivity and the high potential from investment in soil conservation in the region. Moreover, since individuals discount future income more heavily than society does, investment in stone terraces would be more profitable if a social time preference rate were used as a discount factor.

Rural society in Tigray is composed of net sellers and net buyers of cereals. The analysis above uses crop sale price, and is oriented toward net sellers. An alternative price to use could be the mean purchase price or time-of-consumption weighted average price. Since most crop are made right after harvest while rural households make their purchases later in the season, purchase prices are generally higher than sale prices. Hence, if purchase prices were used instead, the profitability of investment in stone terraces would be higher since the cost side of the analysis remains the same.

Although investment in stone terraces has been shown to be profitable to individual farmers, public intervention is still required to encourage wider use of stone terraces in the region. Targeted credit for investment in stone terraces at the current agricultural interest rate of 15 percent could ease the liquidity problem of subsistence farmers and make investment in stone terraces more attractive. Alternatively, a public subsidy to cover part of the investment cost could be instituted. This would be justified by the 50 percent of IRR which makes sense for society despite being a break-even proposition at farmer rates of time preference.

However, neither of these policy approaches can be a substitute for public technical and educational intervention through extension service. More extension service is required to strengthen the knowledge base and technical capability of farmers to construct stone terraces.

Table 6.6: Cash Flow for Wheat-Wheat-Fava Bean Cropping System Under Stone Terraces (in Birr)

Year	Incremental cost	Incremental benefit	Cumulative incremental net benefit	Discounted incremental net benefit		Cumulative discounted incremental net benefit	
				(15%)	(50%)	(15%)	(50%)
1	850	---	(850)	(850)	(850)	(850)	(850)
2	80	---	(930)	(70)	(53)	(920)	(903)
3	80	---	(1010)	(61)	(36)	(981)	(939)
4	200	1486	276	846	381	(135)	(558)
5	200	1486	1562	736	255	601	(303)
6	120	384	1826	131	35	732	(268)
7	200	1486	3112	556	113	1288	(155)
8	200	1486	4398	484	76	1772	(79)
9	120	384	4662	86	10	1858	(69)
10	200	1486	5948	365	33	2223	(36)
11	200	1486	7234	318	22	2541	(14)
12	120	384	7498	57	3	2598	(11)
13	200	1486	8784	241	10	2839	(1)
14	200	1486	10070	210	6	3049	5
15	120	384	10334	37	1	3086	6
16	200	1486	11618	158	3	3244	9
17	200	1486	12906	138	3	3382	12

Table 6.3 (Cont'd)

18	120	384	13170	25	0	3407	12
19	200	1486	14456	104	0	3511	12
20	200	1486	15742	90	0	3601	12
21	120	384	16006	16	0	3617	12
22	200	1486	17292	68	0	3685	12
23	200	1486	18578	59	0	3744	12
24	120	384	18842	11	0	3755	12
25	200	1486	20128	45	0	3800	12
26	200	1486	21414	39	0	3839	12
27	120	384	21678	7	0	3846	12
28	200	1486	22964	30	0	3876	12
29	200	1486	24250	26	0	3902	12
30	120	384	24514	5	0	3907	12

6.6 Summary

Stone terraces improve crop yields under farmer management. Wheat grain and straw yields from soil accumulation zone were more than twice the yields from the control zone (unterraced plots). Fava bean grain and hay yields increased by more than 40 percent due to stone terraces. Yield stability is also enhanced by stone terraces. Yield variance was lower for terraced plots in each crop for both grain and straw. The investment analysis results show that, under current farming practices, stone terraces can be profitable to farmers both at the current 15 percent agricultural interest rate and farmers' time preference rate of 50 percent. However, targeted credit at the current interest rate or a public subsidy to cover part of the investment cost are justifiable to encourage adoption and capture the 50 percent IRR. Technical and institutional support need to be strengthened in order to enhance wider use of stone terraces in the area. Future research on the productivity effects of stone terraces should incorporate other important crops grown in the region, such as barley, sorghum and teff. Moreover, a similar profitability analysis of stone terraces with improved farming practices, such as the application of commercial fertilizer or improved seeds, could shade light on the complementarity between soil conservation and land use intensification.

CHAPTER 7

DETERMINANTS OF FARMERS' PERCEPTIONS OF THE PROBLEM OF SOIL EROSION AND ATTITUDES TOWARDS SOIL CONSERVATION

This chapter deals with the levels and determinants of farmer perceptions regarding soil erosion and conservation, and preferences between own and public campaign conservation work. First, the determinants of farmer awareness of the severity of soil erosion are analyzed followed by the factors affecting farmer perceptions of the yield loss due to soil erosion. Determinants of farmer perceptions of the effectiveness of conservation in reducing soil erosion are presented next. Finally, the factors affecting farmer preferences between own and public campaign work are discussed. Before empirical results are presented, the specification of the econometric models is discussed, and the nature of the dependent variables explained.

7.1. Specification of Empirical Models

7.1.1 Binary Dependent Variable Models

Farmer preferences can be analyzed using binary (qualitative) response statistical models. Using these models, the outcome of interest is modeled to take on the values (0,1), 1 for a choice of an action or preference, and 0 for non-preference. Based on the assumption of utility maximization, a choice t_2 is preferred to another choice t_1 when the utility derived from t_2 is higher than that derived from t_1. The utility function involved in making the decision between choices can be represented as $U(M_t, C_t)$, where utility U is a function of a vector M_t of distribution of net returns for choice t, and a vector C_t of technical characteristics of the choice (Rahm and Huffman, 1984). The variables constituting the vectors M_t and C_t are usually unavailable or unobservable, and the utility function (also unobservable) of the ith farmer is assumed to be a function of a vector of observable farm/firm characteristics, X_{ti}, and a disturbance term e_{ti}. Thus, the utility function takes the form of :

$$U_{ti} = f(X_{ti}) + e_{ti}, \; t=1,2 \text{ and } I= 1,\ldots, n.$$

The ith farmer chooses/prefers t_2 over t_1 when $U_{2i} > U_{1i}$. Thus the choice can be modeled as a binary response variable y, where

$$y = 1, \text{ if } U_{2i} > U_{1i}, \text{ and}$$

$$=0, \text{ if } U_{2i} < U_{1i}.$$

The focus of the binary response models is on the factors that determine the probability of choice. The probability that Y_i takes on the value 1 can be represented as a function of farm/firm characteristics. Thus,

$$P_i = P(y=1) = P(U_{2i}>U_{1i}).$$

$$= P(X_i\alpha_2 + e_{2i} > X_i\alpha_1 + e_{1i})$$

$$= P[(e_{2i} - e_{1i} > X_i(\alpha_1 - \alpha_2)]$$

$$= P(\mu_i < X_i\beta) = F(X_i\beta),$$

Where P(.) is a probability function,

μ_i is a random disturbance term,

β is vector of coefficients and

$F(X_i\beta)$ is a cumulative distribution function for μ_i. The distribution of μ_i determines the distribution F.

It follows, therefore, that in general, the probability of choice/preference of an action can be represented as $P_i = P_i(Y = 1) = G(X_i, B)$, for I= 1,2, ..., n) where X_i is a vector of explanatory variables and B is a vector of unknown parameters (to be estimated). In order to estimate the parameter values, one needs to specify the functional form of G. Three alternative functional forms of G have been suggested: the linear probability, probit and logit models (Greene, 1990).

The linear probability model:

The linear probability model is a linear regression of the binary outcome variable on a set of explanatory variables:

$Y = \beta'X + e$ where Y is the binary dependent variable, X is a vector of explanatory variables and e is the disturbance term. Ordinary Least Square (OLS) is used to estimate the relationship. The linear probability model suffers from two major drawbacks (Greene, 1990): (1) e is hetroskedastic (and depends on β), and (2) the model can produce predicted probabilities less than zero or greater than one. The need to produce probabilities consistent with theory has led to the development of alternative specifications of which the probit and logit models are the most popular.

The probit and logit models:

The difference between the probit and logit models is in the assumed cumulative distribution function of the associated disturbance term. While the probit model assumes the cumulative normal distribution function, the logit model is based on the logistic cumulative distribution function. In the probit model, the probability of a choice/preference

$$P[Y=1] = \int_{-\infty}^{\beta' x} \phi(t)dt.$$

is defined in terms of an index which is converted into probability value through the assumed cumulative normal distribution function. The probit model takes the following form:

$$P[Y=1]=\Phi(\beta' x), \text{where}$$

P is probability of choice/preference and

$\Phi(.)$ is the normal cumulative distribution function

In the logit model, the probability of choice/preference is given as follows:

$$P[Y=1] = \frac{e^{\beta' x}}{1 + e^{\beta' x}}$$

$$= \Lambda(\beta' x),$$

where P is probability and

$\Lambda(.)$ is the logistic cumulative distribution function.

Whatever distribution is used, the probability model is a regression $P(Y) = F(\beta'x)$ where x is a vector of explanatory variables. Unlike in the linear probability model, the relationships are estimated by maximum likelihood estimation technique and the parameter coefficients are not necessarily the marginal effects. However, the marginals can be computed using the estimated parameter coefficients.

The choice between the probit and logit models is hard to make on theoretical grounds. However, unlike in the multiple outcome cases, choice of one over the other does not make much difference in binary outcome situations (Green, 1990). In this study, the probit model is used.

7.1.2 Ordinal Dependent Variable Models

Some choice problems involve multiple choices that are inherently ordered. Ordered probit and logit models have been widely used to analyze such choice outcomes. As in the binary choice models, these models are based on a latent regression:

$$y^* = \beta'x + e$$

where y^* is unobserved. What is observed is:

$$\begin{aligned} y &= 0 \quad \text{if } y^* \le 0, \\ &= 1 \quad \text{if } 0 \le y^* < \mu_1, \\ &= 2 \quad \text{if } \mu_1 \le y^* < \mu_2, \\ &= J \quad \text{if } \mu_{J-1} \le y^*. \end{aligned}$$

The μ's are unknown parameters to be estimated along with β. As in the binary outcome case, the assumption of normal distribution of the disturbance term yields the ordered probit model, while the logistically distributed disturbance term yields the ordered logit model. The choice between the two distributions (hence between the two models) is practically immaterial (Greene, 1990). The normal distribution results in the following probabilities:

$$P(y=0) = \Phi(-\beta'x),$$

$$P(y=1) = \Phi(\mu_1 - \beta'x) - \Phi(-\beta'x)$$

$$P(y=3) = \Phi(\mu_2 - \beta'x) - \Phi(-\beta x)$$

$$\cdot$$

$$P(y=J) = 1 - \Phi(\mu_{J-1} - \beta'x).$$

Again as in the binary outcome models, the parameter coefficients in these models are not the marginal effects and the marginals need to be computed using the estimated coefficients. In this study the ordered probit model is used.

7.2 Empirical Models

7.2.1 Models of Farmer Perception of Soil Erosion and Conservation

Farmers need to perceive the problem of soil erosion before they will consider investing in its prevention. An understanding of the levels and determinants of farmer perceptions of soil erosion and conservation can help design appropriate conservation intervention strategies. Perceptions of farmers regarding (1) the severity of soil erosion,

(2) the productivity effect of soil erosion, and (3) the effectiveness of conservation in reducing soil erosion were examined.

Farmers were asked to rate the severity of soil erosion on each of their plots before any conservation was done[14]. Perceptions were solicited in four ordinal categories (no problem, slight, moderate, severe). These four ordinal categories were then converted into binary categories by classifying farmers into those who perceive erosion as a problem and those who do not. Ordered probit was used for the ordinal dependent variable while ordinary probit was used with the binary dependent variable. Contrasting the results of the two models helped in testing the robustness of the results to model specification.

In order to capture farmer perception of the productivity effect of soil erosion, farmers were asked to estimate the rate of yield reduction on each of their plots due to soil erosion during a normal cropping year before any conservation had been done on each plot. These responses were used both as ordinal and continuous values. The continuous values are the perceived rates of yield reduction. Ordinary linear regression (OLS) was used for the continuous variable and ordered probit was used for the ordinal variable. As in the erosion perception models, a contrast between the results of the two models showed the robustness of the results.

Conservation practices are expected to reduce soil erosion. What factors determine farmer perception of the effectiveness of conservation practices in reducing soil erosion? To answer this question, farmers were asked if they perceived that conservation practices

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[14] By the time the survey was conducted, some farmers already had conservation practices on their plots. This may have caused some bias in the reported perceptions.

had aggravated erosion, left it unchanged or reduced erosion in comparison to the level of erosion before conservation each plot. These responses were used as ordinal values (0, 1, 2) and ordered probit was used to analyze the determinants.

Farmer perception of the severity of soil erosion, its productivity impact, and the effectiveness of soil conservation were all modeled in two steps as follows:

Perception = F (true information, socio-institutional factors, household demographic characteristics)

True Information = F (topographic and ecological characteristics of village, physical characteristics of land holding)

By substituting the factors that explain true information into the perception equation, the following specification was developed:

Farmer Perception = F(**1.** topographic and ecological characteristics of the village, **2.** physical characteristics of the land holding, **3.** socio-institutional factors and **4.** Household demographic characteristics).

7.2.2 Farmer Preference Between Own and Public Campaign Conservation Work Models

Three general approaches are being used in Tigray to conserve land and rehabilitate the environment: (1) communities are organized in mandatory public conservation campaigns to work on communal or private lands (2) agricultural extension services assist farmers to apply conservation techniques by themselves and (3) FFW projects use paid labor to construct terraces, afforest hillsides and protect closed areas. The first two approaches are widely used in the region. Farmers are divided in their attitude towards own versus campaign conservation work. Hence, it was important to understand what factors determine these preferences. An understanding of the determinants can be used to better organize the public campaign work and/or strengthen the extension soil conservation efforts.

All farmers interviewed were asked to reveal their preference between public campaign and own conservation work. Farmers who already had conservation work done on their plot(s) through public campaign work were then asked if they would have done the conservation work by themselves had there been no campaign work available. This was done to see if having campaign work would change farmers' preferences between own and campaign work.

Since the dependent variables were binary, probit models were used to analyze the factors affecting the preferences. The following specification was used:

Farmer preferences between own and campaign work = F(1. topographic and ecological characteristics of the village, 2. physical characteristics of the land holding, 3. socio-institutional factors 4. demographic characteristics of the household and 5. factors affecting capacity to invest).

The same set of explanatory variables was used as for the perception models, except for the additional factors affecting capacity to invest, which may affect private investments in soil conservation.

7.2.3 Econometric Model Tests

A significant multicollinearity problem could make it difficult to isolate the effects of the collinear explanatory variables. Multicollinearity was assessed following the method suggested by Belsley et al. (1980). For the plot level models, only one of the principal components (eigenvalues) of the X'X matrix had a condition index of above 30 (40.17) and the only variables whose coefficient variances accounted for more than 30 percent were the constant, topography of village (HILLYVIL), and literacy of household head (LITERACY). Both variables were retained in the models because neither had its coefficient variance accounted for more than 50 percent. In the models estimated at the household level, no principal component had a condition index greater than 30, so no variable was dropped.

The different levels at which the data were collected (village, household and plot) could result in heteroskedasticity of the error term. Models were estimated using heteroskedasticity robust (White-corrected) standard errors and they resulted in very similar results to the models estimated with ordinary standard errors suggesting that heteroskedasticity was not a problem in the data set.

A specification test for functional form was performed on each of the models estimated, based on the idea that if a model were correctly specified, there should be no other significant variable other than by chance. Each model was refit with the predicted and squared predicted value as the only right-hand side variables. A significant squared predicted value would indicate specification error. All models passed the test.

7.3. Empirical Results and Discussion

7.3.1 Farmer Perceptions of Severity of Erosion

Farmer perceptions of the severity of soil erosion (ERSEV) was measured at plot level as an ordinal variable (0=no problem, 1=slight, 2=moderate and 3=severe). This was later converted into binary variable (ERSEV1) taking on values 0 or 1 (0= no or slight problem, 1= moderate or severe problem).

The determinants of farmer perceptions of the severity of soil erosion were analyzed using ordered probit for the ordinal dependent variable and ordinary probit for the binary dependent variable. The following regressions were estimated:

(1) ERSEV =F[**1.** (HIGHLAND, HILLYVIL, FUELDUNG, FUELDIST),

2. (PLOTAGE, SOILSAND, SOILSILT, SOILOAM, SLOPEDGR, SLOPCNVX, SLOPCNCV, SLOPMIX, DISTHOME, PLOTAREA, PLOTUP, PLOTMID, PLOTLOW),

3. (OWNNOW, FFWAVAIL, CAMPAIGN, EXTCONS), **4.** (AGEHSHED, MALEHEAD, LITERACY)]

(2) ERSEV1= F(**the same variables as in (1)**), where

The explanatory variables are as defined in Table 5.2 (page 128).

The results from the two models are similar (Table 7.1). Farmers perceive soil erosion as a serious problem. An average farmer had a 58 percent probability of perceiving soil erosion as a severe problem. Farmer perceptions of severity of soil erosion are based primarily on village and plot physical characteristics.

Among the village level physical factors, farming in the highland zone (HIGHLAND) reduced erosion perception. This was contrary to expectation as the highland zone has higher rainfall and so more runoff. Villages with more degraded lands (FUELDUNG) raised erosion perception, as expected. Living in a predominantly hilly village (HILLYVIL) raised erosion perception, since hilly villages have steeper slopes.

Among the physical characteristics of plots, steeper slope (SLOPEDGR), convex- (SLOPCNVX) and concave-like (SLOPCNCV) shape of plots were associated with higher erosion perception since these topographic factors aggravate soil erosion. Erosion perception was not influenced by plot location factors.

Farmers are more likely to perceive erosion on plots they cultivated longer (PLOTAGE). Loam soil of plots reduced perception relative to clay soil contrary to expectation. Larger sized plots (PLOTAREA) raised erosion perception of farmers, perhaps because erosion features on cultivated land are more recognizable on wider plots. Plots more distant from the homestead (DISTHOME) were associated with lower perception since such plots are less frequently observed.

Among the household demographic characteristics, age of household head (AGEHSHED) reduced erosion perception indicating that older household heads are less likely to perceive erosion as being serious problem. Older people might be so used to soil erosion that they consider it as a normal process.

Contact with the extension service for natural resource conservation (EXTCONS) was associated with lower erosion perception. This result contradicted expectation and was puzzling. Perhaps, extension services focused on the construction of conservation practices and advantages from conservation to the extent that farmers felt that soil erosion was a manageable problem, thus reducing their perception of its severity. However, an adequate explanation of this counterintuitive result requires a close examination of the messages transferred to farmers via the extension service. Both models were estimated without the extension service variable and the same variables were significant with the same signs as in the models that included the extension variable.

Farmer perception of erosion was not influenced by ownership status of plot. Neither was availability of FFW projects in a village or campaign conservation work on private land important in explaining erosion perception.

TABLE 7.1: Regression Results for Farmer Perception of Severity of Soil Erosion

Variable	ERSEV (std.err) (ordered probit)	ERSEV1 (probit)	
		coefficient (robust std. err.)[a]	marginal effects[b]
1. Village physical factors			
HIGHLAND	-.702 (.204)***	-.472 (.253)*	-.186
HILLYVIL	.355 (.157)**	.438 (.193)**	.173
FUELDUNG	.399 (.145)***	.386 (.172)**	.151
FUELDIST	-.005 (.023)	.009 (.028)	.003
2. Plot physical factors			
PLOTAGE	.024 (.011)**	.019 (.013)	.007
SOILSAND	.109 (.141)	.017 (.175)	.007
SOILSILT	-.162 (.348)	-.569 (.398)	-.224
SOILLOAM	-.191 (.115)*	-.289 (.139)**	-.114
SLOPEDGR	.049 (.011)***	.045 (.014)***	.018
SLOPCNVX	.467 (.229)**	.592 (.287)**	.209
SLOPCNCV	.686 (.210)***	.601 (.245)**	.213
SLOPMIX	.140 (.188)	.239 (.230)	.091
DISTHOME	-.431 (.141)***	-.505 (.156)***	-.197
PLOTAREA	.389 (.160)**	.456 (.188)**	.178
PLOTUP	.017 (.188)	-.069 (.223)	-.027
PLOTMID	.005 (.171)	-.030 (.210)	-.012
PLOTLOW	.144 (.128)	.230 (.157)	.089
3. Socio-institutional factors			
OWNNOW	.039 (.145)	.138 (.170)	.054
FFWAVAIL	.042 (.112)	.052 (.132)	.020
EXTCONS	-.452 (.107)***	-.520 (.130)***	-.198
CAMPAIGN	.073 (.128)	.196 (.151)	.077

Table 7.1 (Cont'd)

4. Demographic characteristics			
AGEHSHED	-.016 (.004)***	-.018 (.005)***	-.007
MALEHEAD	-.161 (.179)	-.248 (.210)	-.094
LITERACY	-.195 (.129)	.092 (.157)	-.036
constant	-----	.213 (.454)	---
Chi-square	128.27	89.78	---
Prob >chi-square	0.0000	0.0000	---
Pseudo R-square	0.084	0.135	---
Predicted prob. at x-bar	---	---	.583
N	565	565	

[a] robust standard errors are white-corrected standard errors
[b] all marginal effects are computed at mean values of variables
***, **, * significant at 1%, 5% and 10% respectively

7.3.2 Farmer Perceptions of the Yield Effect of Soil Erosion

Farmers were asked to estimate the yield reduction that would occur on each of their plots due to soil erosion, assuming a normal cropping year and without any conservation. Responses were solicited in one of five rates (1= 0 or no reduction, 2= one-fifth, 3=one-fourth, 4= one-third, 5= one-half). These responses were used both as ordinal categories (ERSPRD) and as continuous values (ERSPRD1). The continuous values were the perceived rates of yield reduction. Ordered probit was used for the ordinal variable, while OLS was used for the continuous variable.

The following two models were estimated:

(1) ERSPRD = F[1. (HIGHLAND, HILLYVIL, FUELDUNG, FUELDIST),

2. (PLOTAGE, SOILSAND, SOILSILT, SOILOAM,

SLOPEDGR, SLOPCNVX, SLOPCNCV, SLOPMIX,

DISTHOME, PLOTAREA, PLOTUP, PLOTMID, PLOTLOW),

3. (OWNNOW, FFWAVAIL, CAMPAIGN, EXTCONS), 4.

(AGEHSHED, MALEHEAD, LITERACY)]

(2) ERSPRD1 = F (**same variables as in (1)**), where

The explanatory variables are as defined in Table 5.2 (page 128)

Again the results from the two models were similar (Table 7.2). In general, the results from this analysis are consistent with the results obtained from the analysis of the determinants of farmer perceptions of severity of soil erosion. Factors associated with higher farmer perception of the severity of soil erosion were also generally associated with higher perception of yield impact of soil erosion. Farmer perceptions of the yield effect of soil erosion were based on village and plot physical characteristics, and socio-institutional factors.

Living in villages with more degraded land (FUELDUNG) raised farmer perception of the productivity loss due to soil erosion, as expected. Steeper plots (SLOPEDGR), and convex- (SLOPCNVX) and concave-like (SLOPCNCV) shape of plots increased farmer perception of the yield reduction effect of soil erosion, perhaps through their effect on increasing erosion. Perception of yield impact of erosion was not influenced by soil type or location of plot. More distant plots (DISTHOME) reduced farmer perception of yield impacts as expected since more distant plots are less frequently observed or operated.

Extension service contact (EXTCONS) reduced farmer perceptions of the yield impact of soil erosion. This result contradicted expectation but was consistent with the result from the analysis of the determinants of erosion perception. The models were estimated without the extension variable and the same set of explanatory variables were significant with the same signs as in the models that included the extension variable. Farmer benefit from campaign conservation work (CAMPAIGN) also reduced perception of the yield impact of erosion.

Among the demographic factors, age of household head (AGEHSHED) explained yield loss perception significantly but negatively. This result was consistent with the result that the same variable reduced farmer perception of soil erosion.

TABLE 7.2: Regression Results for Farmer Perceptions of Yield Reduction Effect of Soil Erosion

Variable	ERSPRD (std. err) (Ordered probit)	ERSPRD1 (robust std.err)[a] (OLS)
1. Village physical factors		
HIGHLAND	-.049 (.204)	-.003 (.030)
HILLYVIL	-.226 (.198)	-.034 (.027)
FUELDUNG	.318 (.153)**	.031 (.022)
FUELDIST	-.066 (.206)	-.009 (.013)
2. Plot physical factors		
PLOTAGE	-.006 (.011)	-.001 (.002)
SOILSAND	-.160 (.144)	-.024 (.020)
SOILSILT	.178 (.324)	.029 (.027)
SOILLOAM	-.175 (.122)	-.022 (.017)
SLOPEDGR	.031 (.010)***	.004 (.001)**
SLOPCNVX	.362 (.230)	.061 (.028)**
SLOPCNCV	.416 (.197)**	.058 (.030)
SLOPMIX	.174 (.185)	.023 (.028)
DISTHOME	-.349 (.144)**	-.052 (.017)***
PLOTAREA	.136 (.171)	.019 (.024)
PLOTUP	-.264 (.187)	-.027 (.026)
PLOTMID	.027 (.176)	.008 (.026)
PLOTLOW	.186 (.133)	.027 (.019)
3. Socio-institutional factors		
OWNNOW	.149 (.154)	.021 (.022)
FFWAVAIL	-.015 (.119)	-.005 (.016)
EXTCONS	-.344 (.111)***	-.050 (.016)***
CAMPAIGN	-.286 (.141)**	-.036 (.021)***

Table 7.2 (Cont'd)

4. Demographic characteristics		
AGEHSHED	-.011 (.004)***	-.002 (.001)***
MALEHEAD	-.055 (.198)	-.017 (.027)
LITERACY	-.089 (.131)	-.010 (.018)
constant	-----	.393 (.060)
Chi-square / F	72.44	4.52
prob >chi-square / F	0.0000	0.0000
pseudo R-square / R-square	0.0479	0.1487
N	487	487

[a] robust standard errors are white-corrected standard errors
*,**, *** significant at 10%, 5% and 1% respectively.

7.3.3 Farmer Perception of the Effectiveness of Soil Conservation Practices in Reducing Soil Erosion

Farmers were asked about the effectiveness of conservation practices in reducing soil erosion on each of their plots which had physical conservation practices. Farmer perception of the effectiveness of conservation (EFFECTCN) was measured as an ordinal variable (1=aggravated erosion, 2=same erosion, 3=reduced erosion), relative to the level of erosion before conservation was used on the plot. Ordered probit was used to analyze the determinants of perceptions.

The following relationship was estimated:

EFFECTCN = F [**1.** (HIGHLAND, HILLYVIL, FUELDUNG, FUELDIST), **2.** (PLOTAGE, SOILSAND, SOILSILT, SOILOAM, SLOPEDGR, SLOPCNVX, SLOPCNCV, SLOPMIX, DISTHOME, PLOTAREA,

PLOTUP, PLOTMID, PLOTLOW), 3. (OWNNOW, FFWAVAIL, CAMPAIGN, EXTCONS) 4. (AGEHSHED, MALEHEAD, LITERACY)]

The explanatory variables are as defined in Table 5.2 (page 128).

Farmer perceptions of the effectiveness of conservation in reducing soil erosion were explained by village and plot physical factors, and contact with extension service (Table 7.3). Farming in highland villages (HIGHLAND) reduced the likelihood that farmers would consider conservation effective. Perhaps, the conservation practices in the highlands are not effective enough to mitigate the consequences of high runoff.

Farmers considered conservation more effective on plots with predominantly loam soils (SOILLOAM) than on plots of clay soil. Conservation practices used on concave- (SLOPCNCV) or convex-like (SLOPCNVX) shaped plots were more likely to be considered effective by farmers. Perhaps conservation practices reduce erosion more effectively on plots more prone to erode. More distant plots (DISTHOME) make farmers consider conservation less effective; the same variable reduced farmer perception of the severity of soil erosion. Location of plot did not explain perception.

Contact with extension service (EXTCONS) raised the likelihood that farmers would consider conservation effective in reducing soil erosion. This result supports the explanation given above that extension services might be focusing on conservation practices and the advantages on conservation rather than on educating farmers regarding the severity and productivity impact of soil erosion.

The other institutional factors (ownership status of plots, availability of FFW projects and farmer benefit from campaign conservation work) did not explain significantly the perceived effectiveness of conservation practices. Household demographic characteristics also did not influence farmer perception.

Table 7.3: Regression Results for Farmer Perception of Effectiveness of Conservation Practices

Variable	EFFECTCN (std. Err) (ordered probit)
1. Village physical factors	
HIGHLAND	-.956 (.278)***
HILLYVIL	.218 (.298)
FUELDUNG	-.292 (.240)
FUELDIST	.057 (.038)
2. Plot physical factors	
PLOTAGE	-.008 (.016)
SOILSAND	-.082 (.215)
SOILSILT	.196 (.462)
SOILOAM	.332 (.185)*
SLOPEDGR	-.016 (.014)
SLOPCNVX	.823 (.476)*
SLOPCNCV	.325 (.293)
SLOPMIX	.356 (.257)
DISTHOME	-.431 (.255)*
PLOTAREA	-.421 (.242)*
PLOTUP	.006 (.263)
PLOTMID	-.018 (.248)
PLOTLOW	.022 (.195)

Table 7.3 (Cont'd)

3. Socio-institutional factors	
OWNNOW	.086 (.233)
FFWAVAIL	.161 (.191)
EXTCONS	.438 (.158)
CAMPAIGN	-.026 (.238)
4. Demographic characteristics	
AGEHSHED	.002 (.006)
MALEHEAD	-.301 (.297)
LITERACY	.230 (.179)
Chi-square	98.46
Prob. > chi-square	0.0000
Pseudo r-square	0.168
N	392

*, *** significant at 10% and 1% respectively.

7.3.4. Farmer Preference Between Own and Public Campaign Conservation Work

Farmers in the study area differed in their preferences between mandatory public campaign and private conservation work. In this section, we investigate factors that determine farmer preferences between public campaign and own conservation work. First, the preferences between private and public work are analyzed. Farmer preferences between own and campaign conservation work (OWNCGPRF) was measured at the household level as a binary variable (1=own 0=campaign). For those farmers who already had campaign conservation work on their land, we examine the factors affecting their propensity to do the work by themselves had there not been any public conservation campaign. This variable too (OWNFORCG) was measured at the household level as a binary variable (1=yes, 0=no).

The following probit models were estimated:

(1) OWNCGPRF = [**1.** (HIGHLAND, HILLYVIL, FUELDUNG, FUELDIST), **2.** (PLOTCVT, PLOTAGAV, SLOPEAVE, DISTHMAV) **3.** (FFWAVAIL, CAMPAIGN, EXTCONS), **4.** (AGEHSHED, MALEHEAD, LITERACY) **5.** (WORKERS, CREDITAC, AREAPCAP)]

(2) OWNFORCG = F(**same as in (1) with CAMPAIGN omitted**). CAMPAIGN equals one for households who benefit from public campaign conservation work. The explanatory variables are as defined in Table 5.2 (page 128).

The results indicate that, farmers prefer public campaign to private conservation work. For the average household the probability of preferring public work was 59 percent (Table 7.4). Among those who already had public conservation work on their land, the probability of willingness to substitute own work for the public work was even lower (36 percent).

Living in highland areas (HIGHLAND) and exposure to extension service contacts (EXTCONS) were the only variables that affect preferences significantly. Living in highland areas favored preference for public conservation work. Living in highland areas had a very high marginal effect (46 percent) on a household's preference of public campaign work over own work. That highland areas favor campaign work may be indicating that campaigns have been carried out most often in the highland areas. On the other hand, contact with extension services favored private work. These results indicate that the extension service has been effective in teaching farmers of the importance of conservation work and how to construct/use the practices.

Among those who already had campaign conservation work on their land, extension service contact (EXTCONS) and average years of plot cultivation (PLOTAGAV) were the only significant variables. Both variables favored private work. The link between longer period of cultivation and willingness to conserve it by himself suggests that greater land tenure security may encourage farmers to use conservation practices. The positive coefficient of the extension contact indicates that extension service is effective in extending conservation technologies to farmers.

Table 7.4: Regression Results for Farmer Preferences Between Own and Public Campaign Conservation Work

Variable	OWNCGPRF(probit)		OWNFORCG (probit)	
	coefficient (robust std. errors)	marginal effects	coefficient (robust std. error)	marginal effects
1. Village physical factors				
HIGHLAND	-1.418 (.475)***	-.461	-.555 (.493)	-.198
HILLYVIL	.353 (.364)	.132	.711 (.455)	.230
FUELDUNG	.044 (.307)	.017	.254 (.371)	.092
FUELDIST	.011 (.049)	.004	.036 (.061)	.014
2. Plot physical factors				
PLOTCVT	.031 (.078)	.012	.042 (.077)	.016
PLOTAGAV	-.001 (.039)	-.000	.071 (.042)*	.027
SLOPEAVE	.022 (.030)	.009	-.021 (.031)	-.010
DISTHMAV	.307 (.374)	.120	-.126 (.453)	-.047
3. Socio-institutional factors				
FFWAVAIL	.328 (.257)	.126	.413 (.288)	.151
CAMPAIGN	.056 (.270)	.022	---	---
EXTCONS	.774 (.236)***	.290	.623 (.241)***	.225
4. Demographic characteristics				
AGEHSHED	-.005 (.009)	-.002	-.010 (.013)	-.004
MALEHEAD	.328 (.348)	.123	.564 (.470)	.187
LITERACY	.225 (.277)	.088	.182 (.282)	.069

Table 7.4 (Cont'd)

5. Capacity factors				
WORKERS	-.039 (.096)	-.015	-.005 (.111)	-.002
AREAPCAP	.267 (.718)	.104	.503 (.834)	.188
CREDITAC	.264 (.250)	.104	.313 (.264)	.119
Constant	-1.553 (.837)	---	-2.630 (.941)	---
Chi-square	38.84	---	30.45	---
Prob. > chi-square	0.0019	---	0.016	
pseudo R-square	0.1805	---	0.1580	
predicted prob. at x-bar	---	0.414	---	0.359
N	171	---	143	

[a] robust standard errors are white-corrected standard errors
*,**,*** significant at 10%, 5%,and 1% respectively.

7.4 Summary

The analysis in this chapter showed that farmer perceptions regarding soil erosion and conservation are chiefly a function of physical factors. In general, farmer perceptions of the different aspects of soil erosion and conservation are consistent with each other implying the need for and importance of farmer involvement in the design and implementation of conservation programs and projects. Extension services appear to focus on technical service rather than educational intervention to raise farmer awareness of soil erosion. Farmers showed slightly higher preference for campaign work, suggesting the need to proceed with both approaches in the region. However, emphasis needs to be given to strengthening the extension service as farmers will eventually be individually responsible for implementing conservation practices on their land.

CHAPTER 8

FACTORS AFFECTING FARMER ADOPTION AND INTENSITY OF USE OF SOIL CONSERVATION PRACTICES

This chapter deals with the determinants of farmer adoption and intensity of use of conservation practices. Factors affecting plot level adoption of stone terrace and soil bunds are discussed separately. The determinants of household level adoption of biological conservation practices as a group (grass strips, contour plowing, crop rotation and tree planting) are discussed. Factors affecting farmer maintenance of stone terraces are presented and discussed based on household level data collected from a sub-sample of households who claimed need for terrace maintenance.

This chapter is presented in three parts. First, the empirical models are specified. Next, discussion of the nature of dependent variables and categories of explanatory variables included in each model, and econometric tests of the models are presented. Finally, the empirical results are presented and discussed.

8.1 Specification of Empirical Models

The technology adoption behavior of farmers can be studied in terms of the factors affecting probability of adoption and the factors affecting the intensity of use. Adoption and intensity of use decisions can be analyzed jointly or separately. When the decisions are joint, the Tobit model is appropriate for analyzing the factors that affect the joint decision (Greene, 1990).

However, adoption and intensity of use decisions are not necessarily made jointly. The decision to adopt may precede the decision on the intensity of use, and the factors affecting each decision may be different. Such decision situations can be analyzed using the Heckman two-step procedure or the two-part double hurdle model. To use the Heckman sample selection model, one needs strong theoretical justification for the selection of variables that affect the probability of adoption but not the intensity of use or make a functional form assumption for identification of the model. The literature on the economics of soil conservation investment does not identify variables that affect adoption but not intensity of use. Moreover, the results are sensitive to the assumed functional form (StataCorp, 1997).

In this instance, the "double hurdle" model can be used to model adoption as a probabilistic choice (probit model) and intensity of use as a regression truncated at zero (Cragg, 1971). In this study, adoption and intensity of use of conservation practices are considered separate decisions, and the double hurdle model is used to analyze the factors affecting them.

8.1.1 The Double Hurdle Model

The basic situation handled by the double hurdle model is when there is an event which may or may not take place, and if it takes place, takes on continuous positive values. Unlike the Tobit model (Tobin, 1958), the double hurdle model allows the determinants of the size of an event when it is non-zero to differ from those that determine the probability of occurrence of the event.

In the case of farmer adoption and intensity of use decisions of conservation practices, a decision on adopting the practices is made first, and the decision on the intensity of use of the practices follows. Following Cragg (1971), the decision on adoption can be modeled as a probit regression:

$$f(y=1 \mid X_1, X_2) = C(X'_1\beta)$$

where C(.) is the normal cumulative distribution function, and X_1 and X_2 are vectors of independent variables, not necessarily distinct; and the decision on the intensity of use can be modeled as a standard regression:

$$f(y \mid X_1, X_2) = (2\pi)^{-1/2} \sigma^{-1} \exp\{-(y - X'_2\gamma)^2/2\sigma^2\}\ C(X'_1\beta) \text{ for } y \neq 0.$$

To incorporate the non-negativity of y in the model, we need to truncate the distribution at zero:

$$f(y \mid X_1, X_2) = (2\pi)^{-1/2} \sigma^{-1} \exp\{-(y - X'_2\gamma)^2/2\sigma^2\}\ C(X'_1\beta) / C(X'_2\gamma/\sigma) \text{ for } y > 0.$$

In this study, farmer adoption decisions are analyzed using probit models while the decisions on the intensity of use are modeled as truncated regressions.

8.2 Empirical Models

8.2.1 Adoption Models for Physical Conservation Practices

Stone terraces and soil bunds are the two most widely used physical conservation practices in Tigray. Understanding the factors associated with the adoption of each of these practices can be useful in guiding efforts aimed at encouraging wider adoption. Farmers were asked if and what type of physical conservation practice they applied on each of their plots during 1992-95. Adoption was measured at plot level as a binary variable and probit models were estimated to analyze the determinants.

The following specification was used:

Adoption = F(**1.** Financial incentives to invest, **2.** Physical incentives to invest, **3.** Capacity to invest, **4.** Risk of investment, **5.** Socio-institutional factors, **6.** Household demographic characteristics)

8.2.2 Intensity of Use Models of physical Conservation Practices

Intensity of use of a conservation practice can be a better indicator of the efforts that go into conserving soil and the effectiveness of the practices than just adoption. Understanding the factors influencing intensity can help guide efforts aimed at reducing soil erosion effectively. The length of stone terraces and soil bunds constructed by farmers on their plots during 1992-95 were measured in meters. Intensity of use was measured in meters/hectare and truncated regression was used to analyze the factors influencing it.

The following specification was used:

Intensity = F **(same category of variables as in the physical practices adoption model above)**

8.2.3 Adoption Models for Biological Conservation Practices and Maintenance of Stone Terraces

In addition to physical soil conservation practices, farmers in Tigray also use biological practices including grass strips, contour plowing, crop rotation and tree planting. Farmers were asked about their use or non-use of any of these practices during 1992-95. As it was not possible to observe most of the biological practices at plot level during the survey, data were collected at household level. Adoption was measured as a binary variable.

Stone terraces can be damaged or destroyed by agricultural operations, grazing animals or high run-off. Sustained use of the practices requires maintenance. Data on terrace maintenance were collected from a sub-sample of farmers who had need of terrace maintenance. Farmers were asked to indicate if they maintained terraces during 1992-95. As it was not possible to identify maintenance practices at plot level, data were collected at household level. Maintenance was measured as a binary variable. Probit models were estimated to analyze the determinants of adoption and maintenance.

The following specification was used:

Adoption of Biological Practices = F(**same category of variables as in adoption model above that could be measured at household level)**

Maintenance of Stone Terraces = F(**same variables as in adoption model above that could be measured at household level)**

8.2.4 Tests of the Econometric Models

The explanatory variables used in the adoption and intensity of use models included new variables in addition to those used in the perception and preference models in the preceding chapter. Hence it was necessary to conduct another test of multicollinearity. The method developed by Belsley et al. (1980) was applied. In the plot level models, one principal component (eigenvalue) of the X'X matrix had a condition index above 30. This component accounted for more than 30 percent of the variance of the five coefficients. All variables were retained in the models as no variable had its coefficient variance accounted for more than 50 percent by the principal component. Multicollinearity was not a problem in the household level models.

As in the perception models, the different levels at which the data were collected (village, household and plot) could result in heteroskedasticity of the error term. Models were estimated using heteroskedasticity robust (White-corrected) standard errors and resulted in very similar results to the models estimated with ordinary standard errors suggesting that heteroskedasticity was not a problem in the data set.

A specification test for functional form was performed on each of the models estimated, based on the idea that if a model were correctly specified, no other explanatory variable should turn out significant except by chance. Each model was refit with the predicted and squared predicted value as the only right hand side variables. Significant squared predicted value would indicate specification error. Specification errors were not detected.

A test was also conducted to determine whether a double hurdle model would be more suitable than a tobit model. Following Greene (1995), a likelihood ratio test was conducted for the adoption and intensity of use of stone terraces (no test was conducted for soil bunds as the truncated regression was not significant). First the log-likelihood values from the three models were computed:

LLprobit = log-likelihood of probit model = -239

LLtruncated= log-likelihood of truncated model = -913

LLtobit = log-likelihood of tobit model = -356 values. Then, comparing the test statistic, λ = 2(LLprobit + LLtruncated - LLtobit) = 796, with the chi-square value $\chi^2_{.05,40}$ = 55.76, the double hurdle model was found to be more suitable than the tobit model.

8.3 Empirical Results and Discussion

8.3.1 Adoption of Stone Terraces and Soil Bunds

Farmer adoption of physical conservation practices was disaggregated into adoption of stone terraces and soil bunds. Since the two types of practices have different characteristics, it was important to analyze the factors associated with the adoption of each practice separately.

Household adoption of stone terraces (ADOPTTER) and soil bunds (ADOPTBUN) during 1992-95 were measured at plot level as binary variables (1=adoption, 0=non-adoption). To analyze the factors affecting farmer adoption of physical conservation practices, the following probit models were estimated:

(1) ADOPTTER = F[**1.** (MKTDIST, ROADDDIST) **2.** (HIGHLAND, HILLYVIL, FUELDIST, PLOTCVT, PLOTAGE, SOILSAND, SOILSILT, SOILOAM, SLOPEDGR, SLOPESQ, SLOPCNVX, SLOPCNCV, SLOPMIX, DISTHOME, PLOTAREA, PLOTUP, PLOTMID, PLOTLOW) **3.** (WORKERS, LANDSIZE) **4.** (OWNNOW, OWN5YRS, OWNINHRT) **5.** (LANDDSTR, PRESSURE, EXTCONS, FFWAVAIL, CAMPAIGN) **6.** (AGEHSHED, MALEHEAD, LITERACY)].

(2) ADOPTBUN = F(**same variables as in (1) above**), where

ADPOTTER and ADOPTBUN refer to farmer adoption of stone terraces and soil bunds respectively and the explanatory variables are as defined in Table 5.2 (page 128).

Adoption of stone terraces

The regression results (Table 8.1) showed that household investment in stone terraces is influenced by a wide range of factors. Physical incentives to invest, household capacity to invest, risk associated with the investment and socio-institutional factors were important in explaining household adoption of stone terraces. Overall, the likelihood of adoption of stone terraces was low. An average farmer had 14 percent probability of adopting the practices.

Among the physical factors of investment, farming in the highland zone (HIGHLAND) reduced probability of adoption, perhaps because public campaign work was more widely used in the highland zone. Loam soil texture (SOILLOAM) decreased adoption relative to clay soils, contrary to expectation. Farmers are less likely to use stone terraces on plots more distant from the homestead (DISTHOME), perhaps due to the travel time required to conserve those plots. Hilly topography of villages (HILLYVIL), slope of plot (SLOPEDGR) and concave shape of plot (SLOPCNCV) all raised the likelihood of terrace adoption due to their effect on increasing soil erosion. However, farmer adoption of stone terraces decreased as plot slope gets steeper (SLOPESQ). Area of plot (PLOTAREA) increased farmer likelihood of adoption of stone terraces. Farmers tend to favor using terraces on plots at the lower part of a slope (PLOTLOW) relative to flat plots.

Among the factors affecting farmers' capacity to invest, availability of family labor (WORKERS) increased the likelihood of adoption. This could be due to the high labor requirement of terrace construction. Among investment risk factors, the perceived medium-term (OWN5YRS) and long-term (OWNINHRT) tenure security were significant, the former negatively and the latter positively. As investment in stone terraces is necessarily a long-term investment, farmers were more likely to invest in it when they felt secure enough in their land tenure to bequeath land to their children. The investment analysis in stone terraces (chapter 6) showed that at farmers' presumed discount rate of 50 percent, the investment breaks even in seventeen years. Ownership status of plot (OWNNOW) was marginally significant with a positive coefficient indicating that farmers are more likely to conserve their own land as compared to leased land because the lease term in Tigray is very short.

Among the socio-institutional variables, the time elapsed since last land distribution (LANDDSTR), availability of FFW (FFWAVAIL) and farmer benefit from public campaign conservation work (CAMPAIGN) were significant. The longer the period since last land distribution, the more likely were farmers to adopt stone terraces, again suggesting the importance of tenure stability for long term investment. Longer duration of plot operation by a household (PLOTAGE) also increased probability of terrace adoption providing additional justification for the role of tenure stability. Availability of FFW projects increased likelihood of adoption perhaps due to the information and technical service provided to farmers. Benefit from public campaign conservation work reduced own investment, indicating that public works are substituting private investments.

Adoption of soil bunds

Results of the probit regression (Table 8.1) showed that, like stone terraces, adoption of soil bunds is influenced by a wide range of factors. Financial and physical factors of investment, risk of investment, socio-institutional factors and household demographic factors were important in explaining the adoption of soil bunds. However, most of the effects were contrary to those on stone terraces. Overall, the probability of adoption of soil bunds was very low. An average farmer had only 1.3 percent probability of adopting soil bunds.

Distance of villages from market place (MKTDIST) reduced adoption as expected. Among the physical factors of investment, loam soil texture (SOILLOAM) increased adoption relative to clay soils. In addition to the relative severity of soil erosion on fields with loam soils relative to clay soils, this soil texture might be more suitable for the construction of soil bunds. Fragmentation of plots (PLOTCVT) raised the likelihood of adoption of soil bunds perhaps because farmers find it easier to use soil bunds when the transaction cost is higher. The longer a plot was cultivated by a household (PLOTAGE), the more likely farmers would apply soil bunds, indicating the importance of land tenure stability. Slope (SLOPEDGR) and convex shape of plots (SLOPCNVX) raised likelihood of adoption of soil bunds due to their effect on increasing soil erosion. Convex-concave (SLOPMIX) shape of plots reduced use of soil bunds relative to rectilinear shaped slopes. This might be because irregular shaped plots make it difficult to construct soil bunds. All location of plot variables, upper slope (PLOTUP), middle slope (PLOTMID) and lower slope (PLOTLOW), reduced the likelihood of soil bund adoption relative to plain or plateau. This is due to the fact that soil bunds are more effective on relatively flat areas than on steeper slopes.

Farmers preferred to use soil bunds on own plots (OWNNOW) as compared to leased in land. However, long-term tenure security (OWNINHRT) detracted from adoption of the same practice. This indicates that long-term tenure security favors more durable stone terraces. Availability of FFW (FFWAVAIL) explained adoption of soil bunds negatively since FFW projects dealt more with stone terraces. Benefit from public campaign work (CAMPAIGN) detracted from own investment on soil bunds indicating that public conservation works substitute private investments. Among the demographic factors, age (AGEHEAD) and literacy (LITERACY) of household head explained adoption of soil bunds negatively. Perhaps farming experience and access to information show soil bunds less effective in reducing soil erosion.

Contrast between stone terraces and soil bunds

The differences between factors that favored adoption of stone terraces versus soil bunds offer useful insights about soil conservation in Tigray. Farmers were more likely to adopt stone terraces than soil bunds.

Farmers preferred to construct soil bunds on heavier soil textures that are easier to work with and stay compact. Degree of slope increased the use of both stone terraces and soil bunds. On the other hand, the influence of location of plots was much more important for soil bunds than for stone terraces. Farmers prefer to use soil bunds on flat lands. The fact that hilly topography of villages was an important determinant of the adoption stone terraces but did not matter for soil bunds suggests that Tigrayan farmers believe that stone terraces are more effective when soil erosion is more severe. Distance of plots from home detracted from the adoption of stone terraces but did not matter for soil bunds perhaps because bunds do not require transport of their construction materials.

Household capacity to invest, as measured by family labor supply, favored stone terraces due to the more labour intensive nature of stone terraces. However, it did not matter for soil bunds. The effect of long-term tenure security perception of farmers was strongly positive for stone terraces but strongly negative for soil bunds, indicating the importance of land tenure security for investments that have a long-term payoff. In contrast, insecurity of land tenure detracted from adoption of stone terraces but increased the adoption of soil bunds with marginal significance. At the village level, land tenure stability favored stone terraces but detracted from soil bunds. Availability of FFW increased adoption of stone terraces but decreased that of soil bunds. This could be due to the fact that FFW projects emphasized the rehabilitation of hillsides, and thus focused more on stone terraces. Household that had benefited from public conservation campaigns were less prone to adopt either soil bunds or stone terraces, indicating that farmers consider public investments to be substitute for private conservation work.

Household demographic characteristics were more important in influencing soil bunds than stone terraces. The fact that greater age and literacy did not matter for stone terraces but influenced adoption of soil bunds negatively might suggest that, through experience and access to information, farmers find soil bunds less effective in reducing soil erosion.

Table 8.1: Probit Regression Results for Adoption of Stone Terraces and Soil Bunds

Variable	ADOPTTER		ADOPTBUN	
	coefficient (robust std. err.)	marginal effect	coefficient (robust std. err)	**marginal effect**
1. Financial incentives to invest				
MKTDIST	.047 (.114)	.011	-.338 (.194)*	-.011
ROADDIST	.018 (.077)	.004	-.034 (.125)	-.001
2. Physical incentives to invest				
HIGHLAND	-1.087 (.377)***	-.172	-.316 (.469)	-.009
FUELDIST	.035 (.030)	.008	.066 (.056)	.002
HILLYVIL	.923 (.260)***	.139	.271 (461)	.007
PLOTCVT	.059 (.057)	.013	.101 (.061)*	.003
PLOTAGE	.024 (.015)	.005	.038 (.015)**	.001
SOILSAND	-.112 (.181)	-.024	.412 (.266)	.019
SOILSILT	-.008 (.467)	-.002	.704 (.622)	.050
SOILOAM	-.273 (.154)*	-.058	.578 (.243)**	.027
SLOPEDGR	.116 (.040)***	.025	.156 (.053)***	.005
SLOPESQ	-.004 (.001)***	-.001	-.004 (.002)*	-.000
SLOPCNVX	.398 (.259)	.106	.721 (.355)	.050
SLOPCNCV	.550 (.256)**	.153	.038 (.414)	.001
SLOPMIX	.305 (.214)	.077	-.773 (.437)*	-.014
DISTHOME	-.884 (.251)***	-.196	-.262 (.311)	-.009
PLOTAREA	.751 (.233)***	.167	.278 (.335)	.009
PLOTUP	.111 (.106)	.025	-.917 (.366)**	-.031
PLOTMID	.312 (.222)	.078	-.697 (.328)**	-.014
PLOTLOW	.551 (.181)***	.139	-.4041(.275)	-.011
3. Capacity to invest factors				
WORKERS	.111 (.066)*	.025	.020 (.091)	.001
LANDSIZE	-.109 (.089)	-.024	-.089 (.102)	-.003

Table 8.1 (Cont'd)

4.Risk of investment				
OWNNOW	.375 (.233)	.073	.713 (.328)**	.016
OWN5YRS	-.327 (.185)*	-.075	.346 (.257)	.011
OWNINHRT	.332 (.176)*	.077	-1.141 (.268)***	-.036
5. Socio-institutional factors				
LANDDSTR	.075 (.034)**	.017	-.068 (.047)	-.002
PRESSURE	.225 (.172)	.052	-.382 (.244)	-.012
EXTCONS	-.120 (.155)	-.027	-.095 (.223)	-.003
FFWAVAIL	.423 (.169)**	.091	-.898 (.292)***	-.039
CAMPAIGN	-.431 (.177)**	-.108	-.426 (.263)*	-.019
6. Demographic characteristics				
AGEHSHED	-.0001 (.005)	-.000	-.020 (.010)**	-.001
MALEHEAD	-.002 (.246)	-.000	.322 (.535)	.008
LITERACY	.058 (.172)	.013	-.509 (.252)**	-.013
constant	-3.740 (.690)***	---	-1.400 (1.041)	---
Chi-square	141.79	---	101.22	---
Prob. > chi-square	0.0000	---	0.0000	---
Pseudo R-square	0.2839	---	0.2762	---
Predicted prob. at x-bar		.219		.013
N	638	---	638	---

*, **, *** significant at 10%, 5% and 1% respectively.

8.3.2 Intensity of Use of Stone Terraces and Soil Bunds

The density of stone terraces (TERACEHA) and soil bunds (BUNDHA) during 1992-95 was measured in meters per hectare. Density was treated as a measure of intensity of use. Adoption and intensity of use of the conservation practices were modeled as separate decisions. A farmer first decides on adoption of a given practice and then decides on how much to invest in it. This two-stage conservation investment decision of farmers was analyzed using a double hurdle model where the decision on adoption was analyzed using a probit model, and the intensity of use using a truncated regression model.

Results of the adoption decisions (probit models) were presented and discussed in sections 8.3.1 above and are reproduced here for comparison. This section presents results of the truncated regression for stone terraces. The truncated regression for soil bunds was not significant and is not reported.

To determine the factors associated with the intensity of use of stone terraces, the following truncated regression was estimated:

1. TERACEHA = F **(same variables as in the adoption of stone terraces model),** where TERACEHA refers to length of terrace in meters per hectare. Explanatory variables are as defined in Table 5.2 (page 123).

Results of the truncated regression showed that the factors that influence adoption and intensity of use of stone terraces are different (Table 8.2). Capacity to invest, risk of investment and socio-institutional factors which were important in determining adoption, had no influence on intensity of use.

The two financial incentives of investment, distance of villages from market place (MKTDIST) and all weather road (ROADDIST), both favored intensity of terrace construction despite being insignificant in their adoption. Perhaps once they adopted, farmers living in remote villages were more likely to invest in stone terraces due to lower opportunity cost of labor. These variables explained participation in off-farm employment negatively (Chapter 4). Silt soil texture (SOILSILT), which did not matter for adoption, explained intensity of use positively. Size of plot (PLOTAREA), which explained adoption positively, explained intensity negatively. On the other hand, duration of operation of a plot by a farm household (PLOTAGE) explained adoption and intensity of use positively; but was marginally significant in explaining the former. Highland zone (HIGHLAND) which explained adoption negatively, explained intensity of use significantly positively. This might be because once farmers in the highland zone adopt stone terraces, the yield advantage they realize induces them to invest in stone terraces further.

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Table 8.2: Probit and Truncated Regression Results for Adoption and Intensity of Use of Stone Terraces (std. err.)

Variable	ADOPTTER (probit)	TERACEHA (truncated)
1. Financial incentives to invest		
MKTDIST	.047 (.114)	208.80 (126.6)**
ROADDIST	.018 (.077)	164.20 (63.88)**
2. Physical incentives to invest		
HIGHLAND	-1.087 (.377)***	659.47 (296.2)**
FUELDIST	.035 (.030)	-16.74 (32.29)
HILLYVIL	.923 (.260)***	174.54 (245.6)
PLOTCVT	.059 (.057)	-56.13 (51.88)
PLOTAGE	.024 (.015)	18.42 (10.59)*
SOILSAND	-.112 (.181)	207.04 (161.7)
SOILSILT	-.008 (.467)	1383.3 (387.4)***
SOILLOAM	.273 (.154)*	102.33 (214.8)
SLOPEDGR	.116 (.040)***	52.25 (42.64)***
SLOPESQ	-.004 (.001)***	-2.12 (1.73)*
SLOPCNVX	.398 (.259)	191.88 (227.8)
SLOPCNCV	.550 (.256)**	65.41 (208.6)
SLOPMIX	.305 (.214)	145.72 (183.5)
DISTHOME	-.884 (.251)***	-300.97 (222.4)
PLOTAREA	.751 (.233)***	-749.9 (254.8)***
PLOTUP	.111 (.106)	248.92 (232.4)
PLOTMID	.312 (.222)	194.65 (239.8)
PLOTLOW	.551 (.181)***	61.71 (184.2)
3. Capacity to invest factors		
WORKERS	.111 (.066)*	22.22 (66.18)
LANDSIZE	-.109 (.089)	1.19 (87.71)

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Table 8.2 (Cont'd)

4. Risk of investment		
OWNNOW	.375 (.233)	-264.58 (201.3)
OWN5YRS	-.327 (.185)*	113.87 (205.3)
OWNINHRT	.332 (.176)*	-127.88 (185.9)
5. Socio-institutional factors		
LANDDSTR	.075 (.034)**	-39.94 (33.16)
PRESSURE	.225 (.172)	-116.43 (159.2)
EXTCONS	-.120 (.155)	-201.42 (141.1)
FFWAVAIL	.423 (.169)**	241.81 (160.8)
CAMPAIGN	-.431 (.177)	-70.89 (182.6)
6. Household demographic characteristics		
AGEHSHED	-.0001 (.005)	-1.27 (6.86)
MALEHEAD	-.002 (.246)	-162.64 (226.3)
LITERACY	.058 (.172)	-166.24 (161.7)**
constant	-3.740 (.690)***	---
Chi-square	141.79	---
prob. > chi-square	0.0000	---
pseudo R-square	0.2839	---
N	638	139

*, **, *** significant at 10%, 5% and 1% respectively

8.3.3 Farmer Adoption of Biological Practices and Maintenance of Stone Terraces

Biological conservation practices used in the study area included grass strips, contour plowing, crop rotation, and tree planting. It was not possible to collect data on adoption of each of the biological practices at the plot level as most of them were not observable during the field work. Hence the biological practices were considered as a grou

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group. Farmer adoption of any individual or combination of biological conservation practices (ADOPTBIO) during 1992-95 was measured at the household level as a binary variable (0=non-adoption, 1=adoption).

Data on farmer maintenance of stone terraces were collected for those households who claimed a need for maintenance. Again it was not possible to observe the maintenance practices on the plots. Hence, farmer maintenance of stone terraces (MNTNTER) during 1992-95 was also measured at household level as a binary variable (0=did not maintain, 1=maintained).

To determine the factors associated with adoption of biological conservation practices, and maintenance of stone terraces, the following probit models were estimated:

1. ADOPTBIO = F[**1.** (MKTDIST, ROADDIST), **2.** (HIGHLAND, HILLYVIL, FUELDIST, PLOTCVT, PLOTAGAV, SLOPEAVE, DISTHMAV) **4.** (WORKERS, LANDSIZE), **5.** (OWN5YRS, OWNINHRT), **6.** (PRESSURE, EXTCONS, FFWAVAIL, CAMPAIGN) **7.** (AGEHSHED, SEXHSHED, LITERACY)]

2. MNTNTER = F(**same variables as in adoption of biological practices model above**), where

ADOPTBIO and MNTNTER refer to farmer adoption of biological practices and farmer maintenance of stone terraces during 1992-95 respectively. All explanatory variables are as defined in Table 5.2 (page 128).

Adoption of biological practices[15]

Household capacity to invest, risk of investment and socio-institutional factors were important in explaining adoption of biological practices (Table 8.3). Household demographic factors did not matter for the adoption of biological practices. Overall, farmers were highly likely to adopt the practices. An average farmer had 73 percent probability of adopting biological practices.

The severity of land degradation in a village as measured by travel time required to fetch fuel wood (FUELDIST), increased likelihood of adoption as expected. Availability of family labor (WORKERS) detracted from adoption, perhaps because households with more family labor prefer to use physical practices, particularly stone terraces. Medium-term tenure security (OWN5YRS) reduced adoption. This could be because farmers who felt secure of their land holding in the medium-term prefer to invest in physical structures, particularly soil bunds. Time elapsed since last land distribution (LANDDSTR) explained adoption of soil bunds negatively but was marginally significant. Perhaps, physical practices are preferred with stable land tenure.

Extension service contact (EXTCONS) increased the likelihood of adoption of biological practices, as expected. Availability of FFW (FFWAVAIL) explained adoption positively, perhaps due to provision of tree seedlings and related services. Farmers who felt community pressure to conserve soil (PRESSURE) were more likely to adopt biological practices than those who did not.

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[15] Since the biological practices considered here have different characteristics, the results may not apply to individual practices. Consideration of the practices separately will be required to verify if the results are , in fact, generalizable to biological practices as a whole.

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Maintenance of stone terraces

Farmer maintenance of stone terraces was influenced by financial and physical incentives to invest and socio-institutional factors. Capacity to invest, risk of investment and household demographic characteristics did not influence maintenance. Overall, farmers were highly likely to maintain stone terraces. On the an average, a farmer with terraces who perceived a need to maintain them, had 88 percent probability of maintaining stone terraces.

Distance of village from market place (MKTDIST) influenced maintenance positively. This suggests that once terraces are constructed, a low opportunity cost of labor encouraged their maintenance. The longer a plot was cultivated by current owner (PLOTAGAV), the more likely stone terraces would be maintained. This might be because longer period of cultivation increases the likelihood of terrace destruction and thus need for maintenance.

Among the socio-institutional factors, community pressure (PRESSURE), extension service contact (EXTCONS), and public campaign work (CAMPAIGN) all explained maintenance positively. The marginal effects of each of these variables were also high. These results suggest that households respond to community expectations, and the extension service was effective not only in facilitating adoption of stone terraces but also encouraging their sustained use. Having public campaign conservation work done on own land encouraged farmers to maintain the terraces, perhaps by increasing the need for maintenance. Time elapsed since last land distribution in a village significantly detracted from maintenance, contrary to expectation. However, its marginal effect was very low.

Table 8.3: Probit Regression Results for Adoption of Biological Conservation Practices and Maintenance of Stone Terraces

Variable	ADOPTBIO		MNTNTER	
	Coefficient (robust std. err.)	Marginal effects	Coefficient (robust std. err.)	Marginal effects
1. Financial incentives to invest				
MKTDIST	.181 (.192)	.060	.518 (.225)**	.101
ROADDIST	-.060 (.140)	-.020	.053 (.144)	.010
2. Physical factors to invest				
HIGHLAND	.859 (.666)	.246	-.630 (.854)	-.144
FUELDIST	.129 (.052)**	.043	-.048 (.064)	-.009
HILLYVIL	.445 (386)	.160	.367 (.461)	.083
PLOTCVT	.024 (117)	.008	-.027 (117)	-.005
PLOTAGAV	.024 (.040)	.008	.174 (.064)***	.034
SLOPEAVE	.029 (.037)	.010	.078 (.059)	.015
DISTHMAV	-.310 (.400)	-.103	.606 (.660)	.118
3. Capacity to invest factors				
WORKERS	-.168 (.099)*	-.056	.089 (.142)	.017
LANDSIZE	.096 (.147)	.032	.328 (.224)	.064
4. Risk of investment				
OWN5YRS	-.673 (.298)**	-.214	-.127 (.373)	-.025
OWNINHRT	.442 (.306)	.141	-.518 (.436)	-.109
5. Socio-institutional factors				
LANDDSTR	-.091 (.058)	-.030	-.280 (.077)***	-.055
PRESSURE	.657 (.322)**	.226	1.245 (.436)***	.310
EXTCONS	.633 (.251)**	.214	1.035 (.327)***	.228
FFWAVAIL	.505 (.274)*	.172	-.240 (.377)	-.045
CAMPAIGN	-.356 (.301)	-.111	1.07 (.403)***	.276

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Table 8.3 (Cont'd)

6. Household demographic characteristics				
AGEHSHED	.012 (.011)	.004	.013 (.014)	.002
MALEHEAD	.017 (.397)	.006	.680 (.480)	.177
LITERACY	.309 (.319)	.096	-.326 (.381)	-.069
Constant	-1.603 (1.001)	---	-3.61 (1.38)***	---
chi-square	45.33	---	46.03	---
prob. > chi-square	0.0016	---	0.0013	---
pseudo R-square	0.2527	---	0.412	---
predicted prob. at x-bar	---	.73	---	.88
N	174	---	147	---

*, **, *** significant at 10%, 5% and 1% respectively.

8.4 Summary

The likelihood of farmer adoption of stone terraces was higher than that of soil bunds. Long-term land tenure security of farmers and household capacity to invest, which favored adoption of stone terraces detracted from the adoption of soil bunds. The factors that influenced adoption and intensity of use of stone terraces were different. The degree of effort farmers put into conserving soil was influenced by the opportunity costs of labor and foregone land productivity. Farmers had a high probability of maintaining stone terraces once they were built. Terrace maintenance and adoption of biological practices were chiefly influenced by socio-institutional factors.

CHAPTER 9

SUMMARY, CONCLUSIONS AND IMPLICATIONS

9.1 Introduction

9.1.1 Problem Statement

Land degradation, particularly soil erosion, constitutes the basis for the problems of the low productivity and sluggish growth of Ethiopian agriculture. The principal determinants of soil erosion in Ethiopia include hilly and mountainous topography, erosive rainfall, inappropriate agricultural practices, and agricultural policies that were biased against small holders. Massive efforts have been put into combating land degradation in the country since early 1970, mostly in the form of food-for-work (FFW) projects. However, these efforts have been minuscule compared with the magnitude of the problem and conservation practices have not been sustained by farmers.

The northern region of Tigray is one of the most seriously degraded areas in Ethiopia. Increasing land pressure, continuous cultivation, inadequate manuring, overgrazing and cleared forests have left the land barren and susceptible to erosion. Intense tropical rain storms wash away topsoil from the virtually unprotected lands in the region. Lack of appropriate dryland agricultural development policies and civil wars have crippled the economic base of the region.

Since the downfall of the dictatorial military government in 1991, environmental rehabilitation and the conservation and development of natural resources have been at the center of the rural development policies pursued by the regional government of Tigray.

Three general approaches have been used for this purpose: (1) rural communities have been organized in mandatory public campaign work for resource conservation on public or private lands, (2) extension services have been active in transferring conservation technologies to farmers, and (3) FFW projects have been used to rehabilitate hillsides and construct small scale irrigation dams. This study was designed to fill a gap in knowledge regarding the determinants of farmer adoption and intensity of use of soil conservation practices in Tigray, Ethiopia. An understanding of the factors influencing the adoption and use of conservation practices could be used in formulating conservation intervention policies aimed at facilitating wider adoption and sustained use of conservation practices.

9.1.2 Research Objectives

In Tigray, stone terraces and soil bunds are the most widely used physical conservation practices. Biological conservation practices including grass strips, contour plowing, crop rotation and tree planting are also used. The general objective of the study was to determine the physical, social, institutional and economic factors that affect farmer adoption of soil conservation practices in the region.

The specific objectives were to:

(1) Characterize the farming systems of the study area,

(2) Estimate the crop yield and farm profitability impact of stone terraces,

(3) Analyze the levels of and factors that affect farmer perceptions of soil erosion and conservation,

(4) Analyze the determinants of farmer adoption of conservation practices,

(5) Analyze the factors that explain intensity of use of conservation practices

9.1.3 Conservation Adoption Studies: An Overview

Quantitative and qualitative research aimed at understanding the factors influencing farmer adoption of conservation practices has been going on since the 1930's. Most of these studies were conducted in the developed world using detailed technical information and considerable rigor. Studies of soil conservation adoption in the developing world have been fewer and more qualitative. This implies that, in the developing countries, a more concerted and sustained investigation of the causes of land degradation and the factors affecting farmer conservation practice is required.

Statistical and non-statistical methods have been employed in the study of adoption of conservation practices. The predominant statistical method has been multiple regression analysis. The non-statistical methods used in conservation adoption research include simulation and mathematical programming models. While the statistical methods have been more appropriate for studying the determinants of farmer adoption of conservation practices, the non-statistical methods have been used to assess the profitability and yield impact of the practices.

Because farmers need to perceive the problem of soil erosion before they will invest in preventing it, a study of farmer perception of the problem becomes an important component of conservation adoption studies. Farmer adoption and intensity of use of conservation practices are likely to be separate decisions. A farm household first decides on using a conservation practice and subsequently decides how much of the practice to use.

Most studies have ignored this distinction. Moreover, the determinants of adoption and intensity of use of conservation practices may differ by type of practice.

Farmer conservation adoption decisions are complex. Research results to date have shown that demographic, physical, economic, institutional and perceptual variables all contribute to explaining the conservation behavior of farmers. Hence, conservation adoption studies need to expand the number of explanatory variables considered. Cross sectional studies that explicitly differentiate between types of conservation practices and between adoption and intensity of use of practices, and that incorporate the analysis of farmer perceptions of the problem of soil erosion can provide results indicative of important causal factors.

This study analyzed the determinants of adoption by type of practice, and differentiated between the determinants of adoption and intensity of use. Adoption results were supplemented by analysis of the determinants of farmer perception of soil erosion. Data were collected from a randomly selected sample of 250 farm households in Tigray, northern Ethiopia in 1995/96. Data were collected on conservation practices of farmers for the 1992-95 period, as well as agroecological and physical characteristics of villages, physical characteristics of plots, socio-institutional factors, and demographic characteristics of farm households. Probit, ordered probit and double hurdle models were used to analyze the survey data. In addition, a quasi-experimental field plot study was conducted to evaluate the yield and profitability impact of stone terraces. Analysis of variance and investment analysis were used to analyze the field plot data.

9.2 Summary of Results

9.2.1 Farming Systems of the Study Area

The study covered an area of about 400 km^2, consisting of thirty villages in six districts in south central Tigray. Seventy-five percent of the surveyed villages depended primarily on animal dung for fuel. Food-for-work projects were operational in seventeen of the villages during 1992-95. Agriculture is predominantly mixed subsistence farming, and land preparation is entirely based on oxen power. Eighty-three percent of households were headed by men. The average family size was 4.8 with three economically active persons per household.

Land has been distributed to farmers based on family size and farmers have only usufruct rights to land. Farmers feel more insecure about their land holding in the long-term than in the short-term. During 1995-96, cultivated land per household in the study area averaged 1.7 hectares divided among 3.5 plots. About 26 percent of farmers reported having leased out land during 1995-96. Share cropping was the most common rental form. Households headed by women were more likely to lease land out.

Farmers commonly experience seasonal labor shortages. Use of hired labor was limited, and farmers depended on exchange labor to alleviate the problem. Twenty-nine percent of surveyed farmers participated in off-farm activities. The most important off-farm work was construction, followed by trade and selling firewood. Farmers living in villages with more degraded soils and forests were more likely to participate in off-farm work. By contrast, farmers residing in remote villages were less likely to participate.

Interestingly, surveyed farmers believed that the major causes of land degradation were caused by humans. In order of importance, they were deforestation, overcultivation, poor agricultural practices and overgrazing. By comparison, intensity of rain and steep slopes were considered less important factors of land degradation.

Seventy percent of surveyed farmers had conservation work done on their plots by community campaign labor during 1992-95. Thirty-two percent of surveyed farmers invested in stone terraces, while 60 percent applied biological practices during 1992-95. During the same period, 60 percent of surveyed farmers reported having maintained physical conservation structures. Farmers in the study area were divided regarding their preference between mandatory public campaign and private conservation work, with 57 percent preferring campaign work. Surveyed farmers held the opinion that conservation increases crop yield and enhances yield stability. However, farmers also reported operational problems with stone terraces, including reduction of land area and harboring pests such as rats.

9.2.2 Impact of Stone Terraces on Crop Yields and Farm Profitability

A watershed in central Tigray was selected for a on-farm quasi-experimental study to fill the information gap regarding the effect of stone terraces on crop yields and farm profitability. Seventy terraced and 70 non-conserved plots were equally divided between wheat and fava beans. Two quadrates of 8 m^2 were marked on each of the terraced plots; one just above the terrace (soil accumulation zone) and another one parallel to this but below the next upper terrace (soil loss zone). Only one quadrate (control zone) was marked on each of the non-conserved plots. Yields from the conserved plots were adjusted for 5 and 15 percent land loss due to terrace construction.

After yields were adjusted for 5 percent land loss, four major results stood out: (1) grain and straw yields for both crops were significantly higher in the soil accumulation zone than in the soil loss zone or in the non-terraced control zone, (2) crop and straw yields from the soil accumulation zone were more stable than those from the control zone, (3) fava bean benefited less than wheat from stone terraces, and (4) investment in stone terraces was profitable both at the bank loan agricultural rate of 15 percent and at a higher presumed farmer discount rate of 50 percent. However, profitability nearly dropped to the break-even level at the 50 percent discount rate, indicating the need for public intervention to encourage wider adoption of stone terraces.

9.2.3 Farmer Perceptions of Soil Erosion and Conservation

Farmers in the study area perceived soil erosion to be severe. Their perception could be explained statistically primarily by village and field physical characteristics. Location of plots did not affect for farmer perception of soil erosion. In general, the perception was greatest where erosion potential was greatest. Farmers perceived soil erosion to be less severe on plots more distant from the homestead. The perception of soil erosion was less among those households with more experience in farming (older heads), and those having contact with the extension service for natural resource conservation. The latter result, although apparently counter-intuitive, suggests that knowledge of conservation practices reduces farmer rating of the severity of soil erosion.

The results from the analysis of farmer perception of the yield impact of soil erosion were, in general, consistent with the results from the analysis of the severity of soil erosion. Most of the physical factors that explained perception of yield impact of soil erosion significantly also explained the perception of erosion severity, with the same direction of effect. Contact with extension service, which reduced perception of soil erosion, also reduced perception of the yield impact of soil erosion. Farmers who benefited from public campaign conservation work perceived lower yield impact of soil erosion. Older household heads, who perceived soil erosion to be less severe, also perceived lower yield impact of soil erosion.

Farmer perceptions of the effectiveness of conservation practices in reducing soil erosion were primarily determined by village and plot physical characteristics. In general, the factors associated with higher erosion perception were also associated with higher perceived effectiveness of conservation practices. These results supported the findings from the models of farmer perceptions of soil erosion and its yield impact.

Farmers in the study area had different preferences between public campaign and private conservation work, the two most widely used approaches for soil conservation in the Tigray region. Analysis of the determinants of the preferences showed that, on average, farmers had a slight preference for public campaign work. The propensity of those who already had public campaign conservation work done on their plots to substitute their own labor for the campaign work was lower. Farmers who had contact with the extension service preferred to do their own work. Highlanders preferred public campaign work.

9.2.4 Determinants of Adoption and Intensity of Use of Conservation practices

Physical conservation practices

Probit regressions showed that the adoption of stone terraces and soil bunds was affected by a wide range of factors including physical factors, household capacity to invest, risk of investment, socio-institutional and household demographic factors. On average, the probability of adoption of stone terraces and soil bunds was low (22.0 and 1.3 percent, respectively).

Farmers tended to use stone terraces when soil erosion was likely to be more severe. Soil textures that were easier to work with were positively associated with soil bunds. Irregular slope shapes of plots detracted from adoption of soil bunds. Location of plots was important in explaining the adoption of both stone terraces and soil bunds. Farmers used stone terraces on lower sloping land, but they used soil bunds on flat lands.

Family labor availability favored the adoption of stone terraces but did not matter for soil bunds. Long-term land tenure security contributed to the adoption of stone terraces but detracted from the adoption of soil bunds. On the other hand, insecurity of land tenure detracted from adoption of stone terraces but increased the adoption of soil bunds. Land tenure stability at the village level also favored stone terraces. These results indicate that land tenure security is an important determinant of investments that have long-term payoff.

Availability of food-for-work projects at the village level favored adoption of stone terraces but detracted from the adoption of soil bunds, suggesting that stone terraces had been the focus of such projects. Public campaign conservation work substituted for own investment for both stone terraces and soil bunds.

Age and literacy of household head tended to reduce adoption of soil bunds but did not matter for stone terraces. Experience and access to information might have proven that soil bunds were less effective in reducing soil erosion.

The factors that affected the length of stone terraces constructed were different from the factors that affected their adoption. Households located in the highland zone, although less prone to adopt stone terraces, tended to build more terraces if they did adopt. This result indicates that foregone land productivity might be more important in explaining the level of use of conservation practices since land productivity is higher in the highland zone. Distance of villages from the nearest market place and all-weather road (financial incentives to invest factors) were insignificant in explaining adoption but explained intensity of use positively, indicating that once adoption took place, low opportunity cost of labor encourages investment in stone terraces. Tenure security, institutional factors and household demographic factors did not influence effort.

Farmer maintenance of stone terraces were determined by a wide range of factors. Probit regression showed that on average, farmers were highly likely to maintain stone terraces (with 88 percent probability). Low opportunity cost of labor encouraged maintenance. Institutional factors that favored maintenance activities included extension contact, community pressure and benefit from campaign conservation work.

Biological conservation practices

Biological conservation practices including grass strips, crop rotation, contour plowing and tree planting were widely adopted. The likelihood of their adoption was explained by relative severity of land degradation in a village, household capacity to invest, risk of investment and socio-institutional factors. Higher family labor availability and tenure security detracted from adoption of biological practices, perhaps through their effect in favoring stone terraces. Villagers who resided in villages with more degraded lands were more likely to adopt biological practices. Institutional factors encouraged adoption, notably contact with the extension service and availability of FFW, perhaps through provision of technical information and tree seedlings. Farmer perception of community pressure to conserve soil encouraged use of biological practices.

9.3 Policy Implications

No previous study has combined village, household and plot level data for the analysis of the determinants of farmer conservation behavior in Ethiopia. This research attempted to analyze results of four years of conservation efforts (1992-1995) in Tigray region. Since the study had a limited area coverage and the analysis was based on farmer recall data and farm management data collected from one production year, caution must be exercised in drawing specific policy recommendations and actions for conservation intervention for the entire region of Tigray. However, some general recommendations for policy, research and extension are warranted.

9.3.1 Implications for Conservation Policy

Agricultural scientists tend to disregard indigenous farmer knowledge of soil conservation. Natural resource conservation and development programmes and projects are usually designed and implemented without farmer involvement. This study has shown that Tigrayan farmers perceived soil erosion as a severe problem for agricultural production. Their perceptions of soil erosion and conservation were found to be consistent and reasoned. This indicates the need for and importance of farmer involvement in the design of conservation programmes and projects and the choice of specific techniques. Farmers need to take primary responsibility for implementation of conservation programmes and projects.

Soil erosion on upland areas results in negative externalities downstream, and the effectiveness of conservation efforts on lower slopes can be undermined in the absence of similar efforts on upper slope areas. This linkage demands a watershed approach to soil conservation. The public campaign soil conservation work being pursued in Tigray seems to be in line with the watershed approach. However, this study has shown that the public campaign work and the extension-assisted private conservation efforts are substitutes for each other. The public campaign approach may have alleviated the problem of labor shortage and eased the drudgery that farm households would have faced to construct conservation practices. Once all rural lands, private or communal, that suffer erosion have been conserved, public campaign work needs to be restricted to communal lands and emphasis needs to be given to strengthening the extension service to facilitate private investment in soil conservation. Appropriate public policies should accompany the private investments.

The analysis of adoption determinants highlighted the importance of secure land tenure for encouraging farmers to adopt conservation practices such as stone terraces that have a long-term payoff. It would be difficult to expect farmers to invest in land development unless they enjoy secure land tenure for a long enough period to appropriate the returns. This research found that perceived land tenure security influences the choice of conservation practice, and it may compromise the suitability of the practices chosen. With secure land tenure, the choice of techniques is likely to be dictated by suitability. Hence, a legal assurance of farmer land and tree tenure rights remains crucial to facilitate wider use of soil conservation practices in Tigray. This legal assurance of land tenure need not, however, take the form of private ownership of land.

Most Ethiopian farmers are risk averse and tend to discount future income heavily. The stone terrace investment analysis showed that the profitability of investment in stone terraces dropped almost to break-even at a farmer discount rate of 50 percent. Moreover, farmers may not be able to pay for the initial investment cost calling for targeted credit for terrace construction. The 50 percent internal rate of return of investment in stone terraces also justifies public subsidy. The provision of credit or public subsidy should be coordinated with extension services, the latter serving as sources of technical and educational support.

Soil conservation in the region has focussed on curing soil erosion rather than on preventing it. This approach could be justified by the severity of soil erosion that has already taken place in the region and the time it takes to design land use systems to prevent soil erosion. However, a long-term soil conservation strategy needs to focus on changing the farmer land management practices that induce soil erosion, a focus on preventing soil erosion rather than on curing it. One way of doing this is by developing a conservation package that combines physical, biological and agronomic practices. At present, conservation and intensification appear to be considered as separate objectives in the region. In fact, conservation and intensification can and do complement each other. Hence, long-term strategies of agricultural development in the region need to combine conservation and intensification technologies.

9.3.2 Implications for Agricultural Extension

Fifty-seven percent of surveyed farmers reported having contact with extension service related to soil conservation during 1992-95. However, contact with extension service explained neither adoption of stone terraces and soil bunds, nor their intensity of use. Mobilization of the community labor for public campaign conservation work may have taken too much time from extension agents. The future emphasis of extension service for resource conservation needs to be on encouraging private investment in soil conservation.

Adoption of different conservation practices are affected by different factors. The extension services should recognize this fact in their programs. They should devote more effort to the highland zone to promote use of physical conservation structures and their maintenance. The distance of plots from homestead tend to detract from adoption, intensity and maintenance of physical conservation practices. Extension services need to take this fact into account during the program planning stage. The finding that age and literacy of household heads detract from adoption of soil bunds suggests that extension service may need to target such households in areas where soil bunds are more suitable to use. Farmers are highly likely to maintain stone terraces once they are built, suggesting that extension services may not need to deal with maintenance separately.

The factors that affect adoption and intensity of use of conservation practices seem to be different. This suggests the need for different intervention strategies for adoption and sustained use of conservation practices. To encourage effort among those who adopt stone terraces, the extension services need to focus on households with higher opportunity cost of labor and areas of low land productivity.

9.3.3 Implications for Conservation Research

Very limited research has been conducted in Tigray regarding soil erosion and conservation. In particular, very little research has been done on the traditional conservation practices of Tigrayan farmers. An inventory of the traditional conservation practices needs to be done in order to identify the practices that are still in use from those that have been abandoned. An understanding of the reasons for the abandonment of some of the practices and the continuing use of the others could be a valuable information for the design of modern conservation techniques. Moreover, case studies of a few villages which have successfully instituted conservation practices would provide important insights about the sustainable use of conservation practices at the community level.

The same conservation techniques are recommended through out the region. Such a blanket recommendation may result from the lack of research results regarding the feasibility and effectiveness of the conservation practices in different parts of the region. It is likely that different areas may have need for different conservation practices. Wind erosion may be more important than water erosion in some parts of Tigray. Hence, an interdisciplinary study on the feasibility and effectiveness of conservation practices for the different parts of Tigray would be required.

Profitability is an important determinant of investments. Very little research has been conducted on the private or social profitability of conservation practices in Tigray. The on-farm experiment conducted in this study to determine the impact of stone terraces on wheat and fava bean yields and farm profitability needs to be replicated to include other important crops in the region such as sorghum, barley and teff. The study also needs to be conducted on different agroecological zones over several years in order to account for changes in climatic conditions. A more systematic treatment of the social profitability analysis is also required.

The battle against land degradation will continue for many years. Sustained interdisciplinary conservation research plays a key role in this battle. Due to the aggressive rural-centered development strategy being pursued in Ethiopia, the socio-institutional, economic and agroecological environment under which Tigrayan farm households operate is likely to change. As a result, conservation policies need to be updated based on current and emerging research findings on the economic status of farmers, feasibility, effectiveness and profitability of conservation practices, and determinants of farmer adoption of the practices. This requires the institutionalization of conservation research in Tigray.

9.4 Limitations of the Study

Farmer adoption of conservation practices is a complex decision involving agroecological, physical, economic, and socio-institutional factors. The conservation behavior of farmers is partly site-specific. The limitations of the study emerge from these facts.

The most important limitation of the study is its limited time and area coverage, and small sample size. Although an attempt was made to represent the two most important agroecological zones in the region, time and logistics did not allow for a wide enough coverage or a large enough sample size to permit drawing definitive policy recommendations for the entire region of Tigray. Replicating the study in different areas of the region, particularly in the eastern and western zones could help draw some general conclusions.

Biological conservation practices were treated here as a group, but future research should disaggregate them by type of practice at the plot level. As the practices have different characteristics, separate analysis of the determinants of adoption of each practice could provide more useful information.

This research has shown that Tigrayan farmers perceive the problem of soil erosion as a severe problem for agricultural production. Investment in conservation practices may increase and enhance the stability of crop yields but public intervention may be required to make the investment attractive to farmers. Extension service need to treat different conservation practices differently. Farmers make decisions on adoption and intensity of use of conservation practices separately suggesting different intervention strategies for adoption and use intensity.

APPENDIX

APPENDIX I

The Economics of Soil Conservation Investments in the Tigray Region of Ethiopia

Village, Household and Plot Survey Instrument

Name of Enumerator ______________________________

Name of Woreda ______________________________

Name of Tabia ______________________________

Name of Village ______________________________

Name of Respondent

Village Level ______________________________

Household and Plot Level ______________________________

Date of Interview ______________________________

A. Village Characteristics

1. Agroecology **Agroeco** ________

1. Highland 2. Intermediate Highland 3. Lowland

2. Altitude ____________ **Altitud** __________

3. Predominant Topography **Topogra** _________

1. Hilly 2. Plain 3. Intermediate

4. Predominant Vegetation **Vegetat** _________

1. Bush 2. Grass 3. Wood

4. Forest 5. Barren

5. Three major crops grown in normal year in order of importance

by area occupied **Majcrop** ________

1st __________ 2nd __________ 3rd ___________

6. How many times per year do farmers in the village produce? **Intcrop** ________

7. Year land distributed last in village **Landistr** ________

8. Number of land classification categories **Landcls** _________

9. Land classification categories **Landctg** _________

1. ________ 2. ________ 3. _________

10. Size of one gibri ______________ **Landsze** ________

11. Size of land allotted to children _____________ **Landchd** ________

12. Size of land allotted to an adult _____________ **Landadt** ________

13. What is the size of an average family? __________ **Fmszeav** ________

14. What is the area of land holding of this average family

in Timads? ___________ **Avehold** ________

15. Is there a variation of duration of land lease in the village? **Varlease** _______

1. Yes 0. No

16. What is the average duration in years of leasing out land

in village? __________ **Yrlease** _________

17. Is there a lumpsum payment for leasing in land? **Lplease** _________

1. Yes 0. No

18. The rental arrangement for leasing land is in the form of: **Rtlease** _________

1. Cash 2. Share cropping 3. Other (specify)______

19. **Rental Rate for leasing land:**

lumpsum payment: ____________________ (Per timad or plot) **Lumpay** _____

if cash: ____________________ (per timad) **Cashpay**_____

if share: ____________________ (ratio of share) **Shratio**______

20. **Type of Two major livestock reared in the village:** **Mjlvstk**______

____________________ ____________________

21. **Distance of village from nearest market place in walking hours:** **Mktdist**_____

____

22. **Distance of village from all weather road** _______________ **Roaddist** ____

23. **Major off-farm involvement of village people by number of people involved:** **Offarm** _____

1. Arho 2. Construction 3. Handcraft 4. Weaving

5. Food processing 6. Transport 7. Trade 8. Other (specify) ______

24. **Total Number of Households in village:** ____________ **Totlhd** ______

25. **Number of male-headed households in village:** __________ **Malehsd** ____

26. **Number of Female-headed households in village:** ________ **Femlhsd** ____

27. **Major source of cooking and heating fuel in village:** **Fuelsrc** ______

1. Forest and bush 2. Animal dung 3. Crop residue

4. Other (specify) ____________

28. **Average round trip distance traveled for collection of fuelwood in walking hours:** ________________ **Fueldist** _____

29. Predominant soil texture in village: **Soiltyp** ______

1. Sandy 2. Clayey 3. Silt 4. Loam

30. Is there shortage of fuelwood in village? **Fuelsrt** ______

1. Yes 0. No

31. Are there crops that are disappearing (decreasing in area coverage) in the last five years? **Crpdisp** _____

crop	Major Reason
____________	_______________
____________	_______________
____________	_______________

32. Are there crops that are gaining popularity in the village in the last five years? **Croplr** ______

33. What is the number of farm households with the following ox/oxen ownership?

Size of holding	Number of households
1. Without any ox	_____________
2. Only one ox	_____________
3. A pair of oxen	_____________
4. Three oxen	_____________
5. Two pairs of oxen	_____________
6. More than two pairs of oxen	_____________

34. Is there delineated grazing area in the village? _______________ **Grzeare** _____

35. What is the size of the grazing area in timad? ____________ **Grzesiz** _____

36. Is grazing land during rainy season adequate in the village? **Rngrzad** ____

1. Yes 0. NO

37. Is grazing land during dry season adequate in the village? **Drygzad** ____

1. Yes 0. NO

38. What is the major reason for the inadequacy of grazing land during the rainy season? **Rngzind** _____

1. Extensive cultivation 2. Highly degraded land

3. Other (specify)____________

39. What is the reason for the inadequacy of grazing land during the dry season? **Drgzind** _____

1. Highly degraded land 2. Area closure

3. Other (specify) __________

40. How do villagers try to alleviate the problem of shortage of grazing land? **Gzsrtsl** ______

1. Using straw and weeds 2. Using tella residue

3. By Cut and carry 4. Other (specify) _________

41. Is there closed area in the village? **Areacls** _____

1. Yes 0. No

42. What is the size of the closed area in Timad? ___________ **Szeclos** ______

43. When was the area closed? _________ **Yrclose** _____

44. What benefits do villagers get from the closed area?

____

____

____

45. Is there a natural forest(s) in the village? **Natfrst** ______

1. Yes 0. No

46. Is there an man-made forest(s) in the village? **Artfrst** ______

1. Yes 0. No

47. What are the major problems of agricultural production in the village in order of importance?

____

____

____

B. Farm Operations (1995/96 Cropping Year)

1. How many plots did you cultivate last cropping season? ___________ **Plotcvt** ______

Note To Enumerator: Please number the plots by size: 1= largest etc.. In case of equal size, use distance from homestead. The nearest will be numbered first.

2. Have you leased out land? **Ldlseut** _____

1. Yes 0. No

Note to Enumerator : If the answer to question B(2) above is NO, go to question 7; If YES skip question 7.

3. What is the size of the plots you leased out? __________ Szlseut ______

4. What was the rental arrangement? Lserent _____

1. Cash 2. Share cropping

3. Share cropping and lumpsum payment 4. Other (specify) ________

5. What was the rental rate?

Cash (Birr/timad) _______________

Ratio of share _______________

Lumpsum payment ______________

6. What was your reason for leasing land out? Lsereas _____

1. Lack of oxen 2. Lack of labor 3. Lack of seed

4. Other (specify) ______________

7. If you have not leased out land, what was the reason? Ntlsers ______

1. Could not find leasee

2. Low crop share and lumpsum payment

3. Oxen and labor available

4. Other (specify) __________

8. Have you fallowed any of your plots last cropping season? Flwlstyr _____

1. Yes 0. No

9. Have you fallowed any of your plots a year ago? Flwyrago ____

1. Yes 0. No

10. Have you fallowed any of your plots five years ago? Flwfvyr _____

1. Yes 0. No

11. Indicate the number of cattle and other animals you own:

oxen ______________ Cows ___________ Heifer _____________

Calves _____________ Goat ____________ Sheep _____________

Donkey ____________ Mule ____________ Camel _____________

Poultry _____________ Beehives _________

12. What did you use for plowing last cropping season?

(Choose all that apply) **Plwuse** ______

1. Oxen 2. Cow 3. Donkey 4. Mule

5. Other (specify) ________

13. Did you have enough draft power of your own last cropping season? **Enghdrft** ____

1. Yes 0. No

14. If the answer to question B(13) above is no, What was your source of additional plowing power? (Choose all that apply) **Sorcdrft** _____

1. Oxen exchange 2. Cash rent 3. Share cropping

4. Help from relatives and friends 5. None

6. Other (specify) __________

15. Did you use improved seed last cropping season? **Seedimp** ____

1. Yes 0. No

Note to Enumerator: If the answer to question B(15) above is NO, Go to question 18; if yes skip question 18.

16.What was the improved seed(s)?

__________________ ______________ _______________

17. What was the source of the improved seed? **Srcimpsd** ____

1. Market 2. Credit 3. Aid 4. Other (specify) _______

18. If you did not use improved seeds last cropping season, what was the reason(s)? **Rsnntsd** _____

1. Was not available 2. Did not have purchasing power

3. Did not want to use them 4. Other (specify) _______

19. Did you have enough local seed of your own last cropping season? **Loclsdad** ____

1. Yes 0. No

Note to Enumerator: If the answer to question B(19) above is yes, go to question 22.

20. What was the crop (s) for which you faced seed shortage?

_______________ _______________ _______________

21. What was your source of additional seed? **Lclsdsrc** _____

1. Credit 2. Market 3. Relatives and friends 4. Aid

5. Other (specify) ___________

22. Did you have enough agricultural implements of your own? **Agimpad** ____

1. Yes 0. No

Note to Enumerator: If the answer to Question B(22) above is yes, go to question 26.

23. What was the implement(s) for which you faced shortage?

_______________ __________________ _____________

24. What was the cause(s) of the shortage? **Impsrtrs**____

1. Was not available 2. Did not have purchasing power

3. Other (specify) ________________

25. What did you do to alleviate the shortage? **Srceimp** _____

1. Borrowed from friends 2. Shared with others 3. Bought on credit

3. Other (specify) ___________

26. Did you use modern fertilizer last cropping season? **Ftzeuse** _____

1. Yes 0. No

Note to Enumerator: If the answer to question B(26) above is No, go to question 28; if YES, skip question 28.

27. What was the source of the fertilizer? **Ftzesrc** ______

1. Yes 0. No

28. What was the reason for your not using fertilizer? **Ntftzrs** ______

1. Was not available 2. Did not have purchasing power

3. Did not want to use it 4. Other (specify) _________

29. Did you have labor shortage for farm operation last cropping season? **Lbrshrt**_____

1. Yes 0. No

Note to Enumerator: If the answer to question B(29) above is NO, skip questions 30-31.

30. For what crops and operations did you face labor shortage?

Crop	operation	Month
___________	___________	___________

____________ ____________ ____________

31. What was the source of additional labor?

1. Hired labor 2. Exchange labor 3. Help from friends and relatives

4. Other (specify)

32. Plot Description:

	Plot 1	Plot 2	Plot 3	Plot 4
Cultivated by owner since when				
Dominant soil texture				
slope degree				
Shape of slope				
Distance from home stead				
Size in timad (farmer estimate)				
Size in hectare (from measurement)				
owned or leased in				
Water logged or not				
Irrigated or not				
Rental arrangement if leased				
Conserved or not				
Type of Conservation practice				
Year conservation practice was built				
who constructed the conservation practice				
Conservation practice maintained or not				
Who did the maintenance				
Location of plot				

C. Household information

1. Age of household head **Agehead ____**

2. Sex of household head **Sexhshed ____**

3. Household size **Szehshd _____**

4. Number of male household members **Mlehshd ____**

5. Number of female household members **Flehshd _____**

6. Literacy of household head **Literacy _____**

    1. Literate 0. Illiterate

7. Number of household members by age and sex

Age category	Male	Female	Total
0-5			
6-10			
11-17			
18-64			
above 64			

8. Are you sending any of your children to school? **Schlchd _____**

    1. Yes 0. No

9. Number of children being sent to school **Numschcd ___**

10. Major occupations of family members by age and sex

    1. Herding 2. Field work 3. Cultivation 4. Household

    5. Other (specify) _______________

Age	Sex	Three major occupations by time spent		
		1st	2nd	3rd
6-10	female			
	male			
11-17	female			
	male			
18-64	female			
	male			

11. Have you or members of your family participated in food-for-work program for soil and water conservation in the last three years? **Fdwkswc** ____

1. Yes 0. No

Note to Enumerator: If the answer to question C(11) above is NO, go to question 16; If YES, skip questions 16-17.

12. About how many total days have you and your family members worked on this projects? **Tldyswk** ____

13. Do you think that the conservation work projects have or will contribute to improve crop yields? **Swcrpyd** ____

1. Yes 0. No

14. If the conservation project was in your village, do you think that your community has benefited from the project? **Bnftcom**____

1. Yes 0. No

15. If the answer to question C(11) above is NO, Was there food-for-work project in your community? **Fdwkava** ____

1. Yes 0. No

16. If the answer to question C(15) above is YES, why did you or members of your community not participate in the food-for-work project? **Ntfdwkrs** ____

1. Did not want to 2. Did not get the chance 3. Old age

4. Illness 5. Other (specify) ________

17. Did you hire labor for agricultural work last cropping season? **Lbrhire** _____

1. Yes 0. No

Note to Enumerator: If the answer to C(17) above is NO, go to question 22.

18. What type of labor did you employ? (Choose all that apply) **Lbrtype**_____

1. Permanent male 2. Permanent female 3. Casual male

4. Casual female

19.What was the duration of employment in days for:

Permanent male ____________ permanent Female ____________

Casual Male _____________ Casual Male _____________

20. How do you characterize the availability of permanent hired labor in your community? **Lprpmava**___

1. Abundant 2. Scarce 3. Seasonally Scare (specify season) ________

21. How do characterize the availability of casual hired labor in your community? **Lbrcsav** _____

1. Abundant 2. Scare 3. Seasonally scarce (specify Season) ________

22. What was the major work done by permanent hired labor? **Mjpmlb** __

(choose all that apply)

1. Land preparation 2. Cultivation 3. Harvesting 4. Other (specify) ________

23. What was the work done by casual hired labor? **Mjcslb** _____

(choose all that apply)

1. Land preparation 2. Cultivation 3. Harvesting 4. Other (specify) _________

24. Did you or members of your family participate in off-farm work last cropping season? **Ofarmwk** ____

1. Yes 0.No

Note to Enumerator: If the answer to question C(24) above is NO, go to question 29.

25. How many family members including you were involved? **Pernum** _____

26. What was the off-farm work? (Choose all that apply) **Mjofmwk** ___

1. Trade 2. Construction 3. Weaving 4. Food processing

5. Tailoring 6. Crafts 7. Transport 8. Arho

9. Other (specify) ____________

27. How many total days were you and members of your family involved in off-farm work? **Dyswkd** _____

28. How much income did your family get from off-farm work? **Incomgt** _____

29. Were you and members of your family involved in SWC campaign

work last cropping season? **Swcgnwk** ____

30. How many family members including you were involved? **Persinv** _____

31. How many total days were you and members of your family involved in SWC campaign work? **Ttldywk** _____

32. What is the starting time for agricultural work in a day during the peak period? **Agrstart** ____

33. What is the finishing time for agricultural work in a day during the peak period? **Agrfinsh**_____

34. How many times in a day do you take rest from agricultural work during the peak period? **Timerest** ____

35. What is the duration of each rest in hours? **Durest** ______

36. How many religious holidays do you strictly observe (not involved in any agricultural work at all) in a month? **Religdys** ____

37. What are the three most important constraints of agricultural production in your area?

________________ ________________ ________________

38. How much do you pay for taxes per year? **Taxpay** _____

39. What type of taxes do you pay?

________________ ________________ ________________

40. Do you have access to agricultural credit? **Crditac** _____

41. In the last two crop years, what have you done with the intent of increasing crop yield on your plots? (Choose that apply) **Yldincfr** _____

1. Used fertilizer 2. Used manure 3. Used improved seed

4. Used insecticides and herbicides 5. Invested in soil and water conservation

42. What community work were you involved in during last cropping year?

Type of community work	Number of days
____________	__________
____________	__________

43. If you had additional income, how would you spend it? **Priorivt** _____

1. Invest in agriculture 2. Invest in off-farm work
3. Home consumption 4. House construction
5. Education of children 6. Other (specify) __________

44. What are your three priorities (in order of importance) for government support of agriculture in your area? **Gvtsptpr**____

1. Credit for buying draft power 2. Credit for seed
3. Credit for fertilizer 4. Agricultural extension education
5. Supply of farm inputs 6. Development of irrigation structure
7. Other (specify) __________

D. Soil and Water Conservation Activities

1. How do you perceive the problem of soil erosion in your plots before conservation practice was built?

1. Severe 2. Moderate 3. Slight 4. No problem

Plot 1 ____________ Plot 2 ____________

Plot 3 ____________ Plot 4 ____________

2. How do you compare the problem of soil erosion in your plots after conservation practice was built with that before the conservation practice?

1. Aggravated 2. Same 3. Reduced

Plot 1 ___________ Plot 2 ___________

Plot 3 ___________ Plot 4 ____________

3. What do you think is the major cause of soil erosion? **Mjercaus** ____

1. Deforestation 2. Overgrazing 3. Over cultivation

4. Poor agricultural practices 5. Steep slopes

6. Intensity of rain 7. Other (specify) _________

4. What do you think is the consequence of soil erosion? **Eroscons** ____

1. Land preparation becomes more difficult

2. Change in types of crops grown is induced

3. Land productivity is reduced

4. Other (specify) _____________

5. Do you think that time needed for land preparation is reduced as a result of conservation practice? **Lndprcns** ___

1. Yes 0. No

6. If the answer to question D(5) above is YES, by how much? **Lndprhow** ___

1. One-half 2. One-third 3. One-fourth 4. One-fifth

6. Can not estimate

7. By how much do you think soil erosion reduced land productivity in your plots before conservation practice was built assuming a normal cropping year? **Ersprd** ______

1. One-fifth 2. One-fourth 3. One-third 4. One-half

5. No reduction 7. Other (specify) _________

8. Have you built physical conservation practice on your plots by your own in the last three years? **Ownphcn** ___

1. Yes 0. No

9. If the answer to question D(8) above is YES, what is the physical conservation practice? **Phyconpr**____

1. Stone terrace 2. Soil bund 3. Check dam

4. Other (specify) ________

10. Have you used agronomic (biological) conservation practices on your plots by your own in the last three years? **Ownbio** _____

1. Yes 0. No

11. If the answer to question D(10) above is YES, What is the practice? **Biocnpr** _____

1. Grass strip 2. Tree planting 3. Crop rotation

3. Contour plowing 4. Other (specify) ___________

12. Have you done maintenance work of the physical conservation practices in your plots by your own in the last three years? **Ownmtphy**___

1. Yes 0. No

13. What was the physical conservation practice you maintained? **Mtconpr** ____

1. Stone terrace 2. Soil bund 3. Check dam

4. Other (specify)_____

14. If the answer to question D(13) above is NO, what is the reason for not doing any maintenance work? **Ntmtres** _____

1. There was no need for it 2. Shortage of labor

3. Did not want the practice to be maintained 4. Other (specify)________

15. If the physical conservation practices on your plots were built by campaign work, would you have built them by yourself had there been no campaign work? **Owncagn** ____

1. Yes 0. No

16. If the answer to question D(15) above is NO, what is the reason? **Ntownrs** ____

1. Do not want the practice 2. Do not have enough labor

3. Land tenure insecurity 4. Other (specify) _____________

17. Do you think that the conservation practices have resulted in increased yield as compared to the yield without conservation practice in normal year? **Yldcons**_____

1. Yes 0. No

18. Are there any problems that stone terraces are causing on your farming operation? (Choose all that apply) **Stnterpr**_____

1. Land reduction 2. Harboring pests

3. Difficulty in plowing 4. Water logging

5.Other (specify) _________

19. Are there any problems that soil bunds are causing on your farm operation? (Choose all that apply) **Soilbdpr** ____

1. Land reduction 2. Harboring pests

3. Difficulty in plowing 4. Water logging 5. Other (specify) _______

20. How do you think stone terraces affect the stability of crop yield? **Stntrstb**_____

1. Increase stability 2. Decrease stability 3. No difference

21. How do you think soil bunds affect crop yield stability? **Slbdstb** _____

1. Increased stability 2. Reduced stability 3. No difference

22. How do you think biological conservation practices affect the stability of crop yield? **Bioprstb** ____

1. Increased stability 2. Decreased stability 3. No difference

23. Do you believe that you will cultivate the same plots five years from now? **Own5yrs** ____

1.Yes 2. No 3. Am not sure

24. Do you expect you will inherit your plots to your children? **Owninhrt** ___

1. Yes 2. No 3. Am not sure

25. How do you think your community would feel about you if you do not use conservation practices on your plots? **Pressure** ____

1. Positively 2. Negatively 3. Neutral

26. Would you prefer to construct conservation practices on your plots by yourself rather than being involved in campaign work? **Owncgprf** ___

1. Yes 0. No

27. Did you have any extension education on soil and water conservation? **Extcons** _____

1. Yes 0. No

28. Do you think investment in conservation practice is profitable? **Cnsproft** ____

1. Yes 0. No

29. What traditional soil conservation practices do (did) you use?

________________ ________________ ________________

30. What change would you suggest to the current public campaign work approach to soil conservation?

__________________ ____________________ ______________

31. Private investment in soil conservation

	Plot 1	Plot 2	Plot 3	Plot 4
Type of physical practice				
Length in meters of physical practice				
Persondays used in building the practice				
Persondays used in maintaining the practice				
Type of biological practice				
Size of the agronomic practice				
Persondays used in setting up the biological practice				

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