





This is to certify that the

dissertation entitled

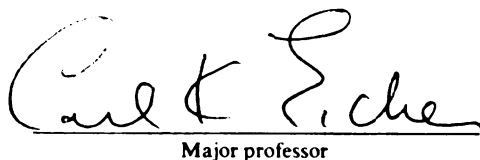
An Economic Analysis of Smallholder Wheat Production
and
Technology Adoption in the Southeastern Highlands
of Ethiopia

presented by

Mulugetta Mekuria

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Agricultural
Economics


Major professor

Date March 28, 1994

LIBRARY

Michigan State University

PLACE IN RETURN BOX to remove this checkout from your record.
 TO AVOID FINES return on or before date due.

DATE DUE	DATE DUE	DATE DUE
AUG 11 1999	_____	_____
MAGIC 2 278 JAN 08 1999	_____	_____
051204 JUN 16 2004	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

**AN ECONOMIC ANALYSIS OF SMALLHOLDER WHEAT PRODUCTION
AND
TECHNOLOGY ADOPTION IN THE SOUTHEASTERN HIGHLANDS
OF ETHIOPIA**

By

Mulugetta Mekuria

A DISSERTATION

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1994

ABSTRACT

AN ECONOMIC ANALYSIS OF SMALLHOLDER WHEAT PRODUCTION AND TECHNOLOGY ADOPTION IN THE SOUTHEASTERN HIGHLANDS OF ETHIOPIA

By

Mulugetta Mekuria

The countries of Sub Saharan Africa are faced with lagging food production, pervasive poverty, high rates of population growth and degradation of natural resources. Most of these countries, including Ethiopia, meet their food requirements from domestic production, imports and food aid. Wheat imports account for 75 percent of wheat consumed in Africa. In Ethiopia about half of the wheat consumed is imported. Increasing wheat production is thus a high-priority topic in Sub Saharan Africa and in Ethiopia. This study is motivated by the need to better understand the economics of smallholder wheat production and technology adoption in Arssi, a major wheat growing region in southeastern Ethiopia.

The study tests the hypothesis that farmers' characteristics, economic and institutional factors, and farmers' perceptions of recommended technologies significantly influence farmers' adoption decisions. Partial budgets and marginal returns analysis are used to compare the profitability of recommended technologies and four alternative production packages. Descriptive statistics, logit, ordered probit, Tobit and discriminant analysis models were used to identify and

estimate the quantitative impact of variables influencing adoption, and to classify farmers into adopter categories. The primary data were collected during the 1990/91 crop season from a sample of 426 wheat farmers in five wheat-growing districts of Arssi region.

All the sample farmers planted improved wheat varieties and 87 percent of the respondents reported using fertilizer. However, only 48 percent were using 50 kg/ha or less fertilizer and only 5-7 percent of them applied the recommended rate of 100 kg/ha. A fifth of the farmers used herbicide. The results of the net benefit and marginal rate of return analysis indicated that wheat production technologies are profitable but inputs are used suboptimally. The econometric model results showed that institutional variables (input availability, credit access and extension contact) significantly affect the incidence of adoption while economic factors (farm size, oxen ownership, labor availability) influence the intensity of use. The analysis of adoption revealed that 17, 46 and 37 percent of the farmers are low, moderate and advanced adopters, respectively. Different factors distinguish the adopter categories in each district. The implications of these results for agricultural research, extension and development policy are summarized.

DEDICATED

In living memory of my mother, **Zenebework Seyoum** who was always eager to see her children attain the highest possible level of education but who sadly passed away just three weeks before the completion of this dissertation,

to my father **Mekuria Asfaw**, who is proud to hear and see that his son has finally achieved the academic dream he always wanted him to realize,

to my dearest wife **Nigist Bekele** whose encouragement, sacrifice and love made this all possible.

ACKNOWLEDGMENTS

I would like to express my gratitude to Professors Carl Eicher, my major professor and Eric Crawford my dissertation adviser whose support and guidance was crucial to the successful completion of my graduate program. I would also like to thank other members of my committee, Professors Richard Bernstein, James Bonnen and Carl Liedhom for their support, understanding and guidance at the various stages of my graduate program.

I deeply acknowledge the Fellowship Award and financial support of the International Development Research Center of Canada and also for allowing me to pursue my training at a university of my choice, Michigan State University. My field work would not have been possible without the financial support of CIMMYT's Economics program and the continued assistance of its Director, Dr. Derek Byerlee. My special thanks goes to him. I wish to acknowledge the support of the Institute of Agricultural Research for granting me the study leave and providing me the necessary facilities for my field research.

I am thankful to my colleagues in the Department of Agricultural Economics at IAR, specially to Hailu Beyene, Alelign Kefyalew, Senait Regassa and Meskerem Haile Mariam, who were able to provide me all they could during my field work and data entry. I am thankful to Amanuel Gorfu, Manager of Kulumsa Research Center, Debela Dinka, Head of the Arssi Regional

Agricultural Development Department, Semu Getahun and Teshome Negussie, Head and agricultural economist of the Regional Planning Office, respectively, who gave me access to the facilities of their respective institutions and their time under difficult security situation. My deep gratitude goes to the farmers and extension agents in the study areas and the ten student enumerators from Alemaya University of Agriculture.

My recognition goes to Dr. Seme Debela, General Manager of IAR (1984-92) whose leadership and vision of institution building greatly contributed to my perspective of research management and interdisciplinary research. I feel proud and privileged to have worked under him. My recognition goes also to many of my colleagues and friends in the IAR and specially Dr. Steven Franzel (now with ICRAF) and Dr. Girma Begashaw of the IMF who always had faith in me and supported me throughout my graduate program. I am grateful to Pat Eisele, Sherry Rich, Ann Robinson and the staff of the computer service of the Department of Agricultural Economics at MSU for giving me the necessary support whenever I asked for it. Professor Carl and Shirley Eicher have always made us feel at home at Michigan State under difficult times and we are grateful for their support and hospitality.

My greatest debt and appreciation are to my wife Nigist, who offered patience, encouragement, love and care throughout our respective graduate programs we both successfully completed.

TABLE OF CONTENTS

	Page
LIST OF TABLES	xii
LIST OF MAPS AND FIGURES	xiv
CHAPTER 1 INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement and Justification for the Study	2
1.3 Wheat Production and Consumption in Africa and Ethiopia	4
1.4 Research Objectives	5
1.4.1 Specific Objectives	7
1.5 Organization of the Dissertation	7
CHAPTER 2 PROBLEM SETTING	9
2.1 Country Profile and the Agricultural Sector	9
2.2 The Resource Endowments	10
2.2.1 The Natural Setting	10
2.2.2 Production Potentials and Limitations	13
2.3 Structure of the Agricultural Sector	16
2.3.1 Land Tenure and Peasant Organizations	16
2.3.2 Institutions: Input Use, Distribution and Credit Services	20
2.4 Agricultural Development Policy : Revisited	22
2.4.1 Agricultural Development Policy: Pre 1974 Period	23
2.4.2 Agrarian Socialism	24
2.4.3 Agricultural Policy in the Transition Period	28
2.5 Agricultural Technology Generation and Transfer	29
2.5.1 Agricultural Research in Ethiopia: Evolution and Development	29
2.5.2 Agricultural Extension Service	32
2.5.3 Agricultural Research and Extension Linkage	34
2.5.4 Experiences in Integrated Rural Development	35
2.5.5 Constraints in Project Activities	38

2.6	Summary	41
CHAPTER 3	CONCEPTUAL FRAMEWORK, LITERATURE REVIEW AND RESEARCH DESIGN	42
3.1	Conceptual Framework of Technology Adoption	42
3.2	Technology Adoption Studies	44
3.3	Research Design and Methodology	48
3.3.1	The Study Area	48
3.3.2	Crop Production	50
3.3.3	Farmers' Organizations	50
3.4	Survey	51
3.4.1	Locations and Sampling Methods	51
3.4.2	Questionnaire Preparation and Enumerator Training	52
3.4.3	Data Collection	53
3.5	Summary	54
CHAPTER 4	SMALLHOLDER WHEAT PRODUCTION IN ETHIOPIA	56
4.1	Introduction	56
4.1.1	Wheat in Ethiopian Agriculture	56
4.1.2	Regional Production Trends	59
4.1.3	Wheat Production, Area and Importance in Arssi	62
4.2	Crop Production Technology Use in Arssi	64
4.2.1	Integrated Rural Development and Technology Adoption	64
4.2.2	Adoption of Commercial Fertilizer	71
4.2.3	Adoption of High Yielding Varieties of Wheat ..	75
4.2.4	Adoption of Herbicides in the study districts	78
4.3	Farmers' Perceptions of Yield Increasing Technologies.	82
4.4	Characteristics of the Households	87
4.4.1	Household Size and Labor Availability	87
4.4.2	Age Categories of Household Heads	89
4.4.3	Educational Levels of Household Heads	89
4.4.4	Farm Sizes of Households	91
4.5	Summary	93

CHAPTER 5	TECHNOLOGY ADOPTION MODEL	96
5.1	The Economics of Adoption and Conceptual Model	96
5.1.1	The Linear Probability Model (LP)	99
5.1.2	Logit and Probit Models	100
5.1.3	Multinomial Logit and Probit Models	103
5.1.4	The Tobit Model	105
5.2	Empirical Model Specification	109
5.2.1	The Binomial Logit Model	110
5.2.2	The Ordered Probit Model	110
5.2.3	The Tobit Model	111
5.2.4	Dependent and Independent Variables	113
5.3	Adopter Categories	120
5.3.1	Discriminant Analysis	120
CHAPTER 6	EMPIRICAL RESULTS	123
6.1	Profitability Analysis of Technologies	123
6.1.1	Partial Budget Analysis	123
6.1.2	Marginal Analysis	133
6.1.3	Comparison of Alternative Wheat Production Packages	139
6.2	Econometric Analysis	143
6.2.1	Binomial Logit Estimates	144
6.2.2	Ordered Probit Analysis	147
6.2.3	Tobit Analysis of Adoption and Use of Fertilizer	150
6.2.4	Logit Analysis of Herbicide Adoption	156
6.3	Discriminant Analysis and Adopter Categories	158
6.4	Summary	164
6.4.1	Profitability of Production Technologies	164
6.4.2	Econometric Analysis of Incidence and Intensity of Adoption	165
6.4.3	Adoption Categories	169
CHAPTER 7	SUMMARY, CONCLUSIONS AND IMPLICATIONS	170
7.1	Introduction	170
7.1.1	Background of the Study	170

7.1.2	Research Objectives	171
7.1.3	Technology Adoption: An Overview	172
7.2	Summary of Results	173
7.2.1	Household Characteristics	173
7.2.2	Profitability of Production Technologies	174
7.2.3	Analysis of Farmers' Production Practices and Technology Adoption	176
7.2.4	Econometric Analysis of Incidence, Intensity and Determinants of	178
7.2.5	Adoption Categories	182
7.3	Policy Implications	183
7.3.1	Implications for Agricultural Research	183
7.3.2	Implications for Agricultural Extension	184
7.3.3	Implications for Agricultural Development Policy	185
7.4	Limitations of the Study and Recommendation for Further Research	186
APPENDIX I		188
APPENDIX II		204
REFERENCES		215

LIST OF TABLES

	Page
Table 2.1 Ethiopia: Average Production, Yield and Area of Major Cereals, 1987-1989	14
Table 2.2 Ethiopia: Number of Domestic Animals ('000)	16
Table 2.3 Ethiopia: Area, Yield and Production of Major Crops by Sector, 1988-1989.	18
Table 2.4 Ethiopia: Yields of Major Cereals by Types of Producers, 1987/88 (kg/ha)	19
Table 2.5 Consumption of Fertilizer in Ethiopia Compared to that in other Countries.	21
Table 3.1 Peasant Associations and Household Heads Interviewed in the Farmer Survey in Arssi Districts, 1990/91.	52
Table 4.1 Production, Consumption and Research Investment Indicators for Selected Wheat Producing Countries in Sub Saharan Africa, 1983-92	58
Table 4.2 Wheat Area, Production and Yield by Farm Types in Ethiopia, 1986	59
Table 4.3 Ethiopia: Cereal and Wheat Area and Production by Regions (1987/88)	60
Table 4.4 Relationship Between Arssi Ecological Zones and Crops Considered Most Important By Farmers	63
Table 4.5 Amount of Fertilizer Distributed in Arssi Districts 1975-1991. .	66
Table 4.6 Amount of Improved Wheat Seed Distributed to Farmers in Arssi Districts 1975-1991.	67
Table 4.7 Use, Experience and Farmers' Knowledge of Fertilizer in Arssi Districts.	72
Table 4.8 Percent of Farmers in Different Fertilizer Application Categories, 1990-1991.	73
Table 4.9 Percent of Farmers and Fertilizer use Levels in Arssi, 1990-1991.	74
Table 4.10 Adoption of Wheat Varieties, Average Area Planted, Seed Rate and Yield in Arssi Districts, 1990-1991.	75
Table 4.11 Average Quantity of Wheat Harvested, Sold and Retained, Farm Gate Prices and Seed Source in Arssi, 1990/91.	78
Table 4.12 Farmers' Weed Control Practices in Arssi Districts, 1990/91 ..	81

Table 4.13	Farmers' Assessment and Perceptions of Wheat Production Technologies in Arssi	84
Table 4.14	Farmers' Criteria for Wheat Varietal Preferences in Arssi	85
Table 4.15	Family Size Categories by percent of Households in Study Districts of Arssi	88
Table 4.16	Age Categories of Household Heads in Arssi Districts	88
Table 4.17	Levels of Education of Household Heads in Arssi Districts, 1990/91	90
Table 4.18	Farm Size of Households in Arssi Districts, 1990/91	92
Table 4.19	Number and Mean Values of Selected Household Characteristics	93
Table 5.1	List of Economic, Social and Institutional Variables Affecting Adoption Decision	112
Table 5.2	Technology Types, Econometric Models, Dependent and Independent Variables Used.	115
Table 6.1	Partial Budget Analysis of Wheat Production Technologies Under Farmers' Practices in Arssi, 1990/91	126
Table 6.2	Adoption of Wheat Production Technologies in Arssi Districts, 1990/91.	130
Table 6.3	Partial Budget Analysis of Wheat Yield Under Selected Fertilizer Levels in Arssi, 1990	133
Table 6.4	Marginal Analysis of Wheat Yields Under Different Fertilizer Levels in Arssi, 1990/91	135
Table 6.5	Adoption, Fertilized Area and Rates of Fertilizer Use in Arssi Districts, 1990	138
Table 6.6	Economic Optimum Rate of Fertilizer for Wheat Production in Arssi, 1986-89.	139
Table 6.7	Partial Budget and Marginal Analysis of Alternative Production Packages for Wheat Farmers in Arssi	142
Table 6.8	Logit Estimates of Fertilizer Adoption in Arssi, 1990/91.	145
Table 6.9	Relative Effects of Significant Variables on Probability of Fertilizer Adoption in Arssi, 1990/91	146
Table 6.10	Ordered Probit Analysis for Different Rates of Fertilizer Use in Arssi, 1990/91.	148
Table 6.11	Tobit Analysis of Adoption and Intensity of Fertilizer Use in Arssi, 1990/91.	152
Table 6.12	Tobit Elasticity Decomposition for Changes in the Explanatory Variables on Fertilizer Adoption and Intensity of Use	154

Table 6.13	Logit Analysis of Herbicide Adoption in Arssi, 1990/91.	157
Table 6.15	Discriminant Estimates for Adopter Categories in Arssi Districts, 1990/91	160
Table 6.16	Discriminant Model Prediction and Actual Classification of Adopter Categories: Percent of Farmers	162

LIST OF MAPS AND FIGURES

	Page
Figure 1	Map of Administrative Regions of Ethiopia, 1991 12
Figure 2	Map of Arssi Region 49
Figure 3	Map of Wheat Producing Regions of Ethiopia 61
Figure 4	Fertilizer Distribution to Smallholders in Arssi Districts, 1975-1991 68
Figure 5	Improved Wheat Seed Distribution to Smallholders in Arssi Districts 1975-1991 69
Figure 6	Response Curve for wheat under selected fertilizer rates, Arssi, 1990/91 136
Figure 7	Net Benefit Curve for Wheat and fertilizer Response in Arssi, 1990/91. 137

CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture occupies a pivotal position in the present and future of African development. In Sub Saharan Africa, agriculture accounts for an overwhelming share of the gross national product, employment, and exports. While some improvement in the productivity of this sector has occurred in some countries, in general agricultural production has been stagnant or declining, and per capita food production has fallen in many countries. Also the Gross Domestic Product (GDP) has stagnated in many Sub Saharan African countries and population continues to grow rapidly (2.5 - 4% per annum) placing a burden on the agricultural sector and its fragile resource base. Increasing the productivity of the agricultural sector is critical in improving food security, providing more employment in the rural areas, increasing exports for foreign exchange, stimulating development in other sectors, and raising the overall standard of living.

The food security of rural households can be improved by 1) increasing food/cash crop production, 2) expanding rural employment opportunities, and/or 3) greater household access to transfers. The first option, food production can be

increased by 1) area expansion, 2) increasing cropping intensity or 3) increasing yields.

1.2 Problem Statement and Justification for the Study

Given the rapidly growing population in Africa and continued degradation of the natural resources, the opportunity to increase production through area expansion is very limited. Since irrigation in Africa is limited, the greatest potential for increasing agricultural productivity is likely to come from increasing yields on rainfed cultivated land. Yields can be increased through more intensive application of labor, more intensive application of existing technologies or adoption of new technologies. Farmers can adopt new inputs and new management practices in their production. Adoption of agricultural production technologies in developing countries is influenced by a wide range of economic, social, physical and technical aspects of farming. Recent adoption studies in Asia (Duraismy, 1989; Lin, 1991; Jansen et al., 1990), Africa (Polson and Spencer, 1991; Kebede et al., 1990; Adesina and Zinnah, 1993, Green and N'ogolala, 1993 and Hassan and Faki, 1993) have identified farmer and farm specific, technology specific, institutional and policy variables and environmental factors to explain the patterns and intensity of adoption. It is important to investigate the role and contributions of these socioeconomic and institutional factors in the adoption of agricultural technologies. Such studies are justified as their results will:

- a) improve the efficiency of technology generation and transfer,

- b) strengthen the links between institutions responsible for technology development and policy formulation, and
- c) help to measure and assess the impact of investments in technology development and transfer (CIMMYT, 1992).

Agriculture in Ethiopia constitutes 45% of the GDP, provides employment for 85% of its population and generates 90% of the foreign exchange. The country has an area of 1.24 million square kilometers of which 69% is estimated to be suitable for agriculture. But less than 15% is under crop production and only 4% of the irrigable land is currently irrigated. Despite 25 years of research and rural development projects, only 10% of the Ethiopian farmers are using fertilizers and only 2% are planting improved seeds. The national average rate of fertilizer application has not exceeded 20 kg per ha and the use of improved seeds has not been more than 5 kg per ha (Debela and Gebre-Mariam, 1990). The national average yield for the major cereals is not more than 1 ton per ha, yet, the potential for attaining higher yields have been demonstrated by several on-farm trials conducted by the Institute of Agricultural Research (IAR) and the Ministry of Agriculture (MOA). This discussion helps explain why the study of technology adoption is of high priority for researchers in Ethiopia. The main objective of this study is to examine the social and economic factors associated with the adoption of agricultural technologies by smallholders in one of the major wheat growing regions of Southeastern Ethiopia.

1.3 Wheat Production and Consumption in Africa and Ethiopia

Sub-Saharan African countries have potential wheat-growing area of about 20 million ha and it is estimated that only 1.3 million hectares are under cultivation. In most of the wheat growing countries of Sub Saharan Africa, wheat is a more recent introduction which is produced using imported technologies, high levels of purchased inputs and mechanized production practices (Morris and Byerlee, 1993). Over half of this area (0.687 million ha.) is cultivated in Ethiopia, which is the largest producer of wheat in the region. Ethiopia is also the center of origin for durum wheat. Traditional production practices and lack of modern inputs contribute to low wheat yield in Ethiopia, which is 1.3 t/ha compared to 5.0 t/ha. yield of Zimbabwe. Three-fourths of all wheat currently consumed in Africa is imported. Wheat production is lagging behind demand and at the same time per capita wheat consumption is increasing. For the period 1961-90 wheat per capita consumption increased at an annual rate of 4.2% (Morris and Byerlee, 1993). Imports increased by more than 600% in most Sub-Saharan African countries (Morris, 1989).

The findings are consistent with wheat production and consumption patterns in Ethiopia. Ethiopia was self-sufficient in wheat production in the 1960s, but by 1980 it was producing only 70% of its requirements. In 1987 only 53% was produced locally while 47% of the wheat consumed was imported (both purchased and food aid). In the 1980s, the growth rate of wheat per capita consumption has been 3.5% per year. A recent IAR-CIMMYT study on wheat

production constraints in Ethiopia reveals that smallholders account for 76% of the total wheat harvested (Beyene et al. 1989). In their review of wheat consumption and production issues in Sub Saharan Africa, Morris and Byerlee (1993) emphasized the need for more economic analysis of wheat production that would help researchers and policy makers design appropriate research and development priorities.

1.4 Research Objectives

Many adoption studies have viewed adoption of a technological practice in isolation from other related practices. Interdependencies between different technological practices have been ignored. Moreover the intensity of adoption of technological practices has not been emphasized since adoption behavior has been considered a discrete choice of adoption or non adoption. A number of studies have examined the importance of household and environmental factors in the adoption of agricultural technologies in LDCs. However, only a few studies have included the intensity of adoption as a dependent variable in the adoption decision model. Modelling the incidence of adoption does not provide adequate information about possible production decisions farmers make. Previous studies of adoption have identified the following factors influencing farmers' decisions to adopt new technologies: the availability of technical and financial assistance, tenurial status, risk attitudes, farm size, education levels and age of head of household and income. Factors that influence the incidence of adoption can be different from those that influence the intensity of adoption. Several of the

adoption models have been under specified as they considered very few explanatory variables.

In Ethiopia, a limited number of adoption studies (Tecle, 1973; Waktola, 1975; Aklilu, 1980 and Kebede et al., 1990) have been conducted. These studies have not dealt with the relative importance of the various constraints listed above. There have been very few commodity-related studies undertaken by local economists.

The research questions addressed by this study are the following:

1. What are the farmers' resources, household characteristics, production practices and technologies used by smallholders growing wheat in Southeastern Ethiopia?
2. How profitable and acceptable are the recommended technologies?
3. What is the relative importance of adoption determinants?
4. What are the socioeconomic characteristics of farmers who adopt new wheat production technologies, and how do advanced adopters differ from moderate and low adopters?
5. What policy and institutional changes are necessary to increase the rate of technology adoption to expand wheat output?

The general objective of this study is to examine the social, economic, and institutional factors that influence the adoption of selected crop production technologies in Arssi, a major wheat production region of the Southeastern highlands of Ethiopia. Components of the production technology to be studied

include high-yielding varieties (HYVs), chemical fertilizers, herbicides, and recommended crop husbandry practices for wheat.

1.4.1 Specific Objectives

The specific objectives of the dissertation are:

1. To present descriptive information on smallholders in Arssi region;
2. To evaluate the economic profitability and acceptability of recommended wheat production technologies;
3. To generate quantitative estimates of the factors influencing the pattern and intensity of adoption using econometric models of logit, probit and Tobit;
4. To identify constraints on the adoption of recommended technologies for wheat;
5. To classify farmers into adopter categories based on adoption pattern and socioeconomic characteristics;
6. To draw implications for agricultural research, extension, and policy changes needed to overcome the constraints on adoption.

1.5 Organization of the Dissertation

The study is presented in seven chapters. Chapter 2 describes the problem setting by discussing the roles of agriculture in the Ethiopian economy, production constraints and the socio-political environment that created the existing agrarian structure of smallholder, cooperative and state farms.

Chapter 3 discusses the conceptual framework, literature review on adoption studies and the research design and methodology employed in the study. Description of the survey areas, survey methods, sampling procedures, questionnaire design and data collection procedures are outlined in the chapter.

Chapter 4 reviews the wheat subsector and presents descriptive statistics on the characteristics of smallholder wheat producers in the study areas. The chapter also reviews the experiences in technology development and transfer and integrated rural development.

Chapter 5 examines the technology adoption model and the econometric analytical techniques used. The applications of logit, probit and Tobit models, model specification issues, selection of dependent and independent variables and the application of discriminant analysis are discussed.

Chapter 6 presents the empirical results of the profitability analysis and the econometric models developed in the previous chapter. In addition adoption patterns, determinants, and relative importance of selected socio economic factors are synthesized in this chapter.

Chapter 7 summarizes the results and draws conclusions and the policy implications for national agricultural research, extension and development policy. Finally the limitations of the study are discussed and further areas of research are recommended.

CHAPTER 2

PROBLEM SETTING

2.1 Country Profile and the Agricultural Sector

Ethiopia is located in the "Horn of Africa " and is the second largest country in Sub Saharan Africa with an area of 1.223 million Km² and a population of 52 million. Agriculture has always been the backbone of the country and today about 86% of the population, engaged in agriculture, produce 40% of Ethiopia's gross domestic product and 90% of the export earnings and supply the raw material for the limited agro-industries. The manufacturing and services sectors contribute 40% and 19%, respectively. The economy suffers from weak infrastructure, heavy dependence on a single agricultural export of coffee, a small industrial base, and shortage of skilled labor. Ethiopia ranks as one of the poorest countries in the world, with a per capita GNP at \$120 (World Bank, 1993).

The performance of Ethiopia's agriculture deteriorated from an average annual growth rate of 2.6% between 1965-75 to less than 1% between 1975-90. The problem of food insecurity and subsequent famines has come to the world's attention because of the publicized 1984 drought that resulted in the loss of many lives. Drought in Ethiopia, a result of limited rainfall, is enormously complicated by economic, political, and other environmental factors.

In addition, with the current annual growth rate of 3.1%, population is projected to reach 70 million by year 2000 and double by year 2015. Thus, food production in general is not keeping pace with population growth. Arable land under cultivation is said to be only 40% of the potential with only 100,000 ha of a possible 2.25 million ha of irrigable land developed. A complex set of factors contribute to the low productivity of agriculture. Yet Ethiopia has the potential to produce adequate food and increase its agricultural export earnings.

2.2 The Resource Endowments

2.2.1 The Natural Setting

Ethiopia is a large and diverse country, both culturally and agro-ecologically. Traditional names have been assigned to zones on the basis of altitude and temperature, e.g., *kola*, *weinadega*, *dega* and *wurch*. However, the amount of rainfall and its periodicity are also important in defining zones (Hurni 1986). Often reference is made to various types of farming systems, for example wheat-tef, or sorghum or coffee-based, which are determined by temperature, altitude, rainfall, and soil conditions.

The highland areas cover the regions of Shewa, Gojam, southwestern Welo, southern Gonder, and eastern Welega, which amount to 47% of the total area of the country, where 74% of the population lives, 14% of the cultivated land, lying between 1800 and 3000 m and receiving 950–1500 mm rainfall, produces 93% of the country's food. The northern Ethiopian highlands (southern Eritrea and western Tigray) have 9% of the cultivated land but only 4% of the production.

The yields are less by 50% compared to those of the other regions because of soil erosion, war, and drought. Sorghum is the most important crop. Southwest Ethiopia, encompassing most of Kefa, Ilubabor, and western Welega, is at about 1500–2400 m and maize is the most important crop. The eastern highlands, including Sidamo, Bale, Arssi, and Harerge, are characterized by having 950–1500 mm of rainfall, an average elevation of 1800 m, 16% of the cultivated land, and 19% of the total production. Sixty percent of Sidamo's cultivated area is under maize. Wheat and barley are the major crops of Arsi and Bale, and Harerge specializes in sorghum (60% of production) and maize (23% of production) (EMA 1988).

It is notable from these statistics the large extent to which food production in general and various major crops specifically are regionalized and furthermore, what a small area of the country produces the majority of the marketed surplus food.¹

¹For details on an overview of Ethiopia's Agriculture see Stroud and Mulugetta Mekuria (1992).



Figure 1 Map of Administrative Regions of Ethiopia, 1991

2.2.2 Production Potentials and Limitations

Ethiopia's agriculture is dominated by a number of cereal crops, which account for about 69% of the calories in the Ethiopian diet, namely maize, tef (*Eragrostis tef*), sorghum, barley, and wheat. Tef, a small indigenous cereal is the most important crop in terms of area. Maize ranks first in total production and yield (Table 2.1). Enset (*Ensete edule*) or false banana, is a major indigenous root crop for approximately 8 million people in the central, southern and western Ethiopia. These crops are augmented by a variety of pulses such as faba bean (*Vicia faba*), chickpea (*Cicer arietinum*), field pea (*Pisum sativum*), haricot bean (*Phaseolus vulgaris*), lentil (*Lens esculenta*) and rough pea (*Lathyrus sativus*). On an area and production basis, faba beans, chickpeas, and field peas are ranked (in descending order) as the most important pulse crops. Noug or niger seed (*Guizotia abyssinica*) is the most important oilseed crop, followed by linseed.

Generally, crop production has been stagnant over the last 15 years and dropped in the drought years (1975 and 1984). There was an annual deficit of around 350,000 tonnes of food crops during this period, which in 1987 increased to 500,000 tonnes. Since 1979 with food aid has provided 8.5% of the calories consumed (Faught 1988; ONCCP 1987). Food imports increased from an annual average of 60,000 tonnes over the period from 1979 to 1983 to 738 800 tonnes over the period from 1985 to 1987. In 1988 food aid reached 825,300 tonnes (UNDP/World Bank 1989).

Table 2.1 Ethiopia: Average Production, Yield and Area of Major Cereals, 1987-1989

	Production (⁰⁰⁰ t)			Area (⁰⁰⁰ ha)			Yield (t/ha)			Average Yield Rank	
Crop Type	1987	1988	1989	1987	1988	1989	1987	1988	1989	1987-89	
Tef	977	923	1201	1212	1161	1354	0.81	0.79	0.89	0.83	5
Barley	834	758	726	745	615	639	1.12	1.23	1.14	1.61	3
Wheat	585	509	635	526	508	531	1.11	1.17	1.19	1.15	4
Maize	1467	1504	1364	887	783	727	1.65	1.92	1.87	1.81	1
Sorghum	922	846	911	715	726	688	1.29	1.16	1.32	1.25	2

Source: Price Studies and Policy Institute, July 1989

Cash crops for Ethiopia include coffee, tobacco, cotton, and other fibers (sisal, enset, and kenaf). For small farmers, coffee, pepper (*Capsicum frutescens*), chat (*Catha edulis*, a stimulant), and some vegetables are the main cash crops. Arabica coffee is produced in Kefa, Ilubabor, Welega, Gamo Gofa, Sidamo, Shewa, and Harerge regions. State farms have about 8,000 ha out of a total of 450,000 ha of cultivated coffee and 150,000 ha of forest coffee. About 20% of government revenue comes from coffee and coffee revenue amounts to 4%–5% of the GDP. Forty percent of coffee is consumed in the country and the rest is exported, accounting for 60% of the foreign exchange earnings. Ethiopia is the sixth major producer and tenth major exporter of coffee in the world (EMA 1988). Coffee produced a moderately good income for farmers in the 1970s and 1980s until 1989/90 when the international coffee cartel and the quota system

collapsed, which resulted in a more competitive market and lower coffee price. Foreign exchange earnings from other export crops including pulses, oilseeds, oilcake, fruits, and vegetables has also dropped in recent years.

Natural resources have been subject to degradation for centuries, a phenomenon particularly well documented in the highland areas, and this is negatively affecting production and the quality of life. Erosion is decreasing soil depth, water-holding capacity, and fertility and it is also increasing the frequency of drought in marginal areas. Deforestation has taken place at a dramatic rate—200,000 ha per year. The area under forests is 4%, down from 16 percent in the 1950s. Fuel is a problem for most families, who resort to using dung, weeds, and crop residues, practices that further erode the soil fertility and organic matter base. There have been many tree planting and soil and water conservation projects in which farmers and their families take part; however, they are seldom left in charge of these resources and the lack of ownership discourages judicious management (Faught 1988, Stroud 1989).

Livestock (cattle, goats, sheep, donkeys, poultry, horses, and camels) are also an important component of all farming systems, although concentrated in the highlands. More numerous than in any other country in Africa, livestock numbers are increasing gradually over time (1970–1988) (Table 2.2). Livestock makes up 17% of the total annual export revenue including hides and skins (sheep, goats, and cattle) and live animals (cattle and goats). Private traders export 57%; the rest is exported through government corporations (EMA 1988). Livestock

productivity indices rank one-third lower than the tropical African average (World Bank 1987).

Table 2.2 Ethiopia: Number of Domestic Animals ('000)

Animal	1979/1981	1986	1987	1988
Cattle	26,000	30,000	30,000	31,000
Sheep	23,250	23,000	23,200	23,400
Goats	17,177	17,000	17,300	17,500
Camels	980	1,000	1,500	1,060

Source: FAO estimate, FAO, 1988.

2.3 Structure of the Agricultural Sector

2.3.1 Land Tenure and Peasant Organizations

The 1975 land reform abolished the old tenancy system including all private ownership of land, without compensation, making land collectively owned by all (Provisional Military Government of Ethiopia, 1975). The land was divided into 800-ha units called peasant associations(PA), which served as the basis for administering land-use directives from the government, administering and conserving public property, and settling land cases. The government felt that PA formation would give people more self-administration based on a group approach

and would eliminate fragmented land holdings (EMA 1988). By 1986, 20, 157 PAs, including 5, 594, 000 households or 65% of the rural population, had been formed. Although the original policy was that a family could farm up to 10 ha, in fact most holdings are only 1–2 ha. The peasants' new relationship to the land has proved to be neither fixed nor secure: peasants can be moved to accommodate expanding cooperatives, state farms, the creation of villages, or for other reasons (MOA, 1988).

Smallholders dominate agricultural production in terms of the population involved, the amount produced, and the area cultivated, accounting for over 94% of each category in 1983. Producer cooperatives which are collective farms ranging in size from a few to several hundred families, accounted for 1.8 % of cultivated area for the same period. State farms, which are large, usually mechanized operations managed by government agencies, accounted for 3.5% of cultivated area. By 1988-89 smallholders still accounted for over 91% of the cultivated area; and the share of the cooperatives had risen to 6-7% while state farms had declined to 3 - 2.7% (Table 2.3).

Table 2.4 illustrates that for major food crops, smallholders have produced higher yields than the cooperatives, despite the fact that the supply of inputs and market pricing structure for inputs and outputs is less favorable for smallholder sector. In some cases (tef and sorghum) yields of the private farms exceed those of the state farms.

Table 2.3 Ethiopia: Area, Yield and Production of Major Crops by Sector, 1988-1989.

Sector	1988						1989					
	Area		Yield		Production		Area		Yield		Production	
	('000 ha)	%	(t/ha)	('000 t)	%		('000 ha)	%	(t/ha)	('000 t)	%	
Smallholder	6492	90	0.98	6384	87		6676	90.8	1.03	6904	88.8	
Cooperatives	494	7	1.11	549	7.5		479	6.5	1.06	508	6.5	
State Farms	208	3	1.99	415	5.5		197	2.7	1.83	361	4.7	

Source: Debela and Gebre-Mariam, 1990

Table 2.4 Ethiopia: Yields of Major Cereals by Types of Producers, 1987/88 (kg/ha)

Crop	Smallholders	Producers' cooperatives	State Farms
Maize	1923	1659	3032
Barely	1234	977	1219
Wheat	1170	1015	1429
Sorghum	1163	939	973
Tef	795	738	172

Source: CSA 1989a

In 1979 government policy encouraged the formation of producers' cooperatives with a target to be one per peasant association. A producers' cooperative is similar to a collective rather than a cooperative in that the land is pooled and the members' income is to be based on the share of labor and resources contributed. Individual households retain 0.1-0.2 ha for their own use. The government's aim in 1979 was to have half of the cultivated land organized into producers' cooperatives by 1994. Incentives were offered to encourage farmers to join this system: any land in a peasant association could be allocated to a producers' cooperative; lower taxes were to be paid; improved seed, fertilizer, credit, and extension services were to be readily available; free labor could be obtained from PAs during peak periods; the Agricultural Marketing Cooperation (AMC) would purchase produce for higher prices; and there would be priority access to consumer goods, training, and building materials. By 1989 there were 3,741 producers' cooperatives involving 321,324 households or about 4% of all rural households. The government introduced service cooperatives with the aim of selling farm inputs, purchase locally produced cereals and pulses, provide loans at fair interest rates, provide storage and savings services, supply basic consumer goods, educate members in socialist philosophy, supply tractor hire services,

collect self-help contributions, provide flour milling services, and promote cottage industries.

2.3.2 Institutions: Input Use, Distribution and Credit Services

Input use (fertilizers, improved varieties, pesticides, veterinary drugs) by smallholders is generally restricted for a number of reasons. Distribution has been through the Agriculture Input Supply Corporation, which receives an estimation of input requirements and arranges for seed production, importation, credit, and distribution. Distribution has often been inefficient and late; inputs in general are expensive relative to produce market prices, and in many instances have not been economic (Franzel et al. 1989). In addition inputs have been allocated to state farms and cooperatives on a priority basis; credit is scarce and is available only through service cooperatives; inputs are not manufactured locally but require foreign exchange, which is limited, or rely on irregular donations. Total fertilizer use has been estimated to be less than 4 kg/ha in Ethiopia. Ethiopia consumes much less fertilizer than many other countries (Table 2.5).

From 1974 to 1980 the cost and use of fertilizer increased moderately. However, the price doubled over the following two years and fertilizer use dropped drastically in response. In the 1981 and 1982 crop seasons, the AMC prices for crops also dropped. From 1979 to 1985, 64% of the improved seed was allocated to state farms, 15% to settlement areas, and 19% to smallholders. Only 2% of the farmers use improved seed. Seed costs up to five times more than the

Table 2.5 Consumption of Fertilizer in Ethiopia Compared to that in other Countries.

Country	Nitrogen fertilizer (kg/ha)	Total amount (kg/ha)
Ethiopia	1.3	3.5
Somalia	1.7	2.3
Kenya	13.4	37.6
USSR	44.3	98.8
USA	53.2	104.4

Source: Awoke and Hailu 1986

crop's marketed price (Faught 1987). In 1986, 63% of the fertilizer² went to the peasant sector, 25% to state farms, and the rest to other government organizations. Fertilizer supplied to the peasant sector is directed to surplus-producing areas.

Institutional credit remains insufficient as funds are short and priority is given to the state farms. Only legally recognized service cooperative can supply loans to peasant associations on behalf of Agricultural and Industrial Development Bank (AIDB). Most of the credit available is used for purchasing fertilizer (15% of the principal; 9.5%–11% interest must be paid in cash in advance and the rest repaid within a 9-month period). Loans are also used for purchase of oxen, equipment, and infrastructure development such as stores. One restrictive repayment policy

² In 1986 fertilizer use went up 72.8% and in 1987 another 13% from the previous year. These increases may have been due to increased supplies from donor agencies in response to the 1984-85 drought (MOA 1988c).

that was adopted by the AIDB and service cooperatives is that if a peasant association does not repay its loans, all farmers in the association will be ineligible to receive additional credit the following year. Smallholders also borrow money from money lenders or relatives.

Taxes include a direct tax of about 20 birr per year per family and indirect taxes where farmers are required to contribute to national or local campaigns. In some areas farmers are required to provide labor for public works (e.g., road building, building schools, farming militia men's farms, which can amount to several days per week).

2.4 Agricultural Development Policy : Revisited

Governments in many countries intervene in the management of the national economy in varying degrees. There is common agreement that the government has an important role to play in regulation and/or taxation and provision of public goods. The Governments of Ethiopia in the past and present had and have adopted national development and central planning as a means to direct the economic development of the country.

2.4.1 Agricultural Development Policy: Pre 1974 Period

The Imperial Government of Ethiopia under the late Emperor Haile Selassie I lasted for almost half a century. The Imperial Government adopted three successive Five Year Plans (1957-62, 1963-68, and 1968-73). The first two plans emphasized the infrastructure and industrial development, respectively. Urban and rural population growth outstripped food production and the efforts in

industrial development did not yield the intended results. The Third Five Year Plan had to explicitly emphasize agricultural development. During the plan period comprehensive rural development projects were established in Chilalo, Wolayita and Ada districts.

The Plan's strategy to promote smallholder agriculture was labelled a "package approach". It aimed to concentrate financial and human resources on the development of a few promising highland areas. Essentially an integrated rural development strategy, the package approach argued for combined investment in agricultural research and extension with initiatives to improve the distribution of seeds and fertilizer, provide credit, develop market facilities, diffuse better farm implements, expand storage facilities, promote rural health, and raise functional literacy³. The projects were found too expensive to duplicate in other parts of the country. In 1970s, they were followed by the Minimum Package Programs. The objectives of the package approach were to provide smallholders with improved seeds, fertilizer and farm implements. The government also gave incentives to the emerging commercial farms growing cash and export crops. The agricultural sector grew at a rate of 2.1% per annum during 1965-73, barely keeping abreast of population growth.

Based on the experiences of the three Plans a Fourth Five Year plan (1974-79) was prepared and it incorporated the lessons from the integrated rural

³For a detailed review of agricultural development policy in the 1960s and evaluation of Integrated Rural Development in Ethiopia see Cohen (1987).

development and minimum package programs. The strategy clearly identified the need to overcome the following constraints facing agricultural development in Ethiopia: insufficient government finance, lack of trained technical and administrative manpower, inaccessibility of much of the subsistence farming areas, shortage of technical and economic data, and lack of proven agricultural technologies (Cohen, 1987). When the 1974 revolution erupted the Fourth Five Year plan was abandoned. During the Imperial era progress was made in building the institutional capacity to support a modernizing smallholder sector. The MOA was established as an organization, and agricultural training and research institutions were established.

2.4.2 Agrarian Socialism

The Provisional Military Government that replaced the Imperial regime in September 1974, declared socialism as its guiding ideology. In 1975 many key financial and manufacturing enterprises were nationalized. Rural and urban land reforms were put into effect and the first references were made to 'villagization' and 'agrarian socialism'. Most peasant farmers have never had secure use of their farms under either the old system or the new. Between 1976 and 1981 central planning and state control over the economy were strengthened, in particular the control over production, distribution, and exchange. From the 1974 revolution until 1990, the Ethiopian government followed a policy of agrarian socialism, an approach based on collective ownership of the means of production, villagization, resettlement, group farming and state farms, and government control of rural

marketing. The arguments for this approach included wider sharing of the rural economy and political power, more equal access to land; more efficient use of labor for agricultural production and rural activities, a reduction of rural-urban migration, more efficient implementation of policies for development with greater control, and economies of scale in agricultural production and marketing (Cohen and Isaksson 1988).

The Development of State Farms: In 1979 the government formed the Ministry of State Farm Development (MSFD). The purpose of the State Farms was to supply urban areas and government organizations with food and to provide some commodities for export. State farms were allocated 222,000 ha in 1983, 3.5% of the agricultural land; by 1988 cultivated area under state farms was 214,000 ha. The average size of a single state farm is 15,000 ha. Tractors, improved varieties, chemical fertilizers, herbicides, and insecticides are used. They absorbed 40% of the government expenditure on agriculture during 1980–1985 period but contributed only 4%–5% to the total production. In 1983 they received 76% of the fertilizer, 95% of the improved seed, and 80% of the credit. The state farms have increased the country's production of cereals, coffee, sugar, cotton, and tobacco but have had problems with mechanization, uneconomic use of inputs, labor shortages, and financial viability (Cohen and Isaksson 1988). Most of the state farms operated at a loss.

Villagization and Resettlement: The objectives of villagization were to conserve natural resources by promoting a better land-use plan, enhance delivery of

extension services, give greater access to public services, and strengthen security and self-defense. Each village has between 200 to 300 households, with 1000 m² (0.10 ha) allocated for each family. Villagization was started in 1986 as Phase 1 in Shewa, Arsi, Harerge, and to a limited extent in Gojam, Welega, Kefa, and Ilubabor. The campaign was easier to implement in areas where (1) annual crops rather than perennial crops had been common, (2) houses had been constructed of wood, mud, and thatch but not stones, and (3) farmers had rights to the land for centuries, as compared to areas where land had been owned by landlords. Villagization brought further disruption. For most of the farmers, walking to and from their fields takes a considerable amount of time. Grazing areas are often too far from home. Bringing hundreds of families together without adequate health facilities has led to frequent outbreaks of human and animal disease. A large number of farm animals died immediately after moving to the new villages. Most farmers had to move their livestock back to their old villages to escape the plagues. Increased livestock and wildlife attacks on crops because of the distance of the fields from the house, overgrazing near the village leading to more erosion, and more pressure on water supplies and tree resources are the potential problems of the villagization effort. Moreover, the government has lacked resources to provide necessary services such as water.

Resettlement was initially recommended by the World Bank as a solution to overcrowded areas where the resource base could no longer support the population. The underlying reasons for resettlement were population growth,

exploitative farming practices, energy shortages, overgrazing, stagnating yields, limited off-farm employment, and low economic growth (World Bank 1987). In 1984 the government planned to resettle 1.5 million people affected by the drought to areas that were supposed to be more productive; 800,000 were moved in a hurried fashion, without the necessary amount of time and effort put into planning. Most of the settlers were moved from the northern highlands to areas of low population density in the western lowlands.

Recent review of Ethiopia's agrarian experience clearly indicate that the 1975 radical land redistribution program was successful as the poor and underprivileged acquired land. However, the subsequent socialist policies launched by administrative fiat, often hurriedly or secretively, and without consultation with peasants did not promote the development of smallholder agriculture. The reform transferred all land to public ownership, prohibited all forms of private property which gave rise to insecurity of holdings and replaced landlords with the state. It ultimately transformed rural Ethiopia into a society of self-laboring peasants (Dessalegn, 1992).

2.4.3 Agricultural Policy in the Transition Period

In 1990 the government of Mengistu Haile Mariam initiated reform measures to liberalize the economy in general and the agricultural sector in particular. Agricultural trade restrictions, grain delivery quotas, fixed prices for the major crops were lifted. Producers' cooperatives members were allowed to make decisions on either to continue to farm collectively or abandon the cooperatives.

Almost all decided to dissolve the cooperatives. The government also attempted to encourage the private sector to invest in commercial agriculture. These measures did not have any significant impact on the already troubled economy. In May 1991, the current the Transitional Government of Ethiopia (TGE) took power. It then introduced a New Economic Policy of the Transitional Period in November, 1991. In terms of the agricultural sector, the new policy included the 1990 reform measures introduced by the defunct regime. Recently the TGE adopted macroeconomic policy reforms and devalued the currency from 2.07 Ethiopian Birr(EB) to 5.00 Birr to a US dollar. Other World Bank prescriptions for implementing the structural adjustment program are being adopted by the government. However, the government does not intend to privatize land which is still public property by decree. To date the TGE owns the State farms and agricultural input distributing enterprises. Appropriate agricultural policy formulation would be the most important challenge for an in-coming democratic government of Ethiopia.

2.5 Agricultural Technology Generation and Transfer

2.5.1 Agricultural Research in Ethiopia: Evolution and Development

The Institute of Agricultural Research (IAR), established in 1966 as a semi-autonomous public institution, is the national organization mandated to coordinate and execute agricultural research in Ethiopia. The Alemaya University of Agriculture (AUA), Addis Ababa University and different units of the Ministries of Agriculture, State Farms, Coffee and Tea Development also

undertake agricultural research. The IAR has established 28 research centers and sub-centers in the different agro-ecological zones of the country.

In the last 25 years IAR adopted different approaches to organizing its research programs. Initially expatriate staff were assigned to conduct their own experiments but gradually commodity programs evolved. Because of the need to strengthen the different agricultural disciplines, departmental approaches followed. Departments of field crops, coffee, horticulture, soil science, animal sciences, agricultural engineering and food science, and agricultural economics were established each having a department head coordinating the program nationally and based at an appropriate research center. Only the agricultural economics program is coordinated from headquarters.

Recent reorganizations led to a two-pronged approach to the generation and transfer of technologies i.e., commodity and zonal/regional research approach. There are eight zonal research programs with one or more research centers in each zone. With this set-up, the centers are responsible for tackling the researchable problems of a particular agro-ecological region. The research program of each center is generally grouped into three major categories: crop production, animal production and natural resources management. All supporting disciplines participate in the research projects.

The national commodity programs are designed to tackle the production problems of selected crops and livestock that are accorded top priority in the national agricultural development objectives: achieving food self-sufficiency,

supplying raw materials for industry and earning foreign exchange. Research problems are identified by a multidisciplinary team consisting of breeders, agronomists, crop protection specialists, soil scientists, agricultural economists and food science experts. By 1991 the IAR has identified 23 commodity research programs to work on selected crops and livestock. The wheat, maize, sorghum, cotton, coffee, highland and lowland pulses and oil crops programs are operational as commodity research programs. The dairy, sheep, beef and animal nutrition and feeds programs are also functional. Farm implements, irrigation, soil and water management research programs are being strengthened. Core and cooperating research centers for each commodity have been designated. The implications of such an expansion in terms of financial and human resources and level of research capability has to be carefully evaluated. The size of research centers and program content is a key issue currently under consideration by the institute and funding agencies.

To build a sustainable NARS a set of necessary and sufficient conditions have to be met. The IAR was able to survive and attain its current status because most of the conditions were met. These conditions were:

1. Continuous government funding and support,
2. Continuous autonomy and de-politicized environment
3. Strong scientific leadership for 18 of the 25 years
4. Investment in and steady supply of human capital (continuous graduate training opportunities despite staff attrition)

5. Articulated and defined requests for international support, including well prepared terms of reference for expatriate staff role
6. Necessary organizational developments and changes without disruption of on going programs (rarely the case in other public institutions).
7. Control of the research agenda (i.e., not donor driven).

The IAR had a total of 592 research personnel (25 Ph.D, 87 MS., 6 DVM., 191 B.Sc. and 284 Diploma holders and additional 63 on study leave as of 1990.) (Debela and Gebre-Mariam, 1990).

The recent World Bank comparison of Asian and African NARS indicated that no African NARS is to the standard of Asian NARS. The study however, identified that of the 47 NARSs in Africa only 9 meet the minimum standard. Based on the Bank's rating score of 0 to 5, a score of 3 is considered to meet the minimum acceptable standard and the IAR was rated to meet the standard (Cleaver, 1993).⁴

The contributions of any national research service are measured by how much its outputs increase the productivity and production of the agricultural sector. The IAR has released a number of crop varieties⁵, crop management practices, improved breeds of animals, farm implements and other kinds of improved

⁴For details on evaluation of African Agricultural research institutions see Cleaver (1993). According to the evaluation the nine NARSs in Sub Saharan Africa that meet the minimum standards are: Cote d'Ivoire, Ethiopia, Ghana, Kenya, Madagascar, Nigeria, Senegal and Zimbabwe. Mauritius is rated above average.

⁵The IAR released 55 varieties of cereals (10 wheat varieties) and oil crops during 1970-1986 period. Disease resistant coffee varieties were also selected and distributed to coffee state farms and farmers (IAR, 1988).

agricultural technologies. It has been both a producing and borrowing (creating and evaluating capability) NARS having strong collaboration with the IARCs⁶.

2.5.2 Agricultural Extension Service

The MOA and the Ministry of Coffee and Tea Development operate extension systems to serve smallholders and PCs. An extensionist's role in Ethiopia is to demonstrate technology, distribute inputs, carry out soil and water conservation projects, villagize farmers, and promote afforestation, among other duties. Although there have been extension-strengthening projects in the past, relatively frequent reorganization, little in-service training of development agents (DAs—those closest to the farmer), frequent transfers, and few incentives including lack of pay raises and transportation to do their job, have resulted in a generally unmotivated staff.

With assistance from the World Bank, the Government introduced a training-and-visit system (T&V) approach to extension in 1986. Under this approach subject matter specialists in agronomy, soil and water conservation, crop protection, socioeconomics, cooperatives, livestock, and home economics are located at district centers. The ideal is to have one DA for each service cooperative (one for every 1,600 households, at the least). Under the T&V system extensionists would consistently visit farmers on a fortnightly schedule and receive in-service training regularly. However, extension agents have not had access to good, appropriate information and do not generally have the training or

⁶On the experiences of building sustainable NARS in Ethiopia, see Mekuria (1992).

the ability to adapt information to the farmer's situation. Many have no background in farming; coming from more urban backgrounds, they lack empathy with the farmer, and their formal training does not give them appropriate communication and technical skills. Furthermore, farmers often view the extension agent with distrust and suspicion because they want to minimize government interference in their lives. However, with some encouragement and training, extension agents could no doubt become much more sensitive and useful to the farmer.

2.5.3 Agricultural Research and Extension Linkage

Historically, there has been a weak linkage between extension and agricultural research, which is coordinated by the Institute for Agricultural Research. For example, extensionists have not been formally involved in IAR's on-farm research activities. The number of forums or appropriate publications where research information is passed to the extension worker has been limited. There have been few attempts by extensionists and researchers to collect farmer feedback concerning newly introduced technologies. In 1986 the Research and Extension Liaison Committee (RELC) was formed with members representing both IAR and MOA. Although active in some sites, it has not been effective in others. With a new reorganization of the regions and MOA, perhaps RELC will have more of a role in linking the researcher, the extensionist, and the farmer. Farming practices, in spite of extension advice, have remained traditional and relatively unchanged over past years. Many argue that there has been little

incentive to change, given the policy environment and land tenure structure both before and after the revolution.

Farmers may plow the land anywhere from two to six times before seeding depending upon the crop to be sown, the soil type, and rainfall. In the highland areas, tef is given priority, and because of its small seed and stature needs a carefully prepared seedbed. Cereal crops, especially tef, are given priority for receiving inputs, e.g., fertilizer, pesticides, and labor. Weeding is usually done by hand, less frequently with a hoe, or by slashing. Herbicides have not been readily available, although the farmer demand in some areas has been high, because of the government's decision to concentrate foreign exchange allocation on items other than herbicides, for which it feels hand labor can be substituted. As a result, weeding is one of the farmer's major problems in many crops. Many crops are broadcast rather than row seeded, a practice that the farmer feels justified in using because it is faster and because inputs such as fertilizer are generally not used (row planting facilitates application of inputs). Most farmers do not use intercropping and farming generally tends to be extensive rather than intensive (Stroud and Mekuria, 1992).

2.5.4 Experiences in Integrated Rural Development

In 1967 the first integrated rural development project in the country was launched in Chilalo district (Arssi region) known as the Chilalo Agricultural Development Unit (CADU). The project was designed to stimulate agricultural change by concentrating resources in high potential areas to provide all the

necessary ingredients in an integrated manner. Chilalo was chosen (from several proposed sites) because of its favorable farming conditions and availability of transport and marketing facilities. CADU was jointly financed by the Swedish and the Ethiopian governments. The main objectives of CADU, as stipulated in the agreement, were: 1) to bring about economic and social development in the district; 2) to give the local population an increased awareness of and responsibility for development work; 3) to verify methods of agricultural development; and 4) to train staff not only for the project itself but for other similar efforts. It was agreed to introduce only intermediate technologies appropriate for small farmers.

CADU provided a combination of different services that were believed to enhance productivity. Its primary functions were: 1) to carry out adaptive research on crops and livestock; 2) to supply inputs; 3) to disseminate proven technologies; 4) to provide credit and marketing services; 5) to promote soil and water conservation and forestry; 6) to develop improved farm implements; and 7) to improve health services.

The amount of resources required to undertake all these activities was clearly enormous and the project was heavily dependent on the generous assistance of the Swedish government. In 1976, the operation area of CADU was expanded to cover the whole of Arssi, it was hence renamed the Arssi Rural Development Unit (ARDU). The project continued to assist 50% of the total fertilizer distribution in the peasant sector of the country. Between 1968 and 1973, cereal

yields doubled for farmers using fertilizer and improved seeds. The gain in wheat yield was particularly significant. It increased from an average of 7 quintals/ha. in 1966 to 16.3 (232%) in Chilalo, 13.3 (190%) in Arba-Gugu and 12.8 (183%) in Ticho awraja (district) in 1981. On the project's own seed farm, wheat and barley yields were as high as 40 quintals in 1981. The potential for further increase is evident from the wide yield gap between the seed farm and the peasant farms, nearly three times higher on the former. With improved management practices, the peasant sector could easily double or even triple its output.

Arssi has increasingly become a major regional contributor to the national marketed surplus of cereals. In 1986, the share of Arssi in the total planned cereal purchase of AMC was 31%. The AMC used to impose a fixed amount of grain be supplied to it by each region and each farm household had to deliver the required amount. A total of 1.78 million quintals was imposed on the farmers of the region, the highest per capita quota share in the country. The rising grain quota sharply contrasted with the fall in yield levels.

New innovation in the livestock sector took the form of upgrading local breeds through crossbreeding with Friesian and Jersey breeds. It is estimated that more than 1,750 crossbred heifers were sold to farmers between 1967 and 1981. The average milk yield of a crossbred cow is reported to be 6 to 10 times more than the average local cow. Few other parts of the country have had access to such improvement opportunity. Significant progress was also made in the

construction of rural roads and water bore holes. As of 1981 a total of 330 kms of roads were built and about 126 bore holes were dug to supply water for home and animal consumption. CADU/ARDU's attempt to introduce new farm implements was not, however, successful. Few of the improved ploughs, barrows and ox-drawn carts were adopted. The implements were heavy (for being pulled by oxen), costly to repair and expensive to buy. Further research was not undertaken to make the implements lighter and cheaper. The contribution of the project in forestry research and soil and water conservation was also minimal⁷.

2.5.5 Constraints in Project Activities

A major problem in reaching small farmers before 1975 was the land tenure system. Many of the small farmers were tenants of absentee landlords. The share of the landowners varied from one-third to half of the total produce. There was a further levy of one-tenth of the value of output, free labor and various kinds of tributes by the landlords. The tenants were unable to benefit from the increasing yields, resulting from the use of new inputs, as land rents increased in many places. The proportion of tenants in Chilalo was estimated at about 52% of all farmers. For many peasants, the threat from commercial farming was more serious than the rise in land rents. Several small farmers were forced to leave their land as many landlords, motivated by the CADU's demonstration of technologies and government subsidy for agricultural machinery, started to buy

⁷Cohen (1987) gives an excellent analysis of the evolution, achievements and the constraints of CADU-ARDU.

tractors or sell/rent their land to commercial farmers. It is estimated that as many as 5,000 tenant households or 20,000 people were evicted from Chilalo during the period from 1968 to 1974. The absence of written leases meant that the tenants had no protection against arbitrary sudden eviction. Government officials who were landowners themselves offered little help to improve the condition of the small farmers.

Another factor that adversely affected the use of new technology in the early years of CADU/ARDU was low and fluctuating grain prices. With less than 10% of the population living in the urban areas, the demand for grains failed to keep up with the increase in production. The project attempted to raise and stabilize prices through its marketing division. But, the volume of grain handled was too small to make a significant contribution.

The land reform legislation of 1975 resolved the problem of tenancy in Arssi. Tenancy was abolished and peasants were freed from all kinds of obligation to the landlords. Many evicted tenants were able to return to their old villages and farmland. But the reform was not accompanied by improved provision of farm inputs and better output prices. The emphasis of CADU/ARDU changed from technical farming problems to activism and social mobilization. In 1986, about 20% of the farmers in the region were members of cooperatives. The proportion is nearly six times the national average. Research and technical innovation were neglected. The resources (staff, vehicle and finance) of the project were used to promote cooperatives and assist political and fund-raising campaigns, and

collection of compulsory quota and national contributions. Most of the experienced professionals left the project.

The number of varieties released by the research department of CADU/ARDU declined from ten during the period of 1967-74 to only four during 1975-83. The number of barley varieties released fell from six to just one during the same period. Most of the new varieties were abandoned in the early 1980s. CADU/ARDU was unable to replace old seeds that had outlived their genetic potential and became susceptible to disease.

The contribution of CADU/ARDU is also undermined by unfavorable input-output price relations. The introduction of compulsory delivery quotas and price control has left the farmers without incentive. A quintal of fertilizer costs the equivalent of 2.7 quintals of wheat in the 1980s, compared to 1.5 quintals in 1971/72.

The marketing services of the project was taken over by the Agricultural Marketing Corporation (AMC) in 1976. In order to ensure complete monopoly of the grain trade by the AMC, all grain merchants in Arssi were banned and movement of grain by individuals made illegal. With no large markets to generate sufficient demand, the open market price in the region has been depressed. According to a recent survey, which covered three major grain supplying administrative regions in 1985, AMC quotas are exceptionally high in Arssi.

Arssi is one of the most fertile regions and one of the least drought-affected areas in the country. The inhabitants of the region have benefited from the Green Revolution technologies introduced by CADU/ARDU. The region is a major supplier of grain to the national market. But development has ceased in recent years because of inadequate resource allocation, low prices, excessive quotas, and disruptions arising from the rapid pace of agrarian transformation.

2.6 Summary

Chapter 2 reviewed the agricultural sector and presented the production potential in the different regions of Ethiopia. The agrarian structure resulting from three different policy eras are discussed. The three major agricultural policy eras are: the Imperial period until 1974, the agrarian socialism period under the Marxist military regime (1974-91) and the current transitional period (1991-present) under the Transitional Government.

Efforts to build a national capacity in technology generation and transfer by the IAR and the extension service are also discussed. The problems related to research and extension linkage and the institutional arrangements made to rectify these problems are briefly presented.

Ethiopia has experienced different kinds of agricultural development strategies with varying degrees of success and failure. The CADU-ARDU experience in integrated rural development, technology development and transfer are reviewed this chapter. In spite of the socio-political problems of the Ethiopian

economy, the experiences of the integrated rural development project have been positive.

In light of this, the study examines technology adoption issues related to wheat production in Arssi, the home of the first integrated rural development project in Ethiopia. The lessons learned from the project have significantly contributed to the design of smallholder agricultural development strategy.

CHAPTER 3

CONCEPTUAL FRAMEWORK, LITERATURE REVIEW AND RESEARCH DESIGN

3.1 Conceptual Framework of Technology Adoption

Agricultural technology includes one or more of the following aspects: mechanical (tractor plowing, harvesting), biological (high - yielding varieties), chemicals (fertilizers, pesticides) and management methods (optimum agronomic practices). The technology may consist of a package of several components which may be adopted simultaneously or independently depending upon whether the specific practice is complementary or not. The technologies can be considered divisible (eg., hybrid seeds, fertilizers, pesticides, etc.) and non-divisible or lumpy (eg., tractor, mechanical harvesters, etc.). Most countries have attempted to encourage the adoption of new technologies in order to increase factor productivity in their agricultural sector assuming that increases in the productivity of scarce resources such as land and labor will increase aggregate output.

At the conceptual level, the adoption of technology is represented as an upward shift in the production function. A shift in the production function will increase both the marginal and average product of the variable input.

The terms "new technology" and "innovations" are used interchangeably in much of the literature. Rogers (1983) makes a distinction between adoption and

diffusion. Adoption refers to an individual decision to use a new practice on a regular basis and is synonymous with intra-firm diffusion (Stoneman, 1983).

Diffusion often refers to the communication of ideas which are not necessarily accepted and implemented whereas adoption always implies the acceptance and implementation of new ideas and practices. Adoption follows sequential and/or overlapping stages of awareness, evaluation, trial and final adoption. Moreover, different groups of farmers adopt innovations depending on their varying amounts of human capital. Schultz (1975) contends that when new technologies are introduced at the farm level, resources are not utilized efficiently by the farms and disequilibrium exists in the firm. A new equilibrium can be obtained only through the process of learning. With this contention, Feder et al. (1985) define farm-level final adoption as the degree of use of new technology in long-run equilibrium when the farmer has full information about the new technology and its potential.

Farmers may not achieve full adoption of a package of improved technology in the short run, because it often takes time for farmers to experiment with one or more components of a technological package. Adoption may be at the aggregate or farm level. Aggregate adoption involves the spread of an innovation within a region and is measured by the aggregate level of use of a specific new technology

within a given geographical area. The farm-level adoption involves adoption by individual farmers.

3.2 Technology Adoption Studies

Several studies have empirically established the strategic role of technological innovation in economic growth (Manning 1984). Moreover studies conducted by Herdt (1984), Sanderson (1984), Thomas (1982), Paulino & Mellor (1984), and Ruttan (1986) have shown that new agricultural technology is a major source of agricultural development in the Third World. The role of technology in achieving a sustained increase in food production in Sub-Saharan Africa is documented by Herdt (1988), Delgado et al. (1987), and Eicher (1990).

Griliches' study of hybrid corn adoption (1957) and other diffusion studies in the U.S. indicate that the proportion of farmers adopting a new technology usually follows an S-shaped path, with the proportion of adoption on the vertical axis and time on the horizontal axis. Griliches approximated these S-shaped paths with logistic functions, then estimated the relationship between the logistic function parameter corresponding to the rate of adoption and various profitability variables. The study, however, did not reveal why producers did not adopt technologies immediately, even if profitable.

Studies of technology adoption in different LDCs have identified several specific sets of explanatory variables: farm size, tenancy, human capital, capital, labor availability, profitability, public policy and socioeconomic variables. Akinola and Young (1985) and Akinola (1987) in their study of adoption of tractor hiring

services schemes in Nigeria found farm income, family labor size, information and distance to input supply points to be the explanatory variables.

In their study of farmers' step-wise adoption of technological packages for barley in Mexico, Byerlee and de Polanco (1986) found that initial capital required, risk and uncertainty associated with rainfall and output prices were crucial in farmers' adoption decisions. Based on these factors farmers followed a step-by-step-adoption process over a five year period of time. A study by Jansen et al. (1990) confirmed that the adoption of coarse cereals in India was mainly affected by infrastructural and environmental (agro-climatic) variables. Jarvis (1981) studied the adoption of improved pasture techniques in Uruguay, pointing out that profitability of the innovation is not constant as is assumed in most logistic function analysis but is a function of varying livestock prices.

ILCA's recent study of technology adoption in Ethiopia investigated the adoption of ILCA's single-oxen technology, fertilizer and pesticides and found that farm size and farming experience were the most important variables explaining farm adoption (Kebede et al. 1990). A recent study on the economics of wheat production in the Sudan revealed that limited access to inputs has restricted the adoption of wheat production technologies. Farmers that have access to inputs delivered by the private sector have faster adoption rates than farmers getting inputs from government controlled distribution systems (Hassan and Faki, 1993).

Although farm and farmer specific factors are considered crucial in influencing adoption, a recent study on the adoption of modern mangrove rice

varieties in West Africa indicated that these factors were not significant in determining adoption. Farmers' perception of the varietal characteristics were the major factors determining adoption of the rice varieties (Adesina and Zinnah, 1993).

Two alternative paradigms have been used to explain adoption lags. Rural sociologists have used a communication network or epidemic model, while economists have used a learning process model. The difference between the paradigms is that adoption in the first model occurs when the farmer gets the information from the right messengers. In the second model the farmer combines information with previous information and evaluates it with respect to the probability of favorable outcomes and his/her decision rules.

The question of why farmers do not adopt profitable new technology immediately has been investigated by numerous social scientists. Studies of the adoption of agricultural innovations in the Third World have shown that immediate and uniform adoption of innovations in agriculture is quite rare (Feder et al. 1985, Byerlee and de Polanco, 1986). In most cases adoption behavior differs across socioeconomic groups and over time.

Preliminary studies have shown that farmers in Ethiopia have been very reluctant to adopt simple recommendations such as high yielding varieties and fertilizers for a number of years. The yield gaps between research stations, on-farm trials and farmers' fields are as high as five and three folds to one. The possible explanations for the slow adoption of improved technology by farmers

include lack of credit, lack of location specific research recommendations, poor extension service and rural infrastructure and repressive pricing policies. This large and diverse list of constraints has to be examined to identify the most limiting ones and to determine their relative importance. It is also important for policy makers to know these critical factors for efficient allocation of the country's meager resources for research and development programs. Furthermore, national research and extension services need to understand factors that induce or inhibit the adoption of technology.

Many of these studies provided evidence to support that:

- a) the Sigmoid diffusion curve approximates a cumulative normal distribution curve,
- b) different categories of adopters have differing adoption lags,
- c) adopters have different sources of information;
- d) demographic and education characteristics are important;
- e) relative profitability, complexity and riskiness of the innovations have significant effects on adoption rates and lags and
- f) environmental factors influence adoption or no adoption of new technologies.

3.3 Research Design and Methodology

3.3.1 The Study Area

Arssi Administrative Region is located in the southeastern highlands of Ethiopia and covers an area of about 24,000 sq.km.. It is the smallest (in land size) of the 14 administrative regions of the country⁸. It is made up of twelve districts (awrajas). The bulk of the landmass is highland with elevation of over 1,500, above sea level. Most districts receive sufficient rainfall, over 900 mm per year. The rainfall pattern is bimodal, with the small rainy season in February-April and the main season in June-September. The amount of rain increases with altitude. Soil characteristics vary from acidic, clay and low phosphorus content in the highlands to mildly alkaline, sandy loam and medium phosphorus levels in the lowlands. The region is generally regarded as one of the most fertile in the country. Unlike in the northern parts of the country, the soil has not been severely exhausted by over-cultivation.

According to the 1984 census, about 1.7 million people live in Arssi and 92% of these are rural. It is estimated that 57% of the inhabitants are Moslem and 43% Christians. The ethnic composition consists of Oromos, Amharas and other minority groups.

⁸ In the mid 1980s a new regional classification was issued by the Military government, based on ethnic, linguistic and agro-ecology resulted in 29 administrative regions and five autonomous regions. This was again changed by the new Transitional Government to 14 ethnic/nationality based regions.

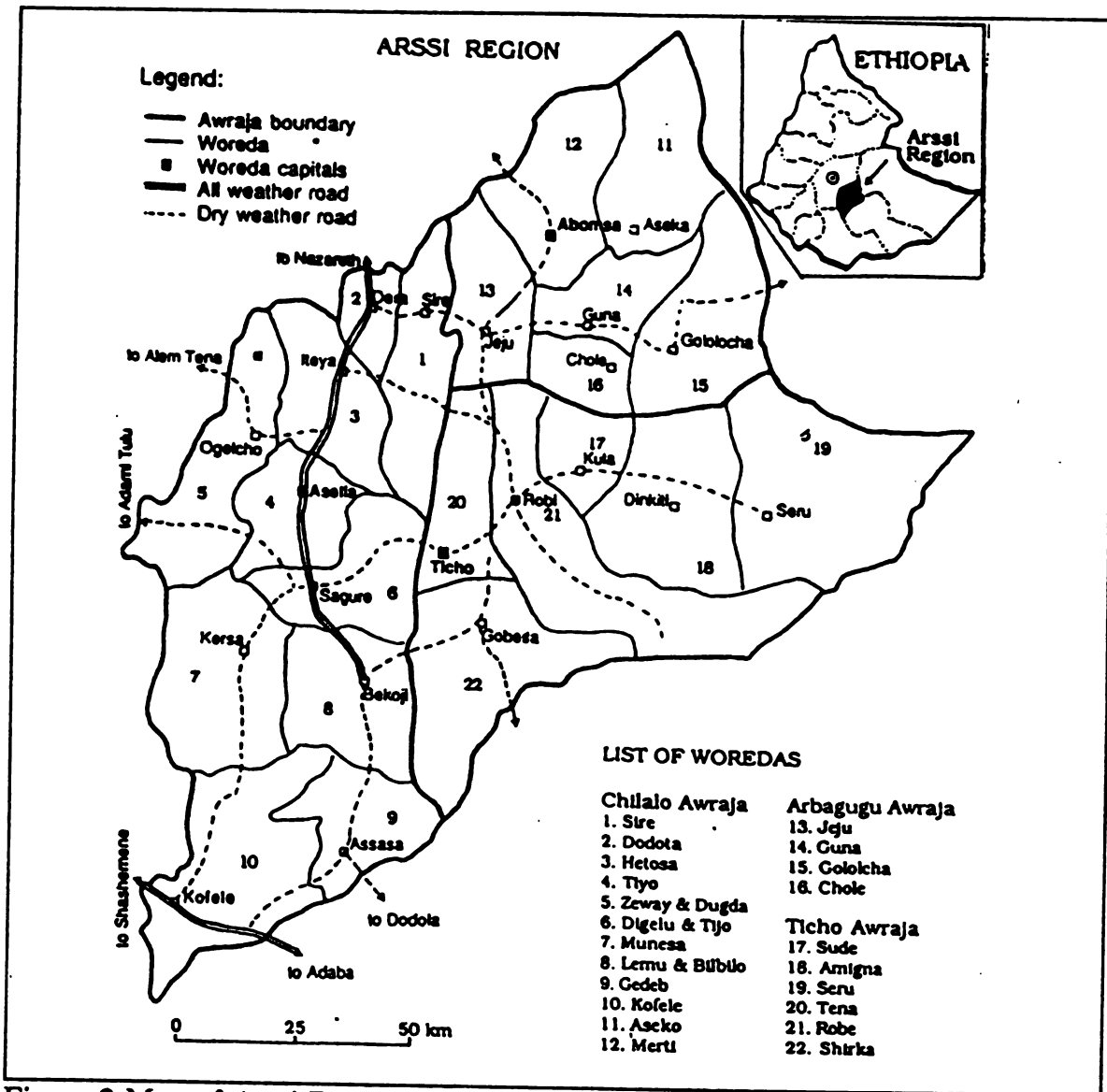


Figure 2 Map of Arssi Region

3.3.2 Crop Production

Crop cultivation is the primary occupation of the rural population. The major cultivated crops are barley, wheat, pulses, tef, maize, sorghum and oil crops. Wheat and barley are grown in most altitudes and account for about 40% of the cultivated area. Maize and sorghum are grown at the lower and medium altitudes. The total arable land in Arssi is about 504,414 hectares with a per capita holding of a little over 2 hectares. Nearly all farmers keep some livestock which serve as a source of draught power for cultivation, additional income and home consumption.

3.3.3 Farmers' Organizations

All farmers are members of peasant associations (PAs). There are 1,0349 PAs with 243,224 household members (1986). All PAs belong to service cooperatives (SCs) totalling 163 in the region. These cooperatives are active in the distribution of some consumer goods and farm inputs and handle grain quota deliveries for the state owned Agricultural Marketing Corporation. The number of producers cooperatives (PCs) was reported to be 409 with a total membership of 37,242 households in 1989 (Arssi Agriculture Dev. Dept., 1989).

The Ministry of State Farms maintains a heavy presence in the region. The Arssi Agricultural Development Enterprise runs six state farms with a total cultivated Area of about 36,000 hectares. Wheat and malt barley are the major crops grown.

3.4 Survey

3.4.1 Locations and Sampling Methods

Multistage sampling was used for the study. First, five of the twelve districts in the region were identified as major wheat producers and included in the survey. The remaining seven districts are either marginal wheat growers or they are not suitable for wheat production because of their agro-ecology. Each district is served by a number of Rural Development Centers (RDCs) depending on the size of the farming population in the district. Each RDC has categorized its PAs into high, medium or low wheat producers. The second stage was to select a sample of PAs based on their productivity from each of the five districts. Five or six PAs per district (2 high, 1 medium and 2 low producers) were identified.

Table 3.1 Peasant Associations and Household Heads Interviewed in the Farmer Survey in Arssi Districts, 1990/91.

District	Number of PAs	PAs Selected	Number of Households Interviewed
Keleta	156	6	100
Chilalo	87	5	82
Galema	107	5	97
Gedeb	107	5	74
Ticho	93	5	99
Total	443	26	452

Source: Field Survey, 1991.

This stratified sampling was based on representativeness and accessibility of the PAs. The assistance of local extension agents in the selection process was critical. A proportional sample of household heads was randomly selected from each sample PA (15-20 Households, HHs per PA). A total of 26 PAs and 452 HHs were selected for the survey and 426 questionnaires are used for the analysis. Table 3.1 indicates the distribution of PAs and HHs in the survey districts.

3.4.2 Questionnaire Preparation and Enumerator Training

Since several farm surveys have been conducted in the region, it was possible to prepare a relevant questionnaire in a short period of time. Questionnaire pretesting was done to modify some of the questions.

Enumerators from the study districts were available for employment and subsequent training. All ten enumerators were students of the Alemaya University of Agriculture which was closed because of the political changes the country was going through. The questionnaire was designed to collect data on farmer characteristics, farm resources, production practices, particularly on the adoption of HYVs, fertilizers, herbicides and other recommended crop production practices. Farmers' opinions on the technologies were asked. Respondents were asked to identify availability, purpose and sources of credit. Extension contact, frequency of visits, and different kinds of farmer training programs and field days are some of the mechanisms through which farmers get access to modern production technologies. Farmers were also asked to identify the institutional support, marketing arrangements and off farm employment opportunities. Information on wheat quantities produced, sold and retained, number and value of oxen, cows and sheep for each respondent was collected. However farmers were reluctant to release information related to their income or wealth status. The enumerators asked if the respondent was willing to disclose such information.

3.4.3 Data Collection

Data used for this study was collected during the eight-month field work undertaken in February-September 1991. Available published data are used to understand the smallholder production practices in the region. The National Wheat Research Center, Kulumsa is located in Chilalo district and has substations

and trial sites in the other four districts. Information from the on-farm trials are used to assess the profitability of the recommended technologies. Previous Farming Systems Research surveys are used as background information for this study. CADU/ARDU publications gave a historical perspective on pilot integrated rural development in Ethiopia. Other statistical information on agriculture in Ethiopia and particularly in the study areas is used for describing the farming systems. The regional planning office has published statistical abstracts for the 12 districts.

3.5 Summary

This chapter presented the conceptual framework on technology adoption and reviewed the literature. Chapter 3 also presented the survey methods used to collect primary data for the study.

The types of agricultural technologies (mechanical, biological, chemical and management methods), the distinction between adoption (an individual decision to use a new practice on a regular basis) and diffusion (communication of ideas which are not necessarily accepted or implemented) are mentioned.

Studies in LDCs have attempted to explain why producers do not adopt profitable technologies. The factors responsible for adoption or no adoption of technologies vary across countries, regions, farms and the kinds of enterprises (food or cash crops) under study. Various studies have documented that economic, social, institutional and environmental variables as well as technology specific characteristics influence farmers' adoption decisions.

During the 1990/91 crop season the field survey was conducted in five major wheat producing districts (Keleta, Chilalo, Galema, Gedeb and Ticho). From a total of 443 peasant associations in the five districts 26 were selected for the survey. A total of 426 household heads were interviewed. Data on farmer characteristics, farm resources, production practices, adoption (incidence and intensity) of wheat varieties, fertilizer and herbicide and farmers' perceptions of recommended technologies was collected. The questionnaire used for the study is presented in appendix 1.

CHAPTER 4

SMALLHOLDER WHEAT PRODUCTION IN ETHIOPIA

4.1 Introduction

4.1.1 Wheat in Ethiopian Agriculture

Ethiopia is the largest wheat producer in Sub Saharan Africa with an average annual area of 687,000 ha. which is half of the total area (1.3 million ha) under wheat in the region. Total wheat production for the period 1990-92 was 886,000 tonnes/year which is 41 percent of the regional total production. The Sudan and Zimbabwe rank second and third with 661,000 and 222,000 tonnes per year, respectively (CIMMYT, 1993). National average wheat yield for recent years is about 1.3 t/ha compared to 1.7 t/ha yield for the rest of Sub Saharan Africa.

In Ethiopia, wheat is the fifth most important cereal crop, in both area and production, grown using traditional varieties and practices. In other African countries it is of most recent introduction and is grown using improved varieties and production practices. The most important wheat growing areas of Ethiopia are the highlands of the central, southeastern and northwestern regions of the country. Wheat is grown at altitudes ranging from 1700 to 2900 meters, and rainfall in these areas is bimodal and varies from 600 to 2000 mm. Although the possibility for irrigated wheat production in the Rift valley has been explored, currently all wheat is produced under rain fed conditions. Most of the wheat is

grown during the main rainy season of June to September. In areas where the short rains of March to May are adequate farmers have the opportunity to produce two crops of wheat.

The two major wheat species grown in Ethiopia are durum and bread wheat. Ethiopia is the center of origin and diversity for durum wheat which accounts to 60% of the total wheat area in the country. Bread wheat has been introduced recently and covers 40% of the total wheat area.

Table 4.1 Production, Consumption and Research Investment Indicators for Selected Wheat Producing Countries in Sub Saharan Africa, 1983-92

Indicators	Ethiopia	Kenya	Sudan	Tanzania	Zambia	Zimbabwe	SSA ^a
Area Harvested, 1990-92 (000 ha)	687	102	368	46	14	41	1,308
Yield, 1990-92 (t/ha)	1.3	1.9	1.8	1.7	..	5.5	1.7
Production, 1990-92 (000 t)	886	195	661	76	..	222	2,160
Growth rate Yield 1983-92 (%)	2.8	1.4	5.3	3.3	..	-0.7	3.7
Growth rate Production 1983-92 (%)	3.2	0.1	21.4	1.6	..	4.8	7.0
Wheat area as % of total cereal area 1990-92	13	6	6	2	2	3	5
Growth rate of per capita consumption 1983-91 (%/yr)	3.5	-0.1	4.9	0.0	-10.0	6.5	2.6
Percent area under modern wheat varieties, 1990	12	100	95	100	100	100	47
Number of wheat varieties released, 1966-90	35	34	8	16	14	25	138
Number of full-time wheat improvement researchers, 1992	13	4	2	..	5	1	27
Farm price of wheat, 1991-92 (US\$/t)	338	196	..	..	233	195	..
Fertilizer applied /ha of arable land, 1988-90 (kg nutrients/ha)	6	47	4	14	17	57	10

Source: CIMMYT 1992/93 World Wheat Facts and Trends. The Wheat Breeding Industry in Developing Countries: An Analysis of Investments and Impacts.

^aSSA refers to Sub Saharan African countries and the figures are aggregates for major and minor wheat producing countries.

Table 4.2 Wheat Area, Production and Yield by Farm Types in Ethiopia, 1986

Sector	Area		Production		Yield (t/ha)
	'000 ha	%	'000 t	%	
Smallholders	527	82	585	76	1.11
Producers' cooperatives	49	8	53	7	1.08
State farms	63	10	129	17	2.04
Total	639	100	767	100	

Source: CSA 1987

Wheat is produced by three types of farms in Ethiopia: smallholders, state farms and producer cooperatives. Government policy changes since 1990 have resulted in the dismantling of producer cooperatives. Smallholders account to 82% of the total wheat area producing 76% of the total wheat harvest with an average yield of 1.1 t/ha. Table 4.2 reveals the relative contributions of the three types of farms in wheat area, production and yield.

4.1.2 Regional Production Trends

Wheat is produced in different parts of the country and the expansion of state farms⁹ (1979-81) coupled with improved wheat production technologies have

⁹ The majority of the State farms are commercial farms nationalized in 1975. The total area under the state farms in 1975/76 was 64,000 ha expanded to 222,000 ha in 1983 and 214,000 ha in 1988. About 70 % of their farm land is under cereal crops (3% of the total cereal crop land) and the remaining are planted with cotton, fruits and coffee (Mirotschie and Taylor, 1993). The farms received 76 % of the fertilizer, 95% of the improved seeds and 80% of the credit in 1983 (Cohen and Isakson, 1988). There are eight state farms in Arssi cultivating 33,974 ha and producing 654,504 quintals of different crops annually. Wheat and barley cover about 75 of the total area of the state farms in Arssi (Arssi Regional Atlas, 1990).

contributed to the concentration of production in the southeastern and central highlands. Durum wheat is mainly grown in the other zones where the vertisols predominate.

Table 4.3 Ethiopia: Cereal and Wheat Area and Production by Regions (1987/88)

Highlands (Regions)	Area (^{'000} ha)		Production (^{'000} t)		% of cereal prodn.
	Cereal	Wheat	Cereal	Wheat	
Southeastern (Arssi-Bale)	606	237	895	341	38.1
Central (Shewa)	1272	218	1451	245	16.8
Northwestern (Gojam-Gonder)	1259	102	1280	92	7.2
Northeastern (Welo)	383	49	491	31	6.4
Eastern (Harerge)	327	14	368	18	5.0
Western (Welega-Kefa-Illubabor)	817	25	1085	25	2.3
Southwestern (Sidamo-Gamo Gofa)	375	14	503	27	5.4
Total	5039	659	6073	779	12.8

Source: CSA 1988.

Table 4.3 indicates that about 75% of the wheat produced in the country comes from the Southeastern and Central highlands and these regions constitute 69% of the national wheat area and have a share of 38% of the total cereal production in the country.

Figure 3 Map of Wheat Producing Regions of Ethiopia

4.1.3 Wheat Production, Area and Importance in Arssi

The major crops grown in Arssi are barley, wheat, faba bean, field pea, maize and sorghum. Oil crops such as linseed and rape seed are grown in some parts of the region. Cereal production has expanded at the expense of grassland and fallow land. From 1967 to 1980 area under wheat per farm increased from 16% to 27% while barley area remained unchanged (44%). Area under maize increased from 3.3% to 12% and Tef area increased from 1% to 5% and flax area declined from 12% to 2.5% for the same period. In general non-cereal crops area dropped from 33.8% to 9.8% (Bengston, 1983).

The large number of state farms operating in the region and increase in the proportion of wheat area in the smallholder sector have made Arssi region the largest wheat supplier to the Agricultural Marketing Corporation (AMC).

According to AMC's classification there are 210 wheat producing sub districts (woredas) in the country and 33 of these are surplus producing and 16 (48%) are in Arssi region (AMC, 1989). A 1980 survey by ARDU and 1984 by Dejene revealed 34 and 60 percent of the farmers in Arssi considered crop production as a major occupation. The same sources suggest that crop farming is the single most important source of cash earnings to Arssi farmers, particularly wheat followed by barley. In the high altitude areas of Arssi about 55 percent of the

cropped land is under wheat and barley and in the mid-altitudes and lower areas these crops occupy almost 71 and 34% respectively¹⁰.

The following table shows that wheat is the primary crop (55%) in the medium altitude areas and the second crop (38%) in the highland zone. Barley is a major crop only in the highland zone of the region.

Table 4.4 Relationship Between Arssi Ecological Zones and Crops Considered Most Important By Farmers

<u>Percent of Farmers Reporting Most Important Crops</u>						
Ecological Zone	Wheat	Barley	Tef	Sorghum	Maize	Others
Highland	38	40	8	0	4	10
Medium Altitude	52	6	20	11	0	11
Lowland	4	4	0	44	48	0

Source: Dejene Survey, 1984.

¹⁰ According to IAR/FSR study in Chilalo district, nearly 96 and 93% of the farmers in the high altitude zone grow barley and wheat, respectively and in the medium altitude zone all the farmers grow both crops (Chilot et al. 1989).

4.2 Crop Production Technology Use in Arssi

4.2.1 Integrated Rural Development and Technology Adoption

Farmers in Arssi have been using improved crop production technologies since 1967 when the CADU project became operational. During the early phases of the project land owners and progressive farmers benefited from the technologies. The then land tenure system had hindered the adoption of technologies by the small and tenant farmers in the region. Land owners and/or bigger farmers obtained significantly larger proportions of the benefits compared to tenants and /or small farmers. Fertilizers and improved seeds were given out by the project in direct proportion to area cultivated, i.e., a one-hectare cultivator was entitled to one quintal of fertilizer while a 20-hectare cultivator was entitled to 20 quintals of fertilizer (Tecele, 1973). As absentee landlords started to fully mechanize their farms and use improved technologies a substantial number of tenants were evicted.

Tables 4.5 and 4.6 present time series data on the volume of fertilizer and improved wheat varieties distributed to small farmers in the five survey districts of Arssi for the period 1975-1991. The data were compiled during the field research from different files at ARDU headquarters. A comparative analysis of the data reveals that the mean annual fertilizer use was the highest in Galema 18,338 quintals/year (31%), followed by Keleta 14,025 quintals/year (24%), Gedeb 12,318 quintals/year (21%), Chilalo 10,877 quintals/year (18%) and Ticho 4,812 quintals/year (8%).

Use of improved wheat varieties in the study areas showed different pattern. Gedeb has the highest annual use of improved wheat seeds; 1,969 quintals/year (29%), Keleta has 1,820 quintals/year (27%), Galema farmers used 1,242 quintals/year (18%), Chilalo used 1,229 quintals/year (18%) and Ticho had used only 621 quintals/year or 9% of the annual total distributed in the region during 1975-91 period. Farmers in Galema, the highest fertilizer users are third in the use of improved wheat and Gedeb farmers are first in wheat seed use but third in fertilizer use. This does not suggest that higher fertilizer use necessarily imply higher seed use or vice versa. However, Keleta, Chilalo and Ticho are second, fourth and fifth respectively in both kinds of input utilization. Districts with larger numbers of producers cooperatives received the highest share of the inputs. Although the aggregate time series data show the above trend, it is important to further investigate differences in input use across farmers in each district to establish a relationship between farmer-specific socioeconomic characteristics, their levels of input use and natural and institutional constraints.

Table 4.5 Amount of Fertilizer Distributed in Arssi Districts 1975-1991.

	Keleta	Chilalo	Galema	Gedeb	Ticho	Arssi Total
Year	Amount of Fertilizer(DAP) distributed in quintals					
1975	15510	17350	16109	6178	N/A	55147
1976	3796	7616	18881	3454	N/A	33747
1977	13429	10918	14607	8906	N/A	47860
1978	11212	7045	20529	5753	N/A	44539
1979	6819	7210	17941	17565	2661	52196
1980	8040	8022	17823	7259	2310	41796
1981	10503	8474	14583	12476	1882	47918
1982	9732	3775	14767	13078	1859	70211
1983	10214	6545	13588	9234	1795	41376
1984	11130	7132	18030	12930	4421	53643
1985	16645	8149	17860	10928	4244	57826
1986	9585	6029	10586	5533	1596	33329
1987	16806	10556	20703	16449	6692	71206
1988	25132	16944	26404	27140	9359	104979
1989	25086	10892	23354	18637	9360	87529
1990	22805	10741	23873	22169	11034	90622
1991	21988	10503	22107	11712	7002	73312
Mean	14025	10876	18338	12318	4812	59237

Source: Compiled by Author from ARDU files, 1991.

Table 4.6 Amount of Improved Wheat Seed Distributed to Farmers in Arssi Districts 1975-1991.

	Keleta	Chilalo	Galema	Gede b	Ticho	Arssi Total
Year	Amount of Improved Wheat seeds distributed in quintals					
1975	241	342	435	135	N/A	1153
1976	3256	1577	580	910	N/A	6323
1977	1491	3239	2430	4518	N/A	11678
1978	2334	332	1110	141	N/A	3917
1979	1045	989	1080	676	411	4201
1980	N/A	N/A	N/A	339	652	991
1981	246	189	855	5099	402	6851
1982	489	219	933	4453	399	6493
1983	704	N/A	306	4161	466	5637
1984	1868	826	114	2296	793	5897
1985	2910	4500	1964	886	468	10728
1986	1900	1300	1947	N/A	N/A	5147
1987	896	924	151	236	249	2456
1988	3075	1143	4049	5968	1055	15290
1989	3075	1143	3949	1345	1055	10567
1990	1460	1775	1210	2310	1400	8155
1991	5957	2396	N/A	N/A	729	9082
Mean	1820	1229	1241	1969	621	6735

Source: Compiled by Author from ARDU files, 1991.

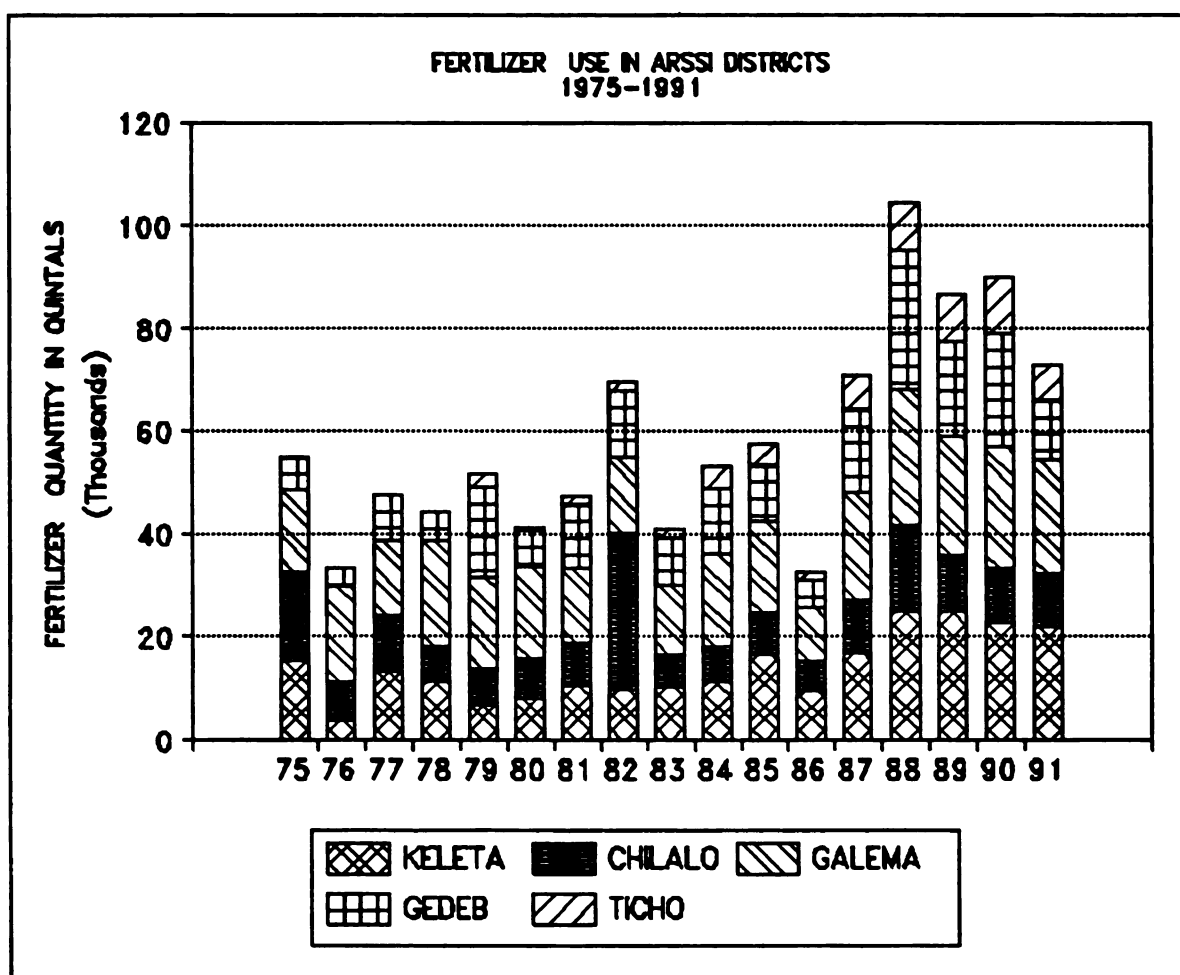
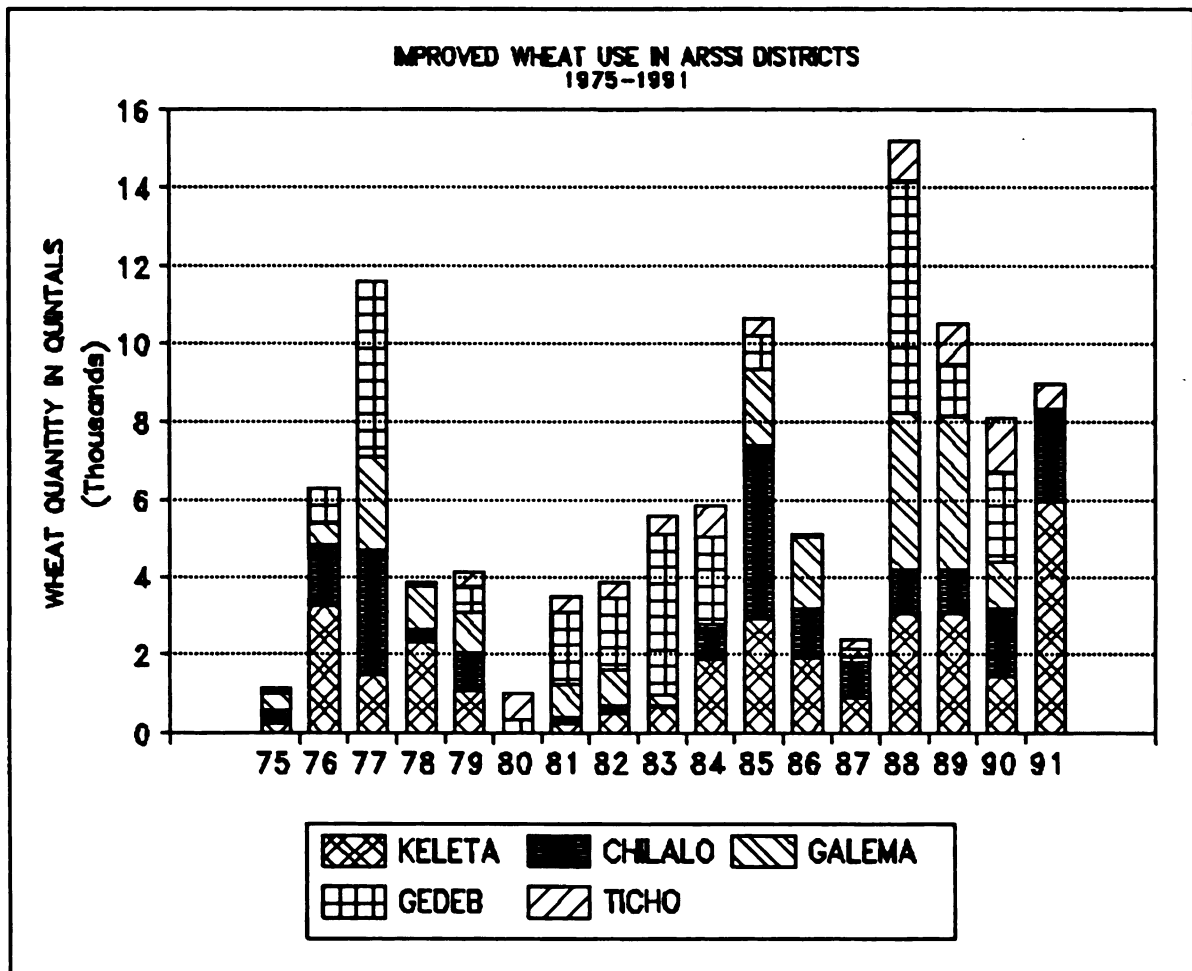


Figure 4 Fertilizer Distribution to Smallholders in Arssi Districts, 1975-1991



**Figure 5 Improved Wheat Seed Distribution to Smallholders in Arssi Districts
1975-1991**

The two graphs (Fig.4 and 5) illustrate that there was a moderate annual increase in the use of both inputs in the four districts except Ticho for the period 1975-78, and 1979-82 for all the districts. The period 1983-86 did not show a marked increase and 1986 and 1980 have the lowest amount of fertilizer and wheat seed distribution, respectively. In 1980 no wheat seed was distributed for three of the five districts.

In 1987 the government declared a new policy to attain food self-sufficiency by adopting an agricultural development strategy known as the Peasant Agricultural Development Program (PADEP). The program concentrates development efforts in selected high potential regions and districts to boost food production in a short period of time. Input distribution, extension service and adaptive research programs are to be directed to 153 districts selected that were identified as high grain-producing areas. A new agricultural marketing and pricing policy that removed the restrictions on private grain trade and a modest increase in farm gate prices for the major crops was instituted in 1988. As a result in the period 1987-1990 both fertilizer and improved wheat seeds distribution increased by more than 50% and 60% respectively in the five districts. The following sections describe farm level adoption of yield increasing inputs and farmers' perception and assessment on the usefulness and/or problems in using these yield increasing inputs.

4.2.2 Adoption of Commercial Fertilizer

Commercial fertilizers are widely used as 86% and 87% of the sample farmers in the region reported that they applied Diammonium Phosphate (DAP)¹¹ in their wheat fields in 1990 and 1991 crop seasons, respectively. The average level of fertilizer use for wheat was 63 and 64 kg per household in the two seasons. Table 4.7 indicates percent of farmers in each district who applied fertilizers on their wheat fields in 1990 and 1991 crop seasons, average amount used per household; number of years of awareness; number of years since first used; farmers' knowledge of recommended rate; assessment on fertilizer availability; average rate of fertilizer applied and percent area fertilized per farm. Categorical data were cross tabulated by districts and a Chi-Square test of significance was calculated. All variables show significant difference between the five districts at the 0.05 level. Values for the descriptive statistics of the continuous variable also suggest statistically significant differences between the study areas. The adoption of yield increasing technologies in Arssi is expected to be higher than in other parts of the country given the many years of integrated rural development programs of ARDU. A closer look at the rate of fertilizer application (kg/ha) across districts reveals that about half of the sample farmers in the region apply less than 50 kg/ha which is less than half of the recommended rate of 100 kg/ha DAP and 50 kg/ha of urea for mid altitudes and 150 kg/ha

¹¹DAP and urea are the two types of fertilizers distributed in Ethiopia. DAP is widely used in Arssi and Urea is used by less than 2% of the farmers.

DAP and 50 kg/ha urea for higher altitudes. The average rate of DAP application on wheat is 71 kg/ha (1990) and 72 kg/ha (1991) and ranged from 7 to 200 kg/ha among the sample farmers.

Table 4.7 Use, Experience and Farmers' Knowledge of Fertilizer in Arssi Districts.

	Keleta	Chilalo	Galema	Gedeb	Ticho	Arssi
Fertilizer use % of farmers	87	97	87	83	78	87
Average Use kg/hh	66	85	65	65	39	63
Awareness mean years	18	20	19	18	15	18
Number of years used	14	18	16	15	11	18
Use fertilizer yearly % farmers	69	89	85	76	51	73
Knowledge of recommended rate % of farmers	69	78	89	75	77	78
On time availability of fertilizer % of farmers	0	44	26	48	51	32
Rate of application mean kg/ha.	67	82	82	60	65	72
% area fertilized mean per hh	64	68	44	43	55	55

Source: Field Survey, 1991.

Tables 4.8 and 4.9 present categories of fertilizer application rates and levels, and the percent of farmers in each category by districts.

Table 4.8 Percent of Farmers in Different Fertilizer Application Categories, 1990-1991.

	Keleta	Chilalo	Galema	Gedeb	Ticho	Arssi
Application Rate kg/ha.	Percent of Farmers					
less than 25	28	13	6	31	28	21
26 - 50	29	19	22	33	33	27
51 - 75	23	22	17	17	16	19
76 - 100	14	32	50	15	18	26
More than 100	6	14	5	4	5	7
Mean	68	82	81	60	65	72

Source: Author's Survey, 1991.

The data further illustrate the difference between the districts in the rate of fertilizer application. Almost 30% of the farmers in each of the three districts of Keleta, Gedeb and Ticho used very low rates of fertilizer, i.e. less or equal to 25 kg/ha. Only 11% of the farmers in Chilalo and 5% in Galema applied less than 26 kg/ha and 45 and 55% of them applied more than 75 kg/ha.

The two districts of Galema and Chilalo are the high production potential districts. Farmers have been aware of fertilizer for almost 20 years while more than 85% have been using fertilizer yearly (Table 4.7).

Table 4.9 Percent of Farmers and Fertilizer use Levels in Arssi, 1990-1991.

Levels of Application	Galema	Chilalo	Keleta	Gedeb	Ticho	Arssi
Low 50 kg/ha or less	28	32	57	64	62	49
Medium 51-75 kg/ha	17	22	23	17	16	19
High more than 75 kg/ha	55	46	20	19	22	32

Source: Field Survey, 1991

Farmers in the three low level fertilizer user districts (Keleta, Gedeb and Ticho) have reported average years of awareness of 18, 17 and 15 years, respectively. Ticho has the least number of farmers using fertilizer yearly and it is not more than eleven years since farmers started to use commercial fertilizers.

Table 4.10 Adoption of Wheat Varieties, Average Area Planted, Seed Rate and Yield in Arssi Districts, 1990-1991.

Wheat Variety	District	% Farmers planting	Mean area planted ha/hh	Seed rate kg/ha	Yield kg/ha
Dashen	Keleta	63	0.71	210	1057
	Chilalo	34	0.59	232	934
Enkoy	Chilalo	66	0.62	231	1330
	Keleta	13	0.50	211	1217
	Galema	89	0.72	207	1441
	Gedeb	68	1.01	148	1068
	Ticho	65	0.49	192	805
Bulk K6295	Chilalo	18	1.06	155	1063
	Gedeb	29	1.86	148	1025
	Ticho	56	1.14	137	965

Source: Field Survey, 1991

4.2.3 Adoption of High Yielding Varieties of Wheat

The adoption of wheat HYVs in Ethiopia is limited as only 12% of the total wheat area in the country is planted to modern wheat varieties while in other major wheat producing countries in Sub Saharan Africa 100 percent of their total

wheat area is planted with HYVs (CIMMYT, 1993)¹². Use of the local wheat varieties, which are generally low yielding, have been identified as limiting constraint to increase wheat production in Ethiopia.

Table 4.10 depicts the adoption, average area, seed rate and yield of three bread wheat varieties in each district. The survey data indicates that the most popular variety grown by farmers in all of the 5 districts is Enkoy followed by Bulk-K6295 produced in 3 of the districts. Variety Dashen is grown in Keleta and Chilalo. Dashen, released in 1984, has been susceptible to diseases; farmers are no longer planting it in the high altitude areas. It is still widely grown in the mid altitude zones of Chilalo and Keleta. The widespread outbreak of yellow rust in 1988/89 almost wiped out the high yielding variety Dashen over a large area in Arssi and Bale regions (Debela, 1990).

Research station yield of 3810 and 4670 kg/ha for Enkoy and Dashen (Hailu, 1991) confirm that there is a potential for increased wheat production through the adoption of improved production technologies. Yields from a number of on-farm trials of four bread wheat varieties ranged 2099 to 2545 kg/ha (Dereje et al., 1990). State farms reported yields were 1450 and 1680 kg/ha for 1989 and 1990 seasons. Despite the widespread use of the three varieties, the yields reported by the respondents in the survey suggest that farmers are not getting more than 1.5

¹²CIMMYT 1992/93 World Wheat Facts and Trends data indicate that the major wheat producing countries i.e., Kenya, Tanzania, Zambia and Zimbabwe have about 100% of their wheat areas under improved varieties while in the Sudan and Ethiopia 95 and 12 % of their wheat fields are planted with HYVs, respectively. Ethiopia is the origin and center of diversity for wheat and most of the fields are under traditional wheat varieties.

t/ha¹³. Compared to the research station, on-farm trial and yields from the state farms the average yield for the sample farmers clearly indicate the presence of yield gaps. Further explanations of the factors responsible for the yield gaps is required.¹⁴ Table 4.15 shows that the variety Enkoy is grown by 89% of the sample farmers in Galema where the other two varieties are not grown at all. In Gedeb and Ticho districts this variety is planted by 64-70% and in Keleta by 8% (1990) and 18% (1991) of the farmers in each district. Bulk variety is popular in Ticho where 55-58% of the farmers are growing it, and in Chilalo and Gedeb 29 and 19% of the respondents have adopted it.

Mean area under these three varieties per household in each of the five districts for the 1990 and 1991 seasons ranges from 0.43 in Chilalo to 2.9 ha in Gedeb for Bulk. The seed rates range from 86 to 240 kg/ha. For most of the cases the seed rates are on the high side relative to recommended rates of 175 kg/ha for broadcast sowing. Farmers believe that higher seed rates will help the crop to out compete weeds and also minimizes the risk of poor germination for seeds purchased from the market or from own store. Table 4.11 reveals that the average quantity harvested per household for the region is between 613 and 812 kg/hh. Enkoy gave the highest mean production of 1001 kg/hh in Gedeb, and

¹³ It is expected that farmers under report their harvest for they are suspicious that government institutions might use the study to increase the agricultural tax burden. The reported harvested quantity and yield during the survey (0.8 to 1.44 t/ha) is hence under estimated at least by 25 %.

¹⁴ Yield gap 1 is defined as the difference between current yield at research stations and researcher managed trials and Yield gap 2 is the difference between yields obtained by farmers and yields from on-farm trials (Dillon and Hardaker, 1984).

Bulk gave the lowest quantity of 467 kg/hh in Ticho. Quantities sold and retained by each household are shown in the table and prices in Keleta are the highest (93 EB/q) and lowest in Ticho (57-60 EB/q). Most farmers used their own seed retained from previous years. The farmers in Ticho (11%), Galema (18 %) and Keleta (23 %) got their wheat seed from the MOA which is an indicator of the inadequate supply of improved seeds and subsequent low yields.

4.2.4 Adoption of Herbicides in the study districts

Smallholder agriculture in Ethiopia is characterized by the prevalence of many enterprises where crop and livestock systems dominate and compete for available farm resources. Farm operations in general and crop production activities in particular are labor intensive and compete for farm labor during the critical periods of weeding and harvesting. Farm families have to make rational decisions in allocating their limited resources between the different farm enterprises. Weed infestation has been recognized as a major constraint to wheat production both at smallholder and state farm sectors. The latter mainly use herbicides to control weeds in their large farms and most of the small farmers use hand weeding.

Surveys on weed control practices have revealed that farmers prepare a fine seed bed preparation to reduce weed infestation. A second practice, high seed rate, facilitates the establishment of a dense stand of wheat to compete with weeds. In many regions wheat fields remain unweeded or weeded very late during the crop cycle after the weeds have affected the crop stand.

Table 4.11 Average Quantity of Wheat Harvested, Sold and Retained, Farm Gate Prices and Seed Source in Arssi, 1990/91.

	Keleta	Chilalo	Galema	Gedeb	Ticho	Arssi
Quantity harvested						
Dashen	721	673				714
Enkoy	650	769	970	1001	411	812
Bulk		669		809	467	613
Sold						
Dashen	393	395				390
Enkoy	350	383	457	380	183	404
Bulk		281		377	184	284
Retained						
Dashen	553	571				561
Enkoy	550	517	711	758	389	614
Bulk		517		567	542	558
Price EB/q						
Dashen	93	76				88
Enkoy	93	66	69	64	57	67
Bulk		64		62	60	62
Seed bought- Kg	114	104	86	130	86	104
Price EB/q	117	90	39	90	95	93
Seed sources	Percent of Farmers					
MOA	23	41	18	30	11	23
Market	19	24	12	16	39	22
Own seed	56	32	69	55	47	53

Source: Field Survey, 1991

The farmers' explanation for suboptimal weeding include the following:
 shortage of labor, insufficient cash to hire labor during the peak flush of weed growth, intense rain fall which can limit the ability to enter fields and hand weed wheat, and the overlapping of the optimal time of weeding with other crops

(Tanner and Giref, 1991; Birhanu, 1983, 1985; Franzel and Mekuria, 1987).

Different research programs have addressed the weed control issue and identified recommendations of time and frequency of hand weeding, a combination of pre-emergence herbicides and hand weeding, pre-emergence and post-emergence herbicides to control different weed species.

Recently the economics of herbicides has been studied by economists in IAR. The objective of the studies is to verify whether family labor is a constraint during critical farm activities such as weeding. The government has been discouraging the use of herbicides by smallholders under the assumption that family labor is available for weeding. However the studies have confirmed that a) in terms of weed control cost per hectare, most of the herbicides cost less than labor, b) herbicides are more efficient and increase yield, c) they release labor for other crop production activities (Hailu, 1990).

Tab

6
1977
Dec
18
18
18
W
SP
1
1
H
C

Table 4.12 Farmers' Weed Control Practices in Arssi Districts, 1990/91

	Keleta	Chilalo	Galema	Gedeb	Ticho	Arssi
% Farmers applying herbicides						
1990	48	52	4	0	8	23
1991	42	21	13	7	19	21
Wheat area sprayed ha						
1990						
1991	0.75	0.96	0.94	2.00	0.57	0.89
	0.83	0.96	0.75	0.87	0.68	0.82
Herbicide cost EB/lit						
1990	28	26	32		15	26
1991	30	32	27		29	26
herbicides disadvantageous %						
Yes	39	43	13	4	13	23
No	61	57	47	96	87	77
Number of weeding % of farmers:						
	1990 1991	1990 1991	1990 1991	1990 1991	1990 1991	1990 1991
once						
twice	64 83	94 96	85 92	59 63	81 91	76 85
three times	29 14	6 4	15 8	38 37	17 6	21 13
	7 3			3	2 3	3 2
Weeding starts- Number of weeks after planting %						
3	30	19	12	20	15	19
4	43	36	44	55	41	43
5	18	28	20	6	17	18
6 or later	9	17	24	19	27	20

Source: Field Survey, 1991.

21-

Ab

be

an

G

w

(

P

Table 4.12 presents farmers' weed control practices in the study areas. Only 21-23 percent of the 426 households applied herbicides either in 1990 or 1991. About half of the sample farmers in both Keleta and Chilalo appear to use herbicides and few farmers have adopted in Galema, Gedeb and Ticho. Average area of wheat sprayed does not exceed 1 ha for most of the locations, except in Gedeb where one farmer sprayed his 2 ha field. The cost of herbicides depending where they get from varies from EB 26 to 32 per liter. Most of the respondents (60-90%) weed their fields only once and weeding starts three to four weeks after planting. Farmers in Chilalo and Galema tend to weed their fields twice and some farmers start the first weeding four and five weeks after planting. Studies in the region have found that the largest yield increases have been obtained with early hand weeding during the interval between 15 and 30 days post emergence of the wheat crop. The weed control practices of the farmers is expected to explain the yield differences between households.

4.3 Farmers' Perceptions of Yield Increasing Technologies.

In their recent study on technology characteristics, farmers' perceptions and adoption in Sierra Leone, Adesina and Zinnah (1993) discuss the three paradigms for adoption decisions: the innovation-diffusion, the economic constraint and the adopters' perceptions paradigms. They assert that farmers' perceptions of technology-specific attributes of the mangrove rice varieties are major determinants of farmers' adoption decisions in Sierra Leone.

imp

La a

tech

est

By

re

di

e

Farmers were asked to identify specific reasons or factors they consider are important in deciding to use or not to use fertilizer, wheat variety or herbicides. In addition they were requested to list the advantages or disadvantages of the technologies. Farmers' criteria for varietal preference were recorded as such information is indispensable for the design of farmer-oriented research programs. Byerlee and Franzel (1993), Mekuria et al.(1992) and Franzel (1992) have reported the contributions of farmers' feedback in influencing technology development and transfer and consequently improving the internal and external efficiency of the research system in Ethiopian agriculture.¹⁵

Farmers who have not used fertilizers indicated that unavailability and high fertilizer prices were the two most important reasons (32 and 24%) for not adopting. The same factors are identified contributing to lower rates of fertilizer applications. About 72 percent ranked unavailability of the inputs forced them use suboptimal levels.

The respondents recognized grain yield (97%) and straw yield (29%) and quality improvement (42%) as the advantages of fertilizers. Some farmers (10 and 17%) indicated that fertilizers damage or burn the crop and favors weed growth. Fertilizer use increases the demand for farm labor.

Less than a quarter of the respondents use herbicides in the region and those not using at all reported that herbicides are not available even if they want to

¹⁵ For detailed analysis refer to Mulugetta Mekuria et al (1992); Franzel (1992), Byerlee and Franzel (1993)

Table 4.13 Farmers' Assessment and Perceptions of Wheat Production Technologies in Arssi

	Fertilizer		Herbicide
	Not using	Lower Rates	Not Using
Farmers' reasons	Percent of Farmers		
Unavailable	32	29	58
Expensive	24	56	53
Late delivery	7	2	
Not heard of it	3		
Damages/ burns crop		5	
Not effective			
Others	32	9	

Source: Field Survey, 1991.

apply. Higher prices are considered as disadvantages of herbicides by farmers and are aware of the labor saving advantages (85%).

Farmers' selection criteria among available wheat varieties differs between farmers and regions of the country. Farmers give different weights to the grain color, size, taste in different foods or the price they receive in the local markets. In terms of production potential of the varieties, criteria includes higher yields, resistance to certain plant diseases and pests, height of the crop as residues are fed to cattle, earliness, weed competition and any other specific factors the farmers consider are important.

Table 4.14 provides information on farmers' criteria for varietal preferences in the study areas. About 75 and 84 percent of the respondents said their preference for Dashen and Enkoy is influenced by the high yielding attributes of the varieties. Half of the farmers who chose Bulk also indicated the yield as a major criteria. For Dashen farmers consider grain color (16%), and taste in bread as their first criteria. The second set of criteria indicated include grain color (31%), taste in bread (23%), taste in Injera (15%), higher prices (23%) and lodging resistance (8%). Enkoy's disease resistance ability (20%), lodging resistance (14%), earliness (10%), its taste in Injera and bread (25 and 15%) are the second group of criteria that farmers identified.

The variety Bulk has been preferred by some farmers for its disease resistance (9%), and its taste in Injera and bread (12 and 8%). Farmers' perceptions of the varieties are clearly indicated in their responses. Apart from the yield consideration farmers prefer Enkoy on its agronomic characteristics (disease and lodging resistance, earliness) relative to the other two varieties. Dashen has also gained popularity in its grain color, taste in Injera and higher market prices.

The development and transfer of wheat production technology requires that farmers' evaluation of recommended technologies and practices be included as important set of criteria in the planning stages of the research programs.

Subsequent sections of the study will examine the appropriateness and profitability of the technologies in order to identify adoption constraints.

Table 4.14 Farmers' Criteria for Wheat Varietal Preferences in Arssi

	Dashen		Enkoy		Bulk 6290	
Criteria	First	Criteria Second	First	Criteria Second	First	Criteria Second
Higher yield	74		84	3	55	
Disease resistance			1	20	9	
Lodging resistance		8	2	14	4	
Earliness			2	10	1	
Grain size				1	1	
Grain color	16	31		1	4	
Weed competition				2		
Taste in 'Injera'		15	2	25	12	
Taste in bread	10	23	2	15	8	
Higher price		23	1	5	3	
Other factors			6	5	3	

Source: Field Survey, 1991

4.4 Characteristics of the Households

4.4.1 Household Size and Labor Availability

The size of the household is an important variable which determines total labor available and the number of individuals the household has to supply necessary requirements such as food, shelter and clothing. Larger households put pressure on the household resources and at same time larger household size implies greater access to labor particularly during critical farm operations. Labor availability has been an important issue in the technology development and transfer. Several FSR studies undertaken by IAR researchers have concluded that despite larger family sizes (5-7 persons per family) in rural households, labor availability during weeding and harvesting is a major constraint in rural Ethiopia¹⁶. For the study region the average family size is 7.3 persons per household. Table 4.15 shows that 29% of the sample farmers have a family size of less than 5 while 58% and 13% of the households have 5 to 10 and more than ten members, respectively. There is no significant difference in family size across the 5 districts surveyed. It is expected that family size differences between households will explain the difference in production decisions that farmers make and it will be examined in subsequent chapters.

¹⁶ For detailed analysis of farm level constraints under different farming systems in western, north central, southeastern and semi-arid areas of Ethiopia, see Franzel and van Houten (1992).

Table 4.15 Family Size Categories by percent of Households in Study Districts of Arssi

Family Members	Keleta	Chilalo	Galema	Gedeb	Ticho	Total
Percent of Farmers						
Less than 5	8.2	4.2	7.3	4.7	4.5	28.9
5-10	12.5	10.1	12.5	9.2	13.4	57.6
Greater than 10	2.6	2.6	2.6	2.1	3.5	13.4
Mean Family size per HH	6.8	7.5	7.0	7.7	7.6	7.3

Source: Field Survey, 1991.

Table 4.16 Age Categories of Household Heads in Arssi Districts

Category	Keleta	Chilalo	Galema	Gedeb	Ticho	Arssi
Percent of Farmers						
15 -25	12.0	6.9	12.6	16.2	1.1	9.6
26 - 35	19.0	23.6	22.1	23.5	15.4	20.4
36 - 55	40.0	37.5	38.9	36.8	64.8	44.1
56 and Older	29.0	31.9	26.3	23.5	18.7	25.8
Mean HH age yrs.	44.5	47.5	43.8	43.0	47.8	45.3

Source: Field Survey, 1991.

4.4.2 Age Categories of Household Heads

About 65% of the sample farmers are in the age categories of 26-55 and a quarter of them are more than 55 years of age while close to 10% are young farmers under 25 years old. The mean household head age for the sample is 45 years. There is no significance difference in age categories between household heads across the districts.

4.4.3 Educational Levels of Household Heads

The country embarked upon a vigorous national literacy campaign in the early 1980s and succeeded in reducing the illiteracy rate from 80% to 35%. All high school graduates were required as a national service to participate in the literacy campaign for 4-5 months before the beginning of the next academic year. The campaigners were living in the rural communities and farmers associations were providing food and shelter while the Ministry of Education was covering transport cost and other teaching materials. The literacy data from Arssi indicate that 17% of the sample farmers are illiterate (percentage of population age 15 or older who cannot read and write a short simple statement about every day life). Half of the respondents have participated in the national literacy campaign while 22% have elementary and 10% of them have secondary level education. The literacy education was given in the local language of the area. According to the World Bank (1992) Ethiopia is in the 20%-39% category of its classification of illiteracy level.

Table 4.17 Levels of Education of Household Heads in Arssi Districts, 1990/91

Level	Keleta	Chilalo	Galema	Gedeb	Ticho	Arssi
Percent of Household Heads						
Illiterate	18.0	11.1	15.8	22.1	18.7	17.1
Literacy Campaign	47.0	51.4	49.5	35.3	65.9	50.5
Elementary	27.0	30.6	20.0	26.5	9.9	22.3
Secondary	8.0	6.9	14.7	16.2	5.5	10.1
Total	100	100	100	100	100	100

Source: Field Survey, 1991.

Given more than 25 years of rural development project experience and the recent national efforts on literacy education the regional literacy level is higher compared to the national average. Among the districts in the region Chilalo has only 11% illiteracy rate while the other four districts have between 18% and 22% illiteracy rate.

As Chilalo is the district where the regional capital Assela is located, with more educational opportunities being available it is not surprising to find higher rates of literacy among the sample households in the district. About 65% of the respondents in Ticho district and half of the sample farmers in Chilalo and Galema indicated that they benefited from the national literacy campaign. Forty seven and 35% of the farmers in Gedeb and Keleta, respectively, have also acquired literacy campaign education. The data reveal that the national literacy program has reduced the illiteracy rate in a very short period of time. Farming

experience of household heads ranges from 25 to 30 years and there appears no significant difference between districts.

4.4.4 Farm Sizes of Households

Average farm sizes per household in Gedeb and Galema are 4.1 ha. and 3.1 ha. while Ticho, Keleta, and Chilalo have 2.0, 2.2 and 2.5 ha. respectively. Differences in farm sizes across districts and between farmers in each district will further be examined to study the relationships with technology adoption. Regional mean farm size is 2.71 ha. and 71% of the sample farmers own less than 3 ha. Nearly 16% and 13% of the farmers in the study area own 3.1 - 4 ha. and more than 4 ha respectively. A quarter of the respondents in Ticho own up to 1 ha. while no farmer in Galema and Gedeb own less than 1 ha. A significant number of the sample farmers in Keleta, Ticho and Chilalo have farm size of 1.1 - 2 ha. Gedeb and Galema districts are characterized by relatively larger farm sizes as 60% of the farmers in Gedeb and 45% in Galema have farm sizes greater than 3 ha. Low population density and lower soil fertility in these districts contribute to larger farm sizes.

A chi-square test of the cross tabulation of farm size category by districts suggested a significant difference in farm sizes across the districts. Moreover an F-test of the mean farm and arable area sizes showed a statistically significant difference across districts.

Table 4.18 Farm Size of Households in Arssi Districts, 1990/91

Farm Size	Keleta	Chilalo	Galema	Gedeb	Ticho	Arssi Total
Percent of Households						
Up to 1 Ha	5.0	8.3	0	0	24.2	7.7
1.1 - 2	52.0	37.5	17.9	13.2	41.8	33.6
2.1 - 3	31.0	29.2	37.9	27.9	20.9	29.6
3.1 - 4	9.0	9.7	27.4	27.9	6.6	15.7
More than 4	3.0	15.3	16.8	30.9	6.6	13.4
Farm size ha./hh	2.2	2.5	3.1	4.1	1.9	2.7
Arable area ha/hh	1.9	1.8	2.0	2.6	1.4	1.9

Source: Field Survey, 1991

Table 4.19 Number and Mean Values of Selected Household Characteristics

	Keleta	Chilalo	Galema	Gedeb	Ticho
Number of Households	100	72	95	68	91
Family Size	6.9	7.6	7.0	7.7	7.6
Age of Household Head	45.0	47.5	43.8	43.1	47.8
Level of Education	1.3	1.3	1.3	1.4	1.0
Farming Experience Years	26.9	28.7	26.2	25.4	29.9
Farm Size per HH in ha.	2.2	2.5	3.1	4.1	2.0

Source: Field Survey, 1991.

4.5 Summary

Chapter 4 discussed the importance of wheat in Ethiopian agriculture in general and in Arssi in particular. Farmers' household characteristics, wheat production practices and technology adoption patterns are presented in the chapter.

Family size/Age: The mean family size for the region is about 7.3 persons and 57 percent of the families have 5 to 10 members. The family sizes in the region are above the national average of 5 persons. The mean household age is 45 years. The age distribution indicate that 30 percent of the household heads are under the age of 36 and 44 percent are between 36 to 55 while 26 percent belong to the 56 or older age category.

Educational Levels: Since rural development project in the study area started in 1967 farmers appeared to have benefitted from the early years of literacy campaign and also from the national literacy program the country launched in the 1980s. Only 17 percent of the sample farmers reported illiterate compared to 20-39% illiteracy level for the country.

Farm Size: The mean farm size and arable area for Arssi are 2.7 and 1.9 ha. There is significant difference in farm sizes across the study districts. The regional data illustrate 40 percent of the households cultivate 2 ha or less and the other 45 percent have farm sizes between 2.1 - 4 ha. Only 13 percent of the farmers own 4 or more hectares of farm land.

Wheat Production Practices and Technology Adoption in Arssi

Historical and current data on the use of improved wheat varieties, and fertilizer in the region and current adoption rates in the selected districts are presented (Tables 4.5 and 4.6, Figures 4 and 5). Although the initial benefits of the integrated rural development project were biased in favor of land-owning class in Arssi, the radical land reform of 1975 gave the small farmers access to land and improved production technologies. The following evidence from the survey support the above assertion. Compared to farmers in other regions of Ethiopia farmers in Arssi a) have high rates of fertilizer adoption (87%), b) on the average they apply 71 kg fertilizer per ha for wheat c) have 55% of their arable area fertilized per household and d) have more than 15 years of awareness and knowledge about fertilizer use (Table 4.12). Almost half of the sample farmers in

the region use 50 or less kg of fertilizer per ha. About 60% of the farmers in the districts of Ticho and Gedeb apply 50 kg or less fertilizer per ha while the same proportion of farmers in Chilalo and Galema use relatively higher rates (75-100 kg/ha).

In terms of varietal adoption, Enkoy is grown in all the districts and is the highest yielder except in Ticho. Bulk K6295 and Dashen are popular in three and two of the districts, respectively. Dashen, though recently released and adopted in a short period of time has been susceptible to yellow rust epidemic in the higher altitudes of Arssi. Enkoy which is well adapted to in the different zones of the region has a yield gap of 45%, between research station and on-farm trials, and a 30% yield gap between on-farm trials and farmers' reported yields. In Chilalo and Keleta 52 and 48% of the farmers reported using herbicides (in the other areas the number of users is insignificant).

Farmers' opinions on specific attributes and their criteria for adopting the recommended wheat production technologies were collected and summarized (Tables 4.13 and 4.14). Unavailability, late delivery and higher prices are the most frequently reported reasons for not using of fertilizer, herbicide and HYVs in the districts. For instance, 75 and 84 and 55% of the respondents said yield is their criteria for selecting Dashen, Enkoy and Bulk. Other factors such as grain color, grain price, taste in preparing local foods, resistance to lodging and diseases are listed as important criteria in varietal preference by farmers.

CHAPTER 5

TECHNOLOGY ADOPTION MODEL

5.1 The Economics of Adoption and Conceptual Model

The adoption of technology is an economic decision based on expected marginal benefits and costs. Most empirical specifications deal with a variety of models of farmer or farm household optimization: maximizing expected profits, expected utility of profits or expected utility of consumption and leisure subject to production function and time. For example, discounted expected profits is the difference in discounted expected value of production of all crops and livestock with and without the adoption of a particular technology, minus the difference in costs. Farmers' adoption decision making is analyzed using qualitative response (QR) models also known as binary, discrete or dichotomous models. Applications of QR models are appropriate for analyzing relationships involving a discrete dependent variable. Based on the assumption that farmers will make the adoption decision based upon an objective of utility maximization, a technology t_2 is preferred to technology t_1 as long as utility derived from t_2 is greater than utility from t_1 .

Following Rahman and Huffman (1984), the utility function that ranks the i th farmers preference of technology is represented as: $U(R_{ti}, A_{ti})$, where utility U depends on a vector R_t that describes the distribution of net returns for

technology t , and a vector A_t of other attributes associated with the technology.

The variables R_{ti} and A_{ti} are unobserved and unavailable, but a linear relationship is postulated for the i th farmer between the utility derived from the i th technology and a vector of observed farm specific characteristics X_i and a zero mean random disturbance term e_t :

$$U_{ti} = X_{it} + e_t, \quad t = 1, 2 \text{ and } i = 1, \dots, n. \quad (1)$$

The i th farmer adopts t_2 if U_{t2} exceeds U_{t1} and the adoption decision can be represented by a qualitative variable Y .

$Y = 1$ if $U_{t1} < U_{t2}$, new technology t_2 is adopted replacing old technology t_1

$$0 \text{ if } U_{t1} \geq U_{t2}, \text{ old technology } t_1 \text{ is continued.} \quad (2)$$

The probability that Y_i is equal to one is expressed as a function of farm/farmer specific characteristics:

$$\begin{aligned} P_i &= P_r(Y_i = 1) = P_r(U_{t1} < U_{t2}) \\ &= P_r(X_i \alpha_1 + e_{1i} < X_i \alpha_2 + e_{2i}) \\ &= P_r[e_{1i} - e_{2i} < X_i(\alpha_2 - \alpha_1)] \\ &= P_r(\mu_i < X_i \beta) = F(X_i \beta), \end{aligned} \quad (3)$$

Where $P_r(.)$ is a probability function,

$\mu_i = e_{1i} - e_{2i}$ is random disturbance term,

$\beta = \alpha_2 - \alpha_1$ is a coefficient vector and

$F(X_i\beta)$ is a cumulative distribution function for μ_i evaluated at $X_i\beta$. The exact distribution of F depends on the distribution of the random term μ_i (if μ_i is normal then F is a cumulative normal).

The marginal effect of a variable X_j on the probability of adopting the new technology can be calculated by differentiating P_i with respect to X_j :

$$\partial P_i / \partial X_{ij} = f(X_i\beta) \cdot \beta_j, \quad (4)$$

Where $f(\bullet)$ is the marginal probability density function of μ_i and $j = 1, 2, \dots, J$ is the number of explanatory variables.

Amemiya (1981) also defined a dichotomous random variable y which takes the value of 1 if the event occurs and 0 if it does not. It is also assumed that the probability of an event depends on a vector of independent variables X and a vector of unknown parameters θ .

The general form of the univariate dichotomous choice model is expressed as

$$P_i = P_i(y_i = 1) = G(X_i\theta), \quad (i = 1, 2, \dots, n) \quad (5)$$

Equation (5) states that the probability that the i th farmer will adopt a technology is a function of the vector of explanatory variables X_i , and the unknown parameter vector, θ . The functional form of G is unknown and it is too general for practical applications. In order to specify G explicitly, three alternative functional relationships are commonly used by researchers : Linear Probability (LP), probit and logit models.

5.1.1 The Linear Probability Model (LP)

One option of specifying G in Equation (5) is by the linear probability functional form which has been frequently used in econometrics applications. The general equation used in the LP model is the form:

$$y_i = X_i' \beta + e_i \quad (6)$$

Where y_i , the dependent variable takes the value of 1 if farmer i adopts a technology and

0 if the farmer does not adopt.

X_i is a matrix of independent variables (regressors) with n observations and k estimable coefficients;

β is a $k \times 1$ vector of parameters and

e_i is the i th identically and independently distributed random disturbance with zero mean.

In this model the observed dependent variable is assigned either the value 1 or 0 and the OLS technique is used to estimate the unknown parameters. While the LP model is computationally and conceptually easier than the logit and probit models, its specification creates estimation problems and the non-normality of the disturbance terms makes the use of traditional tests of significance (the t-test and F-test) inappropriate. Akinola (1988) explains the factors contributing to these problems and the limitations of the LP functional form as:

- 1) it gives a heteroscedastic regression model and that its variance-covariance matrix varies systematically with the independent variables,

- 2) the predicted value of $X'\beta$ is not constrained to lie between 0 and 1 which is inconsistent with the definition of y_i as a conditional probability. This is because the linear function is unbounded and there are certain sets of values of the regressors (X_i s) for which $y_i = X_i'\beta$ exceeds 1 and others for which it is less than 0,
- 3) studies have shown that adoption decision functions are curvilinear rather than linear. The OLS could not be used because it would lead to inefficient parameter estimates (Judge et al. 1988, Kennedy, 1992).

5.1.2 Logit and Probit Models

In an attempt to constrain the estimated probabilities between 0 and 1 range, alternative functions are developed. The two most popular are the logistic and the cumulative normal functions creating the logit and probit models respectively. Univariate and multivariate logit and probit models and their modified forms have been used extensively to study the adoption behavior of farmers. The probability that a given farmer will adopt a new technology can be expressed as a function of :

$P(Y = 1) = F(X\beta)$ as in equation (6). According to the logit model, the probability of an individual household adopting a new technology, T_2 , given economic, social and physical characteristics (X) can be specified as:

$$P(T_2|X) = \exp(X\beta + e) / \{1 + \exp(X\beta + e)\} \quad (7)$$

where e is a random disturbance term

The probability of continuing to use the traditional technology (i.e., not adopting the new technology) is then:

$$\begin{aligned}
 P(T_1|X) &= 1 - P(T_2|X) \\
 &= 1 - [\exp(X\beta + e) / \{1 + \exp(X\beta + e)\}] \\
 &= 1 / \{1 + \exp(X\beta + e)\}
 \end{aligned} \tag{8}$$

The relative odds of adopting versus not adopting a new technology are given by

$$\begin{aligned}
 P(T_2|X) / P(T_1|X) &= [\exp(X\beta + e)] / [1 + \exp(X\beta + e)] \\
 &= \exp(X\beta + e)
 \end{aligned}$$

Taking the logarithm of both sides:

$$\ln [P(T_2|X) / P(T_1|X)] = X\beta + e \tag{9}$$

The basic merit in the logit model is that the parameter estimates are linear and thus estimation is computationally simpler (Kennedy, 1992). The estimates only require transformation in exponential form to arrive at the probabilities. Assuming a normally distributed error term (E) the logit maximum likelihood (LML) estimation procedure is used to obtain consistent, efficient and asymptotically normal estimators. The estimates will indicate the effects and significance of the independent variables on the adoption of specific technology (Judge et al.1988).

Probit analysis is a procedure that takes account of heteroscedasticity of the disturbances and restricts predictions to values between 0 and 1. In the probit model, the probability of observing a response in this study whether a farmer adopts improved wheat production technologies or not, is defined in terms of the

level of an observed index. The standard cumulative normal distribution is used to transform the index into probability value. The relationship between the index and the probability follows a sigmoid curve. The index may take on any value between $-\infty$ and $+\infty$, but the transformation ensures that all corresponding probability values lie between 0 and 1.

The functional form can be expressed as:

$$F(w) = \Phi(w) = \int_{-\infty}^w \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{u^2}{2\sigma^2}} du.$$

Where $w = X_1'\beta$ (10)

The linear equation in (6) is used and parameters are estimated using the Maximum Likelihood Estimation. An estimated β value in a logit or probit does not estimate the change in the dependent variable due to a unit change in the relevant independent variable. The effect of an explanatory variable on the dependent variable is given by the partial derivative of the expression for Prob($y=1$) with respect to β which is not equal to β .¹⁷

¹⁷The marginal effects of the independent variables in a logit model is calculated as: $[\text{Prob}(y = 1)][1 - \text{Prob}(y = 1)]\beta$, which is usually reported by estimating it at the mean value of the explanatory variables. This formula is appropriate for continuous variables only and it is recommended to measure the effects of categorical variables by estimating the difference before and after the change (i.e. when $X=1$ and $X=0$).

5.1.3 Multinomial Logit and Probit Models

The preceding section addressed the problem of binary, or dichotomous variables for which there are only two choice categories. Categorical variables that can be classified into many categories are called polychotomous variables. A farmer may be presented with a choice of planting one of the three wheat varieties or choices of different levels of fertilizer application (from the lowest to the highest rate). Estimation of the probability of adoption of any of the varieties or rate of fertilizer use can be undertaken by means of a generalization of the binomial logit or probit models, called, respectively the multinomial logit and the multinomial probit models. These generalizations employ the random utility model where the utility to an individual farmer of an alternative is specified as a linear function of the characteristics of the farm household and the attributes of the alternative plus an error term.

The probability that a farmer will choose a particular alternative can be given by the probability that the utility of that alternative to that farmer is greater than the utility of all other available alternatives. If the error terms are assumed to be independently and identically distributed we will end up with the multinomial logit model. If however the distribution is assumed to be distributed multivariate-normally, the multinomial probit model results. Kennedy (1992) discusses that multinomial logit model has a disadvantage of the independence of irrelevant alternatives property. When an identical alternative is included in the choice set, one would expect that as a result the probability from this model of choosing the

duplicated alternative would be cut in half and the probabilities of choosing the other alternatives would be unaffected. The multinomial logit model does not overcome such a problem and it will be inappropriate to use the multinomial logit whenever two or more of the alternatives are close substitutes. The probit model allows the error terms to be correlated across alternatives and thereby circumvents the problem of the independence of irrelevant alternatives mentioned earlier. Some multinomial-choice variables are inherently ordered and the individual producer or consumer has to make the selection from the ranked sets of choices. In this study examples of ordered choices include different rates of input use (i.e. no use, very low, low, medium and high levels). Another example is farmers' opinions related to different technologies ranked in order of preference. The ordered probit and logit models are used for analyzing such ordered responses. According to Greene (1990), such a model is built around a latent regression in the same manner as the binomial models such as:

$$Y^* = \beta'X + \varepsilon$$

where y^* is unobserved and we observe :

$$\begin{aligned}
 y &= 0 \text{ if } Y^* \leq 0, \\
 &= 1 \text{ if } 0 \leq Y^* < \mu_1 \\
 &= 2 \text{ if } \mu_1 \leq Y^* < \mu_2 \\
 &\cdot \\
 &\cdot \\
 &= J \text{ if } \mu_{J-1} \leq Y^* .
 \end{aligned} \tag{11}$$

Where the alternative choices are represented by $j = 0, 1, 2, \dots, J$,

the μ 's are unknown parameters to be estimated with β ,

the ϵ is normally distributed across observations and mean and variance of ϵ are zero and one.

Given the normal distribution we have the following probabilities for each of the choices:

$$\begin{aligned}
 \text{Prob}[Y=0] &= \Phi(-\beta'X), \\
 \text{Prob}[Y=1] &= \Phi(\mu_1 - \beta'X) - \Phi(-\beta'X), \\
 \text{Prob}[Y=2] &= \Phi(\mu_2 - \beta'X) - \Phi(\mu_1 - \beta'X) \\
 &\vdots \\
 &\vdots \\
 \text{Prob}[Y=J] &= 1 - \Phi(\mu_{J-1} - \beta'X).
 \end{aligned} \tag{12}$$

Where Φ is the cumulative standard distribution function.

In order for the probabilities to be positive the following must hold: $0 < \mu_1 < \mu_2 < \dots < \mu_{J-1}$. The maximum likelihood techniques are used to estimate the coefficients and calculate the marginal effects of the regressors on the probabilities of the different alternatives.

5.1.4 The Tobit Model

Once the models are used to predict the probability of adoption of a certain technology, it will be useful to estimate the intensity of adoption by different categories of farmers. The degree of adoption can be divided into very low, low, moderate and high. Depending on the type of technology a specific level of

quantity or range will be defined to indicate the quantity of use or the intensity. In their recent study, Adesina and Zinnah (1993) used the Tobit model to measure both the probability of adoption and the intensity of use of modern mangrove rice varieties in Sierra Leone. Shakaya and Flinn (1985) applied the Tobit model for analyzing the adoption of modern rice varieties and fertilizer use in Nepal and referred the Tobit model as a more general case of Probit model or a "hybrid Probit". Sureshwaran et al. (1992) and Norris and Batie (1987) also employed Tobit analysis to study the intensity of adoption and factors affecting soil conservation decisions by farmers in the Philippines and Virginia, respectively. Following the linear probability model (equation 6), where the probability of technology adoption is given as a function of a vector of explanatory variables and of unknown parameters and error term:

$P_i = F_i(X_i\beta)$, the functional form of F can be specified with a Tobit model, where μ_i is an independently, normally distributed error term with zero mean and constant variance σ^2 :

$$\begin{aligned} Y_i &= X_i\beta, \text{ if } i^* = X_i\beta + \mu_i > T \\ &= 0 \text{ if } i^* = X_i\beta + \mu_i \leq T \end{aligned} \quad (13)$$

Where Y_i is the probability of adopting (and the intensity of use of) the technology (fertilizer or improved wheat varieties); i^* is a non-observable latent variable, and T is a non-observed threshold level. The Tobit model (Tobin, 1958) measures not only the probability that a farmer will adopt the new technology (the decision to adopt), but also the intensity of use (the effort to continue using

Handwritten signature and text at the bottom of the page.

the technology) of the technology once adopted. The above equation is a simultaneous and a stochastic decision model. If the non-observed latent variable i^* is greater than T , the observed qualitative variable Y_i becomes a continuous function of the independent variables, and 0 otherwise. The value of a Tobit coefficient does not represent the expected change in the dependent variable given a one unit change in an explanatory variable. The model estimates a vector of normalized coefficients which can be transformed into the vector of first derivatives (Adesina and Zinnah, 1992). McDonald and Moffitt (1980) explain that Tobit effects can be decomposed into a) changes in the probability of being above the limit and b) changes in the value of the dependent variable if it is already above the limit. Given such a decomposition we can use the means of the explanatory variables to calculate the elasticity of adoption and elasticity of intensity /effort once adoption occurs. The model below illustrates the decomposition process and the transformation of the coefficients into a vector of first derivatives and subsequent calculation of the elasticity of adoption.

The basic Tobit model (as in equation 13) is

$$Y = X\beta + e \text{ if } X\beta + e > 0$$

$$Y = 0 \quad \text{if } X\beta + e \leq 0$$

The expected value of Y in the model (Tobin, 1958) is given as:

$$E(Y) = X\beta F(z) + \sigma f(z),$$

Where $z = X\beta/\sigma$, $f(z)$ is the unit normal density, and $F(z)$ is the cumulative normal distribution function.

The expected probability of being above a certain value once adoption occurs is given as

$$E(Y^*) = E(Y|Y > 0),$$

$$E(Y^*) = X\beta + \sigma f(z)/F(z)^{18}$$

The relationship between the expected value of all observations $E(Y)$, the expected value conditional upon being the limit $E(Y^*)$ and the probability of being above the limit $F(z)$ is represented as

$$E(Y) = F(z) \cdot E(Y^*). \quad (14)$$

To calculate the marginal effects of the explanatory variables and to decompose the total effect we differentiate the following:

$$\partial E(Y)/\partial X = F(z)[\partial E(Y^*)/\partial X] + E(Y^*)[\partial F(z)/\partial X]$$

Where, $E(Y^*)/\partial X$ represents the effect of the variable X on the intensity of use and $\partial F(z)/\partial X$ is the effect on the probability of adoption.

Manipulating the above equation (multiplying both sides by $X/E(Y)$) we can calculate the total elasticity of change due to changes in the level of any of the explanatory variables.¹⁹ Adoption elasticity in this study can be decomposed

¹⁸ McDonald and Moffitt(1980) reported that the expected value of Y for the observations above the threshold or limit here referred as $E(Y^*)$ is $X\beta$ plus the expected value of the truncated normal error term:

$$\begin{aligned} E(Y^*) &= E(Y|Y > 0) \\ &= E(Y|z > -X\beta) \\ &= X\beta + \sigma f(z)/F(z). \\ E(Y) &= F(z)E(Y^*) \end{aligned}$$

¹⁹ Given that $E(Y) = F(z)E(Y^*)$ then $F(z) = E(Y)/E(Y^*)$ and $E(Y^*) = E(Y)/F(z)$
 Given $\partial E(Y)/\partial X = F(z)[\partial E(Y^*)/\partial X] + E(Y^*)[\partial F(z)/\partial X]$ and multiplying by $X/E(Y)$
 $\{\partial E(Y)/\partial X\}X/E(Y) = F(z)\{\partial E(Y^*)/\partial X\}X/E(Y) + E(Y^*)\{\partial F(z)/\partial X\}X/E(Y)$
 and substituting for $F(z)$ and $E(Y^*)$ we get
 $\partial E(Y)/\partial X\}X/E(Y) = E(Y)/E(Y^*) \{\partial E(Y^*)/\partial X\}X/E(Y) + E(Y)/F(z)\{\partial F(z)/\partial X\}X/E(Y)$

into a) the change in the elasticity of the use intensities of technologies and b) the change in the probability of being an adopter.

The elasticity equation is:

$$\{\partial E(Y)/\partial X\}X/E(Y) = \{\partial E(Y^*)/\partial X\}X/E(Y^*) + \{\partial F(z)/\partial X\}X/F(z) \quad (15)$$

5.2 Empirical Model Specification

The probability of adoption of HYVs, fertilizers, herbicides and agronomic practices for wheat will be specified as a function of economic, social, and physical variables and it is hypothesized to depend on a wide range of explanatory variables. Three kinds models will be used to study the probability of adoption, probability of choosing an alternative and to measure the intensity of adoption. The binomial logit and probit models will be employed to study the factors affecting the adoption of fertilizers, herbicides and improved wheat varieties. The ordered probit model will be used to determine the variables explaining the adoption of different rates of fertilizer applications and different wheat varieties in the study areas. The third model, the Tobit model will be used to estimate both the probability of adoption and the level of intensity of fertilizer application as this input appears to vary among and across farmers in the region.

$$\partial E(Y)/\partial X\}X/E(Y) = \{\partial E(Y^*)/\partial X\}X/E(Y^*) + \{\partial F(z)/\partial X\}X/F(z)$$

The data on which the empirical models are based is discussed in chapter 3. The estimated empirical models, derived from the binomial logit model (equations 7-9), ordered probit model (equations 11- 12) and the Tobit model (equation 13) are presented below. The various farm and farmer specific characteristics and the associated variables are also listed in Table 5.1.

5.2.1 The Binomial Logit Model

$$P(T_2|X) = \exp (X\beta + e) / \{1 + \exp (X\beta + e)\} \quad (7)$$

The probability of continuing to use the traditional technology T_1 (i.e. not adopting the new technology) is then:

$$\begin{aligned} P(T_1|X) &= 1 - P(T_2|X) \\ &= 1 - [\exp (X\beta + e)/\{1 + \exp(X\beta + e)\}] \\ &= 1/\{1 + \exp (X\beta + e)\} \end{aligned} \quad (8)$$

The relative odds of adopting versus not adopting a new technology are given by

$$\begin{aligned} P(T_2|X)/P(T_1|X) &= [\exp (X\beta + e)] / \{1 + \exp (X\beta + e)\} / [1 / \{1 + \exp(X\beta + e)\}] \\ &= \exp (X\beta + e) \end{aligned}$$

Taking the logarithm of both sides:

$$\ln [P(T_2|X) / P(T_1|X)] = X\beta + e \quad (9)$$

5.2.2 The Ordered Probit Model

$$\begin{aligned} Y &= 0 \text{ if } Y^* \leq 0, \\ &= 1 \text{ if } 0 \leq Y^* < \mu_1 \\ &= 2 \text{ if } \mu_1 \leq Y^* < \mu_2 \end{aligned} \quad (11)$$

$$\begin{aligned}
& \cdot \\
& = J \text{ if } \mu_{J-1} \leq Y^* \cdot \\
& \text{Prob}[Y = 0] = \Phi(-\beta'X), \\
& \text{Prob}[Y = 1] = \Phi(\mu_1 - \beta'X) - \Phi(-\beta'X), \\
& \text{Prob}[Y = 2] = \Phi(\mu_2 - \beta'X) - \Phi(\mu_1 - \beta'X)
\end{aligned} \tag{12}$$

$$\begin{aligned}
& \cdot \\
& \cdot \\
& \text{Prob}[Y = J] = 1 - \Phi(\mu_{J-1} - \beta'X).
\end{aligned}$$

5.2.3 The Tobit Model

$$\begin{aligned}
Y_i &= X_i\beta, \text{ if } i^* = X_i\beta + \mu_i > T \\
&= 0 \text{ if } i^* = X_i\beta + \mu_i \leq T \\
\text{or } Y &= X\beta + e \text{ if } X\beta + e > 0 \\
Y &= 0 \quad \text{if } X\beta + e \leq 0
\end{aligned} \tag{13}$$

The elasticity of adoption is given by equation 15 as discussed earlier:

$$\{\partial E(Y)/\partial X\}X/E(Y) = \{\partial E(Y^*)/\partial X\}X/E(Y^*) + \{\partial F(z)/\partial X\}X/F(z) \tag{15}$$

Table 5.1 List of Economic, Social and Institutional Variables Affecting Adoption Decision

Category	Variable Name	Variable Code	Measurement/Value
Economic Factors	Farm Size per HH Arable Area per HH Oxen owned Cow owned Sheep owned Wheat Production per Variety Yield of each Variety Wheat prices by variety	FARMSZHA ARBLHA OXNUM CWNUM SHPNUM DSHPRDKG, ENKPRDKG BLKPRDKG DSHYLDKG, ENKYLDKG, BLKYL DKG DSHPRQ, ENKPRQ BLKPRQ	Hectares Hectares Numbers numbers Numbers Quintals Quintals Kg/ha. Kg/ha. Kg/ha. ETB/qnt ETB/qnt
Social Factors	Age of Household Head(HH) Sex of HH Level of Education of HH Farming Experience Family Size	AGEHH SEXHH LVLEDHH FARMEXP FMLSZ	Years M/F (1,2) (1-4) Years Numbers
Crop production technology applications	Seed availability and sources Reasons for not using improved seeds sources of improved seeds Varietal preference criteria Fertilizer availability, use, rates, farmers' perception on advantages and disadvantages of fertilizers	SRCWSD1, SRWSD2 RDSHPRF1, RENKPRF1, RBLKPRF1 RDSHPRF2, RENKPRF2, RBLKPRF2 GTFTML, KWRFTRT, FTAWYR, FTUSYR, USFTYRL, RNNOFAP1, RLFTAP1, ADVFT1, DADVFT1, APHBW90, THKHBDV	Yes/No (1,0) Coded Choices
Institutional Factors	Herbicide availability, use, rates, farmers' perception on advantages and disadvantages of herbicide Credit availability, source and purpose Extension service, farmer training, Field days and demonstrations Information access Distance to nearest market, town Own radio Listen to ag. education programs	GETCRDT, SRCCRDT1, SRCCRDT2, PRPCRDT1, PRPCRDT2 DAVST90, ATFLDD, ATFTRNG, NRMKKM, FTDSTKM, OWNRDIO, LSNAGED	Distance in Km. Yes/No

5.2.4 Dependent and Independent Variables

The preceding sections highlighted the econometric theory and the conceptual models underlying the proposed analysis and the models to be used. This section attempts to define the dependent and explanatory variables used in the binomial logit, ordered probit and Tobit models discussed above. The dependent variables used for the adoption models estimated in the study:

- a) Fertilizer adoption or no adoption in 1990 and 1991 crop seasons (FW90 and FW91) Yes/No response coded 1 or 0 ,
- b) Herbicide application on no application in 1990 and 1991 (APHBW90 and APHBW91) Yes/No response coded 1 or 0,
- c) Farmers' choice among the three widely used varieties of wheat, i.e., Dashen, Enkoy and Bulk (DSHHAP, ENKHAP and BLKHAP coded 0,1,2, respectively) ,
- d) Fertilizer application rates group (FAPGP) the farmer belongs: response coded 0 if fertilizer application rate less than 25kg/ha.,
1 if greater than 25 and less or equal to 50 kg/ha.,
2 if greater than 50 and less or equal to 75 kg/ha.,
3 if greater than 75 and less or equal to 100 kg/ha. and
4 if greater than 100 kg/ha.
- e) Fertilizer adoption and intensity of use: Quantity of fertilizer used per farm and rate of fertilizer use in the two crop seasons (WDAPKG90, WDAPKG91, FRTRW90 and FRTRW91) and the response are coded:

*Primary
Interview
Schedule*

0 if no fertilizer is used,
total quantity reported in kg.,
and rate of fertilizer application (kg/ha.) calculated by dividing total quantity
by wheat area.

The binomial logit model is used for the binary responses in a and b above
while for c and d the ordered probit model is employed to estimate the empirical
model. The Tobit model is applied to investigate both the probability and
intensity of fertilizer adoption.

Table

Vari

Ty
T
F
C

Table 5.2 Technology Types, Econometric Models, Dependent and Independent Variables Used.

Type of Technology	Econometric Models Used	Dependent Variable(s)	Independent Variables
Fertilizer Use (Yes/No)	Binomial Logit	FW90, (Fertilizer use in 1990/91)	AGEHH, LVLEDHH, FMLSZ, FARMSZHA, OXNUM90, GTFTML, GETCRDT, KWRFTRT, USFTYRL, APHBW90, DAVST90
Herbicide Use (Yes/No)	Binomial Logit	APHBW90, (Herbicide application)	AGEHH, LVLEDHH, FMLSZ, FARMSZHA, OXNUM90, GETCRDT, FW90, DAVST90
Choice of Wheat Varieties (Dashen, Enkoy and Bulk)	Ordered Probit	WHVCH (Wheat Variety Choice)	AGEHH, LVLEDHH, FMLSZ, FARMSZHA, OXNUM90, GTFTML, GETCRDT, FW90, KWRFTRT, USFTYRL, APHBW90, DAVST90
Fertilizer Application Rates (0,1,2,3,4)	Ordered Probit	FAPGP90 FAPGP91 (Fertilizer rates groups used)	AGEHH, LVLEDHH, FMLSZ, FARMSZHA, OXNUM90, GTFTML, GETCRDT, KWRFTRT, USFTYRL, APHBW90, DAVST90, DSHPHA90, ENKPHA90, BLKPHA90
Fertilizer Adoption and Intensity of use (Kg/Farm, Kg/ha)	Tobit	WDAPKG90, FRTRW90, (Fertilizer quantity and rates)	AGEHH, LVLEDHH, FMLSZ, FARMSZHA, OXNUM90, GTFTML, GETCRDT, KWRFTRT, USFTYRL, APHBW90, DAVST90, DSHPHA90, ENKPHA90, BLKPHA90

Explanatory Variables of Technology Adoption: Most technological adoption studies have under-specified the models of adoption behavior by using only a few decision variables. A farmer's decision making process in adopting is complex and should be examined taking into account economic, social, cultural and institutional factors. In this study as indicated in Table 5.2 different categories of explanatory variables are used to study the relationship between the farmer's decision (to adopt or not to adopt fertilizer and/or herbicides, which wheat varieties to choose, which rate of fertilizer to use and what quantity of fertilizer to apply and their social and economic characteristics, farm specific factors and institutions that affect adoption.

Farm size has been shown to positively affect adoption decisions and it is hypothesized that farm size will have a positive sign in the empirical model. Earlier studies indicate that older farmers tend to be risk averse and are reluctant to adopt new production techniques. Younger farmers have access to education and appear more knowledgeable about new production technologies. It is then hypothesized that farmer's age (AGEHH) is negatively related while level of education of household head (LVLEDHH) is positively related to adoption. Formal schooling enhances the farmer's ability to perceive, interpret, and respond to new events in the context of risk. Several empirical studies have verified the link between higher levels of educational attainment and early adoption of new technologies. A large family (FMLSZ) is expected to have a large number of working members and this might positively influence the use of labor using

technologies and negatively affect the adoption of labor saving technologies.

Adoption of herbicides is expected to be related negatively with family size as family labor (for hand weeding) can substitute for herbicide use.

In most cases adoption of new technologies requires the purchase of farm inputs such as fertilizers, improved seeds, herbicides and hiring of farm labor when family labor is not adequate. The role of credit in accelerating adoption and agricultural development is widely discussed. If farmers do not generate their own savings or have no access to credit their ability to adopt new technologies will be constrained. The variables that indicate credit availability, sources and purposes of credit (GETCRDT, SRCCRDT, PRPCRDT) and the wealth variable oxen number (OXNUM90, OXNUM91) are used as proxies for access to capital. Availability of credit and number of livestock owned are expected to positively affect adoption decisions.

Farmers' perceptions on fertilizer availability (GTFTML), knowledge of fertilizer recommended rates (KWRFTRT), frequency of fertilizer use (USFRTYRL) are important to enhance the adoption process. Proximity to marketing centers will obviously reduce transport cost to acquire fertilizer and other purchased inputs and sale of farm produce. Distance to the nearest market (NRMKKM) is expected to negatively affect the adoption of purchased inputs. Access to information is represented by extension agent visit (DAVST90), farmer's attendance at farmer training programs, field days, ownership of radio, farmers' listening to agricultural education programs (ATFTRNG, ATFLDD,

OWNRDIO, LSNAGED). Contact with extension and farmers' access to these sources of knowledge will stimulate adoption.

Preference to either of the three wheat varieties is assumed to depend on their adaptability in each district, respective yields, prices and specific agronomic characteristics (AWRAJA, DSHYLDKG, ENKYLKGK, BLKYLDKG, DSHPQ, ENKPRQ, BLKPRQ, RENKPRF1, RBLKPRF1). The use of complementary inputs such as fertilizer and herbicides is also an important adoption decision. (FW90, FW91, APHBW90, APHBW91). It is hypothesized that some farmers can adopt both inputs simultaneously, while others adopt fertilizers first and then adopt herbicides at a latter stage, an illustration of the 'step-wise adoption behavior' of farmers that Byerlee and Polanco found in Mexico²⁰.

The complete empirical models specified as above and their dependent independent variables defined in Tables 5.1 and 5.2 are listed below.

I. Binomial Logit Model

$$\begin{aligned}
 \text{FW90} &= \beta_0 + \beta_1 \text{AGEHH} + \beta_2 \text{LVLEDHH} + \beta_3 \text{FMLSZ} + \beta_4 \text{FARMSZHA} \\
 &+ \beta_5 \text{OXNUM90} + \beta_6 \text{GTFTML} + \beta_7 \text{GTCRDT} + \beta_8 \text{KWRFTRT} + \\
 &\beta_9 \text{APHBW90} + \beta_{10} \text{DAVST90} \\
 \text{APHBW90} &= \beta_0 + \beta_1 \text{AGEHH} + \beta_2 \text{LVLEDHH} + \beta_3 \text{FMLSZ} + \\
 &\beta_4 \text{FARMSZHA} + \beta_5 \text{OXNUM90} + \beta_6 \text{GTFTML} + \beta_7 \text{GTCRDT} + \\
 &\beta_8 \text{KWRFTRT} + \beta_9 \text{FW90} + \beta_{10} \text{DAVST90}
 \end{aligned}$$

²⁰Byerlee and de Polanco (1985) found out that because of capital scarcity and risk considerations, Mexican farmers did not adopt a given package of technologies, rather they adopted individual components of a package of technology. Adoption followed a stepwise process, i.e., farmers first adopted improved barley varieties, fertilizer and then herbicide.

II. ORDERED PROBIT MODEL

$$\begin{aligned} \text{FAPG90} = & \beta_0 + \beta_1 \text{AGEHH} + \beta_2 \text{LVLEDHH} + \beta_3 \text{FMLSZ} + \\ & \beta_4 \text{FARMSZHA} + \beta_5 \text{OXNUM90} + \beta_6 \text{GTFTML} + \beta_7 \text{GTCRDT} + \\ & \beta_8 \text{KWRFTRT} + \beta_9 \text{APHBW90} + \beta_{10} \text{DAVST90} \end{aligned}$$

III. TOBIT MODEL

$$\begin{aligned} \text{WDPKG90} = & \beta_0 + \beta_1 \text{AGEHH} + \beta_2 \text{LVLEDHH} + \beta_3 \text{FMLSZ} + \\ & \beta_4 \text{FARMSZHA} + \beta_5 \text{OXNUM90} + \beta_6 \text{GTFTML} + \beta_7 \text{GTCRDT} + \\ & \beta_8 \text{KWRFTRT} + \beta_9 \text{APHBW90} + \beta_{10} \text{DAVST90} + \beta_{11} \text{NRMKKM} \\ & + \beta_{12} \text{WHVCH} + \beta_{13} \text{ATFLDD} + \beta_{14} \text{LSNAGED} \end{aligned}$$

5.3 Adopter Categories

One of the objectives of the study is to classify farmers into adopter categories based on adoption pattern and socioeconomic characteristics. Incidence of adoption is represented by the use or non use of fertilizer and herbicide, and intensity of input use are used to classify the farmers to different adopter categories. The first stage dealt with users and non users while the second stage attempted to identify farmers into : low adopters, moderate adopters and advanced adopters. Farmers using less than 25 kg of fertilizer per hectare and not using herbicide at all are categorized as low adopters. The moderate adopters category are farmers who apply 50 - 75 kg of fertilizer per hectare and also have used herbicide but not on a regular basis. Advanced adopters are those who apply fertilizer at a rate of 75 kg/ha or more and at the same time apply herbicide regularly if available. The survey data on farmers' use of herbicide and fertilizer is then used to identify the sample farmers into the different groups of adopters.

5.3.1 Discriminant Analysis

The general objective of this study has been to identify the socioeconomic factors that are responsible for technology adoption in the region. In this section a statistical model is developed based on farmers' socioeconomic characteristics and institutional factors to see if the variables can discriminate statistically between the different adopter categories. Discriminant analysis is one of the statistical techniques often used to identify the characteristics that differentiate

observations in one group from those in another group. In discriminant analysis a linear combination of independent variables is formed to serve as a basis for assigning sample cases to groups. Information contained in multiple independent variables is summarized in a single score (Norusis, 1990). The technique suggests that a variable having the largest absolute discriminant weight possesses the greatest power in discriminating one group from another. The discriminant model used to classify farmers into different adopter categories is :

$$D_g = B_0 + B_1 X_1 + B_2 X_2 + B_3 X_3 + B_4 X + \dots + B_n X_n \quad (16)$$

Where D_g = Discriminant score for each group (D_l , D_m , D_a for low, moderate and advanced adopter category), B's are coefficients to be estimated from the data and the X's are the values of the independent variables.

After the discriminant function is determined, the independent variables for each observation are multiplied by the discriminant coefficients to obtain a single discriminant score. The score is then used to classify each case to one of the categories of adopters. The results of the discriminant analysis in which the standardized coefficient, Wilk's Lambda, the ratio of the with-in groups sum of squares to the total sum of squares and the level of significance for the estimates by district and the region are presented in the empirical results chapter. The interpretation of the coefficients is similar to that in multiple regression. Variables with large coefficients are thought to contribute more to the overall discriminating function. The relative importance of the variables can be

measured by the standardized coefficients²¹. Large values of lambda show that group means do not differ significantly while smaller values indicate that the group means are different. Lambda only gives a test of the null hypothesis that the population means are equal. It is important to note that even though Wilk's lambda may be statistically significant it does not provide adequate information on the effectiveness of the discriminant function in classification. Comparing actual and predicted classification of the cases into different categories is used to test the effectiveness of the model.

²¹The magnitude of the unstandardized coefficients is not a good index of the relative importance when the variables differ in their units of measurement. Coefficients are standardized to adjust for the unequal means and standard deviations of the independent variables. In addition the signs of the coefficients are arbitrary and only determine which variable values result in large or small discriminant score (D_g). For details and procedures in discriminant analysis see Norusis (1990).

CHAPTER 6

EMPIRICAL RESULTS

This chapter is divided into three sections. The first section examines the profitability of wheat production technologies by presenting results of partial budgets and marginal returns analysis. The second section describes the econometric analysis of adoption in the study areas. The binomial logit, ordered probit and Tobit analysis and the respective results of the models will be presented. Moreover, the determinants of adoption and the relative contributions and effects of identified and significant variables affecting adoption are examined in the chapter. The third section deals with the results of the discriminant analysis.

6.1 Profitability Analysis of Technologies

6.1.1 Partial Budget Analysis

A partial budget summarizes the value of cost and revenue items that would change when one production activity or several production activities are replaced by another. Costs and returns that do not vary from one activity to another are not included in the analysis as they do not affect the profitability of adopting an activity. The decision to invest in production technologies (such as purchasing improved wheat varieties, fertilizers and/or herbicides) depends on the farmer's expected increase in yields and reduction in production costs. Partial budget analysis will consider the added benefits (increased revenues and reduced costs),

and increased costs and reduced revenues if any as a result of adopting all or part of a given package of production technologies.

In the study areas almost all farmers reported using improved wheat varieties. The intensity of fertilizer and herbicide use (as discussed in chapter 4) varies among farmers and across districts. Farmers' decisions to use or not to use these inputs depend on the expected net benefits from each level of input use. When making adoption decisions, small farmers will consider not only an increase in expected net benefits and/or profit but also want to make sure that family food security is attained. Empirical studies have shown that subsistence farmers are risk averse and hence tend to adopt technologies that will reduce production and/or income variability. Farmers continue to use traditional production practices which they are sure will secure them the minimum level of production to sustain the family's well-being. Small farmers employ a safety-first strategy before making adoption decision on new production techniques.

Economic analysis of crop responses to fertilizers has been carried out by IAR scientists in the different agro-ecological zones of the country. In Arssi CADU/ARDU, MOA and IAR agronomists and recently agricultural economists have conducted on-station and on-farm fertilizer, variety and other agronomic experiments. The results of the research programs have helped to reorient on-station research programs and develop a set of recommended production technologies for farmers in the region.

Partial budget analysis is used to compare the profitability of alternative production practices. Partial budget analysis for the three wheat varieties of Enkoy, Dashen and Bulk in the five districts is presented in Table 6.1.

Gross benefits are calculated by multiplying adjusted yield (allowing a 10% harvesting and storage loss) by the average farm gate prices²² that farmers reported. The farm gate price of wheat is considered to reflect the opportunity cost of seed used from farmers' own previous harvests.

²²Consumers prefer Dashen to other varieties (for its baking qualities), hence commands higher price. Enkoy is the second preferred and has higher farm gate price except in Ticho.

Table 6.1 Partial Budget Analysis of Wheat Production Technologies Under Farmers' Practices in Arssi, 1990/91

		Keleta		Chilalo			Galema	Gedeb		Ticho	
Item	Unit	Enkoy	Dashen	Enkoy	Dashen	Bulk	Enkoy	Enkoy	Bulk	Enkoy	Bulk
Average Yield	Kg/ha	1217.00	1057.00	1330.00	934.00	1063.00	1441.00	1068.00	1025.00	805.00	965.00
Adjusted Yield (10% Loss)	Kg/ha	1095.30	951.30	1197.00	840.60	956.70	1296.90	961.20	922.50	724.50	868.50
Crop Price	EB/kg	0.93	0.93	0.66	0.76	0.64	0.69	0.64	0.62	0.57	0.60
Gross Benefits	EB/ha	1018.63	884.71	790.02	638.86	612.29	894.86	615.17	571.95	412.97	521.10
Inputs and Costs											
Labor ^a	Mandays/ha	64.73	62.53	66.29	60.84	62.62	67.81	62.69	62.09	59.07	61.27
Labor Cost	EB/ha	124.29	120.06	127.27	116.82	120.22	130.20	120.36	119.22	113.41	117.64
Oxen	Oxendays/ha	35.26	32.86	36.95	31.01	32.95	38.62	33.02	32.38	29.08	31.48
Cost OXEN	EB/ha	105.77	98.57	110.85	93.03	98.84	115.85	99.06	97.13	87.23	94.43
Seed Rate	Kg/ha	196.00	210.00	240.00	222.00	215.00	206.00	147.00	148.00	190.00	188.00
Seed Cost	EB/HA	182.28	195.3	158.4	168.72	137.6	142.14	94.08	91.76	108.3	112.8
Fertilizer Rate	KG/ha	64.50	64.50	81.00	81.00	81.00	81.90	59.00	59.00	66.90	66.90
Cost of Fertilizer	EB/kg	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Fertilizer Cost /ha	EB/ha	58.70	58.70	73.71	73.71	73.71	74.53	53.69	53.69	60.88	60.88
Total Variable Cost	EB/ha	471.03	472.62	470.23	452.28	430.37	462.72	367.19	361.80	369.82	385.74
Net Benefit	EB/ha	547.60	412.08	319.79	186.58	181.92	432.14	247.98	210.16	43.15	135.36

^aLabor and oxen use for harvesting and threshing is estimated using ARDU(1980) studies in which 1.375 Man days and 1.5 oxen days per 100 kg yield are required and valued at their respective opportunity costs

Labor and oxen use are assumed not to vary either between the districts and across the three varieties. Introduction of improved production practices will eventually require additional oxen power and labor²³ at least to harvest the incremental yield. The opportunity costs for these inputs are the local wage and rental rates, respectively. The average rate of fertilizer application is significantly different across the study areas. Farmers do not use different rates of fertilizer for the varieties. The variety Enkoy, grown in all the study districts gave the highest and lowest yields in Galema and Ticho, respectively. It generated the highest net benefit of 548 EB/ha in Keleta district during the 1990 cropping season. The same variety also gave the second highest net benefit of 432 EB/ha at Galema. Dashen gave the third highest net benefit of 412 EB/ha at Keleta. The yields for both Enkoy and Dashen are not the highest at Keleta but a 40% higher farm gate price resulted in the high net benefits indicated.

The variety Bulk had a net benefit range of 135 to 182 EB/ha in the three areas. At Ticho Enkoy's net benefit is the lowest (43.EB/ha) but in the other four districts it out-yielded all the varieties and generated higher net benefits. At Galema the only variety farmers grow is Enkoy where the farmers' reported yield was the highest. Farm gate prices and reported yields are the lowest at Ticho contributing to lower net benefits. Variable costs (mainly fertilizer²⁴, labor and

²³ Based on the ARDU (1980) study, labor and oxen power requirement for the increased yield is estimated as 1.375 Mandays and 1.50 Oxendays per 100 kg grain.

²⁴ Ethiopia has the potential to produce fertilizers but does not yet have a fertilizer manufacturing plant. There is no subsidy for fertilizer. All fertilizer is imported and the retail prices have generally been in line with the import parity price.

seed costs) range from 362 to 471 EB/ha. Given farmers' estimate of yield, prices and the lack of detailed data on labor, draft power use, the partial budget figures have to be considered as proxy indicators of profitability of the farmers' wheat production practices.

Research and extension services have developed a set of recommended production packages to increase crop production in the region. Despite more than 20 years of regional agricultural development effort farmers have not yet adopted all the recommended practices. Preliminary analysis of the data (as presented in the descriptive statistics in chapter 4) reveal that about 21% the sample farmers apply below 25 kg/ha and almost 48% of them use 50 or less kg/ha of fertilizers. However, there is a significant variation among the five districts. Chilalo and Galema farmers apply higher rates (81 kg/ha), followed by Ticho and Keleta (65 and 70 kg/ha) while farmers in Gedeb use an average of 59 kg/ha. Improved seeds are widely used in the region but extension agents express their concern on the quality of the improved seeds that farmers use. The varieties released more than ten years ago have been mixed up with the local seeds and farmers plant uncleaned seeds. The majority of the sample farmers (53%) use their own seed from the previous harvest while 22% purchase seeds from the local markets. Only 23% of the farmers purchase improved wheat seeds from their local MOA office. Farmers in Chilalo (41%) are the major beneficiaries and 11% of the farmers in Ticho bought seeds from MOA. In 1990/91 seasons about 77

and 79% of the farmers did not apply any herbicides at all, although herbicides are considered very effective and economical in controlling weeds in the region.

Table 6.2 Adoption of Wheat Production Technologies in Arssi Districts, 1990/91.

Variety	Keleta	Chilalo	Galema	Gedeb	Ticho
ENKOY					
Average Yield kg/ha	1216	1330	1441	1068	805
Adoption Rate(% of Farmers)	74	41	88	69	49
DASHEN					
Average Yield kg/ha	1057	934	900		
Adoption Rate(% of Farmers)	6	51	2		
BULK					
Average Yield kg/ha		1333	1950	1025	965
Adoption Rate(% of Farmers)		15	2	28	43
Fertilizer Adoption	Percent of Farmers				
% of Farmers Not Using	13	3	14	13	26
% of Farmers Using	87	97	86	87	74
Rates of Fertilizer kg/ha					
Less than 25 kg/ha	30	11	5	29	28
GT 25 LE 50 kg/ha	32	18	19	34	34
GT 50 LE 75	21	25	20	15	13
GT 75 LE 100	11	36	53	19	19
GT 100	6	10	3	3	4
Use of Herbicides					
Not Using	52	47	96	100	92
Using	48	53	4		8

Source: Field Survey, 1991.

A recent study by the Ministry of Agriculture's National Fertilizer and Inputs Unit (NFIU) supported by FAO Fertilizer Program reports that fertilizer consumption in Ethiopia has concentrated in Arssi, Gojam and Shewa regions amounting to 75% of the country's fertilizer consumption. These regions produce half of the total cereal production cultivating 45% of the national area under food crops. In these regions, the study shows that about a third of the farmers have adopted fertilizer use, implying a 15 to 20 percent adoption rate at the national level (Fischer and Shah, 1990). In order to select and subsequently recommend a viable package of production practices for small farmers we need to compare alternative technical packages using the partial budgets and marginal rate of return analysis. Analysis for the farmers' reported production practices is presented in the last table.

The MOA /FAO study on crop yield response and fertilizer policies estimated fertilizer response functions (using a quadratic polynomial response curve)²⁵ for six cereal crops including wheat, and three categories of oilseeds and pulses for the different agro-ecological zones of Ethiopia. The estimated models provide a useful set of values for important parameters that can be used in arriving at economically optimal levels of fertilizer. According to the wheat yield response function, a maximum yield of 3227 kg/ha is attained at the level of

²⁵ Quadratic polynomial response curve is given as: $y = A + B \cdot F + C \cdot F^2$ where y is yield per ha., F is fertilizer use per ha. and A,B,C are yield function parameters. Further mathematical proofs show that parameters A,B and C measure maximum yield, the share of yield explained by fertilizer use and maximum level of fertilizer use respectively. For further details see Fischer and Shah, 1990.

143 kg/ha fertilizer. Fertilizer use contributed 75% of the increase in wheat yield. The economically optimal rate is 131 kg/ha. The following Tables (6.2 and 6.3) show the partial budget and marginal analysis of wheat yield response under zero level and six incremental levels of the most commonly used and available fertilizer (DAP) in Arssi. Farmers' use of fertilizers ranges from none to more than 100 kg/ha. Accordingly farmers' levels of fertilizer use are grouped into:

- a) 0 - 25 kg/ha,
- b) 26 - 50 kg/ha,
- c) 51 - 75 kg/ha,
- d) 76 - 100 kg/ha and

e) more than 100 kg/ha. The grouping is similar to the levels indicated in Tables 6.2 and 6.3. Other on-farm trials have used different rates and sources of nitrogen and phosphorus.²⁶ A response function estimated from fertilizer and variety on-farm trials recommended for the region's predominant soil type and color is employed to estimate the wheat yield for the different levels of fertilizers used in the analysis. The yields range from 1582 kg/ha for the control plot to 2776 kg/ha for the 150 kg/ha fertilizer level. The highest rate of 200 kg/ha gave a yield of 2739 kg/ha as shown on the response curve of Figure 3.

²⁶For more detailed explanations on alternative sources of Nitrogen and Phosphorus for wheat producing areas see Tanner et al " Developing Technologies to Improve Soil Fertility, Weed Control and Wheat Varieties" In Franzel and van Houten(1992).

Table 6.3 Partial Budget Analysis of Wheat Yield Under Selected Fertilizer Levels in Arssi, 1990

DAP Kg/ha (N:P ₂ O ₅)	Yield Kg/ha	Gross benefit EB/ha	Fertilizer Cost EB/ha	Net Benefit EB/ha
0	1582	965	0	965
25.00 (4.5:11.5)	2241	1367	24.43	1343
50.00 (9 :23)	2420	1476	48.86	1427
75.00 (13.5:34.5)	2563	1564	73.29	1490
100.00 (18:46)	2670	1629	97.72	1531
150.00 (27:69)	2777	1694	146.58	1547
200.00 (36:92)	2739	1671	195.44	1476

Source: Yield data obtained from the MOA/NFIU/FAO(1990) Fertilizer and Variety on-farm Trials for Southeastern Ethiopia

6.1.2 Marginal Analysis

Marginal rate of return (MRR) is the ratio of marginal net benefits to marginal variable cost expressed as a percentage. In this particular study MRR is calculated for different rates of fertilizer applications to determine alternative recommendations for farmers. After estimating the net benefits of the different fertilizer levels as shown in the partial budget analysis in Table 6.2, we need to compare their relative profitability from the farmers' perspectives. Marginal

analysis helps to determine the rate of increase in net benefits as investments increase.

Boughton et al. (1990) list the four steps in marginal analysis:

- 1) dominance analysis (identification and elimination of inferior treatments)
- 2) construction of a net benefit curve,
- 3) calculation of the marginal rate of return (MRR) between treatments of incremental cost,
- 4) comparison of MRR to the minimum rate acceptable to farmers (50-100%).

The 200 kg/ha level has a higher cost of 195 EB/ha and a net benefit of 1475 EB/ha. The next lower level of 150 kg/ha has a higher net benefit of 1547 EB/ha with a cost of 146.58 EB/ha. The 200 kg/ha level is therefore a dominated treatment when compared to the next lower rate. Moving from no fertilizer application to 25 kg/ha gave the highest MRR(1546%) while the move from 100 to 150 kg/ha treatment generated only 33% MRR. Although the net benefit increases as one moves from the lower to the next higher rate, the MRR is decreasing. The results of this analysis suggest that given current yield, wheat and fertilizer prices, farmers' application rates should not exceed the 100 kg/ha level as the next higher level gives an MRR of only 33%, which is lower than the generally accepted minimum return of 50 to 100%. Adoption of other production practices to increase the yield, and changes in the crop-fertilizer price relationship, are required to make fertilizer use economical and acceptable to small farmers.

Table 6.4 Marginal Analysis of Wheat Yields Under Different Fertilizer Levels in Arssi, 1990/91

Fertilizer Level	Net Benefit	Variable Costs	Dominated	MRR
Kg/ha	EB/ha	EB/ha	Yes/No	%
200	1476	195	YES	-147
150	1548	147	NO	33
100	1531	98	NO	168
75	1490	73	NO	257
50	1427	48	NO	347
25	1343	24	NO	1546
0	965	0		

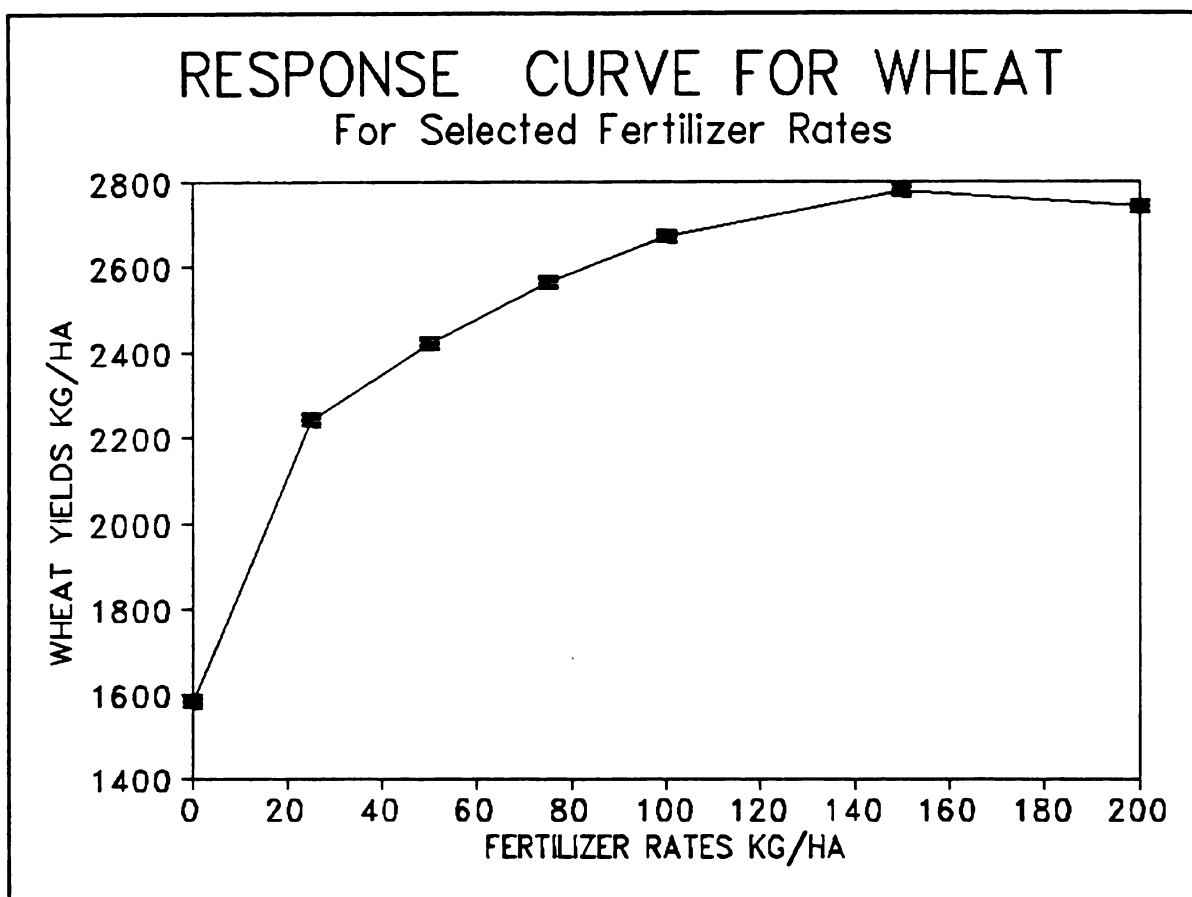


Figure 6 Response Curve for wheat under selected fertilizer rates, Arssi, 1990/91

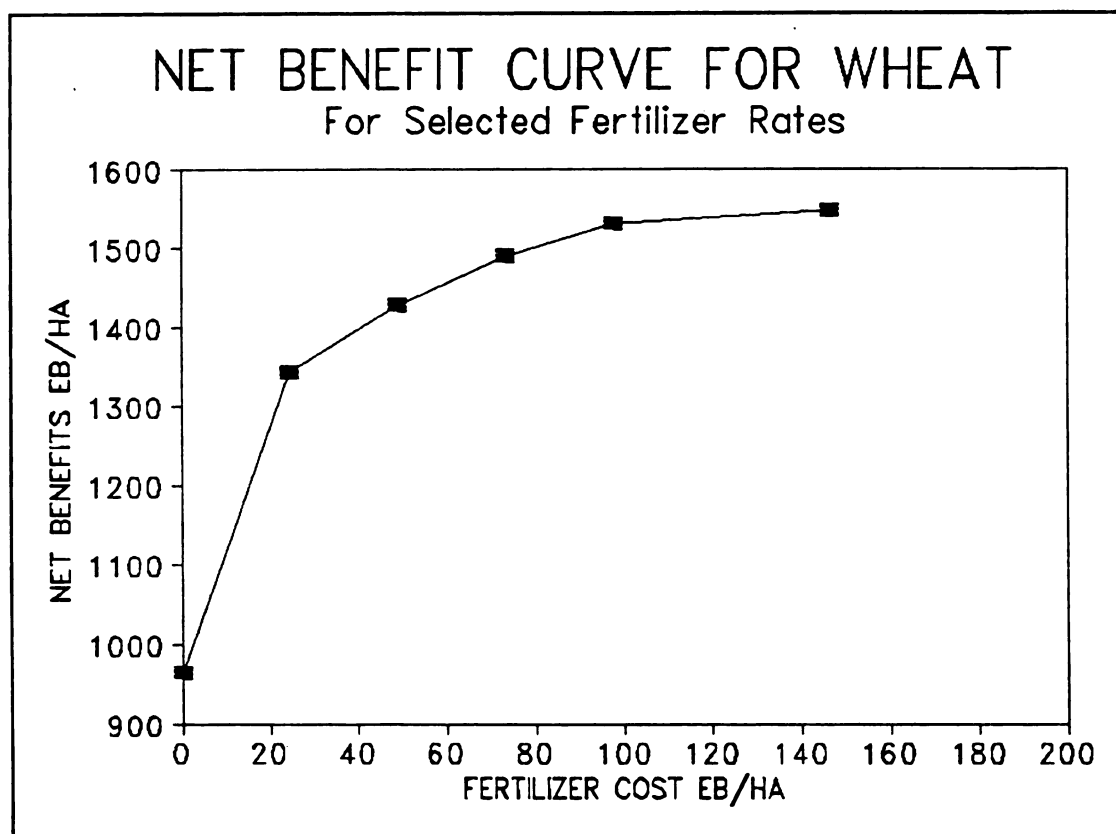


Figure 7 Net Benefit Curve for Wheat and fertilizer Response in Arssi, 1990/91.

Table 6.5 Adoption, Fertilized Area and Rates of Fertilizer Use in Arssi Districts, 1990

District	Sample Farmers Number	Adopters Percent	Average Fertilized Area Per farm Ha	Area Fertilized Percent	Application Rate Kg/Ha
Keleta	103	99	0.79	97	89
Chilalo	54	100	0.64	100	91
Galema	65	100	0.88	97	94
Gedeb	20	95	0.71	98	69
Ticho	11	91	0.72	88	78
Arssi	344	98	0.78	98	90

Source: Crop-Wise Fertilizer Usage Study, Planning and Programming Dept., MOA/NFIU, May 1991

Tables 6.5 and 6.6 are compiled from MOA data on Crop-wise Fertilizer Usage 1991 and Fertilizer Trials on Major Cereal Crops, 1986-89 published in 1991. The studies indicate that 98% of the sample farmers in the districts have used fertilizer on their wheat fields. The average rate of fertilizer application for the region is about 90 kg/ha.

The survey results report lower rates of adoption (87%) and 72 kg/ha rate of fertilizer application. One possible explanation for the difference could be that extension agents tend to report to their superiors at headquarters higher rates that are closer to the recommended levels of 100-150 kg/ha.

Table 6.6 Economic Optimum Rate of Fertilizer for Wheat Production in Arssi, 1986-89.

Table 6.6 Economic Optimum Rate of Fertilizer Levels for Wheat Production in Arssi

Control Plot yield Range kg/ha	Average Yield of Control Plot kg/ha	Nutrient Level N P ₂ O ₅ kg/ha	Increase in Yield kg/ha	Profit EB/ha	VCR ^a
Less than 1100	735	28 55	720	264	3.2
1100 - 1700	1444	42 50	833	312	3.4
Greater than 1700	2355	19 44	454	152	2.7

Source: ADD/NFIU/ MOA/FAO Results of Fertilizer Trials Conducted on Major Cereal Crops(1986-1989), January 1991.

^aVCR is Value Cost Ratio (the ratio of the value of yield increase to cost of fertilizer)

The economic optimum rates of fertilizer levels recommended for three control yield levels indicate that farmers have to use about 136 kg/ha of DAP and Urea combined to increase the less than 1100 kg/ha yield without fertilizer by 720 kg/ha. Use of 158 kg/ha fertilizer will increase yield from 1444 to 2277 kg/ha. The potential areas where the control yield is greater than 1700 kg/ha are recommended to use about 100 kg/ha fertilizer to push the yield level from 2355 to 2809 kg/ha. The value cost ratio of wheat yield value to fertilizer cost suggest that farmers can benefit 2.7 to 3.4 Birr for every Birr they invest in fertilizer use.

6.1.3 Comparison of Alternative Wheat Production Packages

Four alternative wheat production packages will be compared to assess the profitability of the technologies. The packages will also identify farmers' adoption

categories and can be used to relate to specific farmer characteristics. The packages identified have the following components:

- a) HYV of wheat either retained or purchased from MOA office,
- b) different levels of fertilizer use and
- c) herbicide use or hand weeding.

Production Packages: The data from the study areas reveal that farmers' production practices differ in terms of the levels of purchased inputs used in the production process. Four possible production practices are identified for the analysis:

- 1) **Low input package (LIP):** in which farmers use 50 or less kg/ha of fertilizer, own/retained wheat seeds, and family labor for hand weeding (no herbicides are used);
- 2) **Limited Inputs Package (LMIP):** use of 50 - 75 kg/ha of fertilizer, purchased wheat seeds and no herbicides but hand weeding using family labor;
- 3) **Medium Inputs Package (MIP):** 75 - 100 kg/ha of fertilizer, purchased seeds and herbicides
- 4) **High Inputs Package (HIP):** greater than 100 kg/ha of fertilizer, purchased seeds and herbicides.

Previous studies undertaken by CADU/ARDU indicate yield differentials of 23.9 %, 15% and 32% between farmers not weeding, hand weeding only, late application of herbicides and early spraying of herbicides, respectively. Seed purity is estimated to affect the yield level at least by 200 kg/ha (Tanner and

Giref, 1991). Calculations of the expected benefits and costs are presented in Table 6.7. It is assumed that the averages for purchased improved wheat, fertilizer and herbicides are: 0.93 EB/kg, 0.91 EB/kg, 0.29 EB/lit, respectively. Farm gate wheat prices are assumed to be 0.71 EB/kg while the opportunity cost of labor for weeding at the peak season is imputed at 3 EB/day. Based on these assumptions gross benefits, variable costs and net benefits are calculated for the four alternative packages designated as LIP, LMIP, MIP and HIP reflecting the intensity of input use. The HIP alternative gave the highest net benefit per ha (1713 EB) while the minimum/low input LIP produced a net benefit of 1158 EB/ha. Prices, levels of fertilizer use, seed quality and source, use of herbicide and time of application have contributed to the apparent difference in the yields, costs and subsequently in the net benefits shown in Table 6.7. Similarly the marginal rate of return analysis confirms that the MIP yields the highest MRR of 437% over the LMIP alternative. Farmers who have better access to resources can invest in the HIP production alternative and earn 208% MRR. The availability of high yielding varieties, level of input use, crop, fertilizer and herbicide prices will obviously affect the net benefits and the marginal rates of return of each alternative package. The magnitude and the relative impact of possible and assumed changes can be calculated using sensitivity analysis.

Table 6.7 Partial Budget and Marginal Analysis of Alternative Production Packages^a for Wheat Farmers in Arssi

Item	UNIT	LIP	LMIP	MIP	HIP
Average Yield ^b	KG/HA	2330	2765	3284	3468
Adjusted Yield (10% Loss)	KG/HA	2097	2488	2956	3121
Crop Price	EB/KG	0.70	0.70	0.70	0.70
Gross Benefits	EB/HA	1468	1742	2069	2185
Inputs and Costs					
Labor ^c	MANDAYS/HA	32	38	46	48
Labor Cost	EB/HA	96	114	138	144
Seed Rate	KG/HA	240	206	190	175
Seed Cost /ha ^d	EB/HA	168	191	177	163
Fertilizer Rate	KG/HA	50	75	100	150
Cost of Fertilizer	EB/KG	0.91	0.91	0.91	0.91
Fertilizer Cost/ha	EB/HA	45	68	91	136
Herbicide Rate/ha	LITER/HA	0	0	1	1
Herbicide Unit Cost	EB/HA	0	0	29	29
Herbicide Cost/ha	EB/HA	0	0	29.00	29
Total Variable Cost	EB/HA	309	374	435	472
Net Benefit	EB/HA	1158	1368	1634	1713
MRR	%		326	437	209

^a Alternative Packages are identified as Low, Limited, Medium and High Inputs Packages (LIP, LMIP, MIP and HIP).

^b Average wheat yields are estimated using MOA/NFTU trial data and the yield response functions for Arssi.

^c Labor use includes harvesting, weeding and herbicide application and computed at its opportunity cost during peak season.

^d Seed used from previous harvest is assumed to have an opportunity cost of EB 0.70/kg which the farm gate price.

6.2 Econometric Analysis

This section presents the econometric analysis that identify the determinants of adoption and assess the effects of significant variables on the probability and intensity of adoption. Econometric models discussed in chapter 5 are employed to analyze technology adoption in the study region. Logit models are used to identify factors responsible for adoption and no adoption of fertilizers and herbicides by wheat growers. Ordered probit model is employed to study the factors responsible for farmers' choices of different rates of fertilizer application, i.e, from no use to higher rates of fertilizer use. Tobit model is used to further analyze the variables contributing to the continued adoption and quantity of fertilizer use. The econometric analysis on the choice of the different wheat varieties did not give a satisfactory result. This could be because farmers mostly use their own seed from past harvests and even if they want to buy them the improved seeds are not available. They do not have a choice but to use the available variety that has adapted in their respective districts. However a survey of farmers' opinions on varietal preference indicate that variety-specific characteristics are important in their adoption decision. Characteristics that farmers consider important are yield, color, resistance to diseases, tastes in local foods ('injera'), bread, price and adaptability in the area.

6.2.1 Binomial Logit Estimates

Farmers' socio-economic circumstances and other institutional variables are used in the logit analysis of fertilizer and herbicide adoption or nonadoption. The dependent variable for fertilizer use is fertilizer used for wheat in 1990 (FW90), coded as 0 or 1. Similarly the dependent variable for herbicide use is APHBW90, coded 0 for not using and 1 for application of herbicides. Maximum likelihood estimation techniques are used and the results are presented in the following tables. The coefficient for farmer's age category (AGEHCAT) as expected has a negative sign implying that older household heads tend not to adopt fertilizer technologies. Level of education of household heads, family size (FMLSZ) and farm size (FARMSZHA) have positive effects on the probability of adoption. LVLEDHH and FARMSZHA are not statistically significant while FMLSZ is significant at the 5 % level in this specific analysis.

Further analysis is useful to determine whether farm size will have an effect in the intensity of use rather than on the incidence of technology adoption. The Logit analysis results suggest that access to credit (GETCRDT), herbicide use (APHBW90) and timely availability of fertilizer (GTFTML) variables are the most important determinants of fertilizer adoption and no adoption. Their coefficients have the expected positive signs and are statistically significant at the 1%, 1% and 5% levels, respectively. Farmers' knowledge of fertilizer use, number of oxen owned and extension contact have positive signs as expected but are nonsignificant.

Table 6.8 Logit Estimates of Fertilizer Adoption in Arssi, 1990/91.

<u>Variables</u>	<u>Coefficients</u> (t-ratio)	<u>Partials</u>
Constant	0.5202 (0.662)	0.02386
AGEHCAT*	-0.3151 (-1.641)	-0.0144
LVLEDHH	0.0585 (0.289)	0.0027
FMLSZ	0.1131 (1.892)	0.0052
FARMSZHA	0.0756 (0.642)	0.00346
OXNUM90	0.1601 (1.079)	0.0073
GTFTML**	0.6338 (1.851)	0.0289
GETCRDT***	0.9958 (3.071)	0.0455
KWRFTRT	0.1034 (0.385)	0.0047
APHBW90***	1.2758 (2.537)	0.0583
DAVST90	0.2641 (0.504)	0.0121

(***, **, * indicate level of significance at the 1,5, and 10% levels, respectively)

The model correctly predicted the probability of adoption and no adoption for 85 per cent of the cases. The partial derivatives given in column 3 of Table 6.8 reflect the respective effects of the continuous explanatory variables on the probability of adoption that are very minimal.

The marginal effects of the binary regressors (coded as 0 or 1) are calculated by substituting their values (0 or 1) and the results are reported in Table 6.9.

The effects of technical and institutional variables on farmers' decisions to use or not use fertilizer are indicated in the table above.

Table 6.9 Relative Effects of Significant Variables on Probability of Fertilizer Adoption in Arssi, 1990/91

VARIABLES Values of Selected Binary Variables Coded 0 or 1								
GTFTML	0	1	0	0	0	0	1	1
GETCRDT	0	0	1	0	0	0	1	1
KWRFTRT	0	0	0	1	0	0	1	0
APHBW90	0	0	0	0	1	0	1	0
DAVST90	0	0	0	0	0	1	1	0
PROB.OF ADOPTION	0.7368	0.8407	0.8834	0.7563	0.9093	0.7847	0.9866	0.9346

<u>RELATIVE EFFECTS ON PROBABILITY</u>	<u>PROBABILITY OF ADOPTION</u>
NO TECHNICAL OR INSTITUTIONAL SUPPORT	0.7368
EXTENSION SERVICE	0.7847
ACCESS TO CREDIT	0.8834
HERBICIDE AVAILABILITY	0.9093
TIMELY FERTILIZER AND CREDIT AVAILABILITY	0.9346
AVERAGE ADOPTER BASED ON MEAN VALUES	0.8891
INPUTS AND SUPPORTS AVAILABLE	0.9866

Since the farmers in the region have been aware of improved production technologies since 1968, it is not surprising that the average farmer has an 88% probability of using fertilizer. Those farmers having no access to extension service, and no knowledge of the recommended rates of fertilizer and herbicides

rates) and institutional support (access to credit, timely availability of fertilizer and herbicide) will increase the incidence of adoption to more than 90 per cent. The complete package of inputs and services will raise the use of fertilizer to 98 per cent. It is worth mentioning that farmers' decisions to use fertilizer are related to their use of herbicide as these inputs are complementary in crop production. Farmers' resources of land, labor and number of oxen owned appeared less important in determining the incidence of adoption. However, the Tobit analysis will identify the effects of economic, technical and institutional variables on both the adoption and the intensity of fertilizer use.

6.2.2 Ordered Probit Analysis

Agricultural extension and research organizations have attempted to develop fertilizer recommendations for different crops based upon agro-ecological zones and soil types as discussed in the earlier sections. Given farmers' resources and environmental circumstances, researchers have to further refine their technical recommendations to be economically and socially feasible and acceptable. The ordered probit model is used to identify the factors influencing farmers' decisions to select any of the five rates of fertilizer levels (no use or less than 25 kg, 25 -50 kg, 50 -75 kg, 75 - 100 kg, greater than 100 kg/ha). The ordered probit estimates in Table 6.10 show that farmers' knowledge of fertilizer recommended rates, educational levels, and ability to get fertilizer on time are critical variables (significant at 1 % level) influencing the decision to use higher rates of fertilizer per hectares. Age category (young, middle age, old) and family size have a

Table 6.10 Ordered Probit Analysis for Different Rates of Fertilizer Use in Arssi,

1000/01

<u>Variable</u>	<u>Coefficient</u> (t-ratio)
Constant	0.19525 (0.634)
AGEHCAT	-0.61320 (-0.820)
LVLEDHH***	0.20464 (2.569)
FMLSZ	-0.1005 (-0.511)
FARMSZHA	0.45490 (1.066)
OXNUM90*	0.81287 (1.593)
GTFTML**	0.26073 (2.262)
GETCRDT*	0.17130 (1.527)
KWRFTRT***	0.18847 (3.136)
APHBW90	0.20295 (1.517)
DAVST90	0.10004 (0.573)
MU(1)	0.82230 (12.142)
MU(2)	1.3355 (16.765)
MU(3)	2.5586 (21.348)

(***, **, * indicate level of significance at the 1,5, and 10% levels, respectively)

negative effect on the dependent variable. The results confirm that older farmers and larger families tend to avert risk by not investing in higher rates of fertilizer.

The coefficients are not equal to the marginal effects of the regressors.

The probabilities of adopting the five different fertilizer rates are computed using equation 12²⁷.

$$\begin{aligned}
 \text{Prob}[Y = 0] &= \Phi(-\beta'X), \\
 \text{Prob}[Y = 1] &= \Phi(\mu_1 - \beta'X) - \Phi(-\beta'X), \\
 \text{Prob}[Y = 2] &= \Phi(\mu_2 - \beta'X) - \Phi(\mu_1 - \beta'X) \\
 \text{Prob}[Y = 3] &= \Phi(\mu_3 - \beta'X) - \Phi(\mu_2 - \beta'X) \\
 \text{Prob}[Y = 4] &= 1 - \Phi(\mu_3 - \beta'X).
 \end{aligned} \tag{12}$$

The predicted probabilities are computed by substituting the estimated values for $\beta'X$ and μ_s and Φ values from Z table.

<u>Predicted probabilities</u>	<u>Actual Relative Frequencies</u>
Prob[Y = 0] = 0.2005	0.21127
Prob[Y = 1] = 0.2955	0.27465
Prob[Y = 2] = 0.2025	0.18779
Prob[Y = 3] = 0.2588	0.27465
Prob[Y = 4] = 0.0427	0.05164

The model predictions are very close to the actual frequencies of the data and it correctly predicts 76 % of the cases. Given the mean values for the explanatory variables it is expected that only 4.2% of the farmers in the study area will use the

²⁷The predicted probabilities for the five rates coded j=0, 1, 2, 3 and 4 are calculated using the regression estimates for $\beta'X$ and MUs given a normal distribution.

recommended rate of 100 kg/ha and 26 % of the farmers will apply 75 - 100 kg/ha.

6.2.3 Tobit Analysis of Adoption and Use of Fertilizer

The coefficients of the Tobit model used to investigate factors associated with the adoption and the quantity of fertilizer used in wheat production are reported in Table 6.11. The results of the Logit and Ordered Probit models suggest that the institutional variables are more important explaining the incidence or choice of adoption. The findings of the Tobit analysis confirm that resource endowments and their availability play critical role in the adoption and intensity of fertilizer use. Variables FARMSZHA, OXNUM90, APHBW90, and DAVST90 have a significant effect on adoption and use of fertilizer. The regression equation is computed using the mean values of the independent variables.

The predicted probability of adoption for a farmer with characteristics X (the vector of explanatory variables) is estimated as²⁸ :

$$F(X'B/\sigma) = 0.85591,$$

where F is the cumulative standard normal distribution function.

According to these findings there is 85.6% chance that an average farmer would apply fertilizer. Expected value of fertilizer use across all observations as defined by the Tobit model (Tobin, 1958) is given as:

²⁸The predicted probability is computed using results in Table 6.11:

Where $X'B = 49.2974$,

$\sigma = 46.41346$ then

$F(X'B/\sigma) = F(49.2974/46.41346) = F(1.062136)$,
from the Z table $F(1.06216) = 0.855913$.

$E(Y) = X\beta F(z) + \sigma f(z)$ and substituting the values for the estimates shown in the table, $E(Y) = 49.2974(0.85591) + 46.41346(0.2651609) = 54.50117$ kg.

where $z = X\beta/\sigma$ and $f(z)$ is the unit normal density.

Similarly the expected quantity of fertilizer used by an adopter is :

$$E(Y^*) = X\beta + \sigma f(z)/F(z) = 63.67628 \text{ kg.}$$

Table 6.11 Tobit Analysis of Adoption and Intensity of Fertilizer Use in Arssi, 1990/91.

<u>Variable</u>	<u>Coefficient</u> (t-ratio)
Constant	-3.6448 (0.292)
AGEHCAT*	-4.6776 (1.510)
LVLEDHH	4.1675 (1.294)
FMLSZ	0.64187 (0.703)
FARMSZHA***	9.9668 (5.569)
OXNUM90***	8.6339 (3.943)
GTFTML	0.65634 (0.130)
GETCRDT	5.0806 (1.074)
KWRFTRT*	5.5388 (1.550)
APHBW90***	17.810 (3.084)
DAVST90**	14.557 (2.135)
σ	46.413 (26.027)

(***, **, * indicate level of significance at the 1,5, and 10% levels, respectively)

These estimates show that the average (considering adopters and non adopters) farmer is expected to use 55 kg of fertilizer while those farmers who have adopted will use 64 kg of fertilizer per farm. This expected rate of application would be less than 25 kg/ha given an average farm size of 2.7 hectares per household. This

suboptimal rate of fertilizer use hence calls for a comprehensive approach to alleviate the constraints of adoption.

Furthermore, the results of the Tobit model can be used to identify the effects of changes in an explanatory variable on the adoption and intensity of use. McDonald and Moffitt (1980) present a Tobit decomposition approach to separate two effects. The two effects are: changes due to likelihood of new adoption and expected changes in intensity of adoption by those who have already adopted. For the study the total probability of adoption (i.e, 0.85) is decomposed to give probability of 0.55 and 0.30 for new adoption and intensity of use, respectively. The decomposition of the effects is important to identify the influence of adoption determinants on the sequential stages of adoption, i.e., to adopt or not to adopt and then to continue using the technology.

Table 6.12 presents the elasticity of decomposition for changes in the explanatory variables. Total elasticity of a change in the level of any of the variables consists of two effects: elasticity of expected use intensity (E_1) and elasticity of adoption probability (E_2).

Table 6.12 Tobit Elasticity Decomposition for Changes in the Explanatory Variables on Fertilizer Adoption and Intensity of Use

VARIABLE	MEAN	BETA	XB	Partials			Marginals			Elasticity	
				dE_y^*/dX_1	$dF(z)/dX_1$		ME_1	ME_2		E_1	E_2
CONSTANT	1.0000	-3.6448	-3.6448								
AGEHH	2.8615	-4.6776	-13.3850	-2.6892	-0.0267	-2.3017	-2.3017	-1.7020	-0.1208	-0.0894	
LVLEDHH	1.2535	4.1675	5.2240	2.3959	0.0238	2.0507	2.0507	1.5164	0.0472	0.0349	
FMLSZ	7.3310	0.6419	4.7058	0.3690	0.0037	0.3159	0.3159	0.2336	0.0425	0.0314	
FARMSZHA	2.7124	9.9668	27.0343	5.7299	0.0569	4.9043	4.9043	3.6264	0.2441	0.1805	
OXNUM90	1.8920	8.6339	16.3355	4.9637	0.0493	4.2484	4.2484	3.1415	0.1475	0.1091	
GTFTML	0.3216	0.6563	0.2111	0.3773	0.0038	0.3229	0.3229	0.2388	0.0019	0.0014	
GETCRDT	0.4390	5.0806	2.2302	2.9208	0.0290	2.5000	2.5000	1.8486	0.0201	0.0149	
KWRTRT	0.8028	5.5388	4.4466	3.1843	0.0316	2.7254	2.7254	2.0153	0.0401	0.0297	
APHEW90	0.2277	17.8100	4.0553	10.2390	0.1018	8.7636	8.7636	6.4802	0.0366	0.0271	
DAVST90	0.1432	14.5570	2.0844	8.3689	0.0832	7.1629	7.1629	5.2966	0.0188	0.0139	
TOTAL XB				49.2976							

ME_1 (Marginal Effect on Adoption) = $E_y^* \cdot (dF(z)/dX_1)$

ME_2 (Marginal Effect on Intensity) = $F(z) \cdot (dE_y^*/dX_1)$

E_1 (Elasticity of Intensity) = $dE_y^*/dX_1 \cdot (x/E_y^*)$

E_2 (Elasticity of Adoption) = $dF(z)/dX_1 \cdot x/F(z)$

The following are estimated by the model and used in the calculation of elasticities above.

$XB = 49.2976$

$F(z) = 0.8359$

$f(z) = 0.2652, \sigma^2 = 46.4135, z = 1.0621$

$[1 - z \cdot f(z)]/F(z) - f(z)^2/F(z)^2 = 0.5749$

$dF(z)/dX_1 = f(z)B_1/\sigma, E_y^* = XB + f(z)/F(z) = 63.6788$

$E_y = F(z)E_y^* = 54.5027, E_y^* \cdot dX_1 = 81 \cdot [1 - z \cdot f(z)/F(z) - f(z)^2/F(z)^2]$

Adding the two effects will give us the total elasticity. Given that there is a high rate or incidence of adoption it is expected that any change in the determinants of adoption will affect more the intensity than the probability of adoption. The elasticities computed therefore confirm that marginal changes in the independent variables listed increase the use intensities(E_1) more than the probability of adoption. Elasticities of adoption probabilities(E_2) are relatively smaller than E_1 . Overall the elasticity estimates in Table 6.12 reflect inelastic ($E < 1$) response to changes in the adoption variables²⁹. Farm size has the highest impact on the use intensity and probability of adoption with a total elasticity value of 0.42. This value is divided into 0.24 and 0.18 for intensity and adoption probability respectively. The implications of these estimates are useful to evaluate proposed policy changes affecting technical and institutional variables used in this study. For example a 10% change in farm size is expected to result in about a 4.2% increase in adoption and use of fertilizer. The expected intensity will increase by 2.4% while the probability of adoption will increase by 1.8%. In addition the wealth variable used in the analysis, i.e., number of oxen owned, has a total elasticity value of 0.26, which is composed of 0.14 and 0.11, the elasticities of intensity and adoption respectively. The other variables are also important in affecting the adoption and quantity of fertilizer use.

²⁹Inappropriate government intervention based on the command economy model has handicapped the performance of agriculture in Ethiopia as discussed in chapter 2. Consequently, input and output prices were fixed for many years by the government. The price responsiveness of small farmers and the effect of prices on technology adoption is not covered in this study. For details on price responsiveness of smallholders in Ethiopia see Shire (1986).

6.2.4 Logit Analysis of Herbicide Adoption

Estimates of the logit model for herbicide use in Table 6.13 show that farm size has a negative effect on the adoption of herbicide in the study area. This is contrary to the previous literature on technology adoption. Farmers reported that they were unable to buy the input in the market as it is rationed by the local extension office. Government policy in the past discouraged the use of herbicides by the smallholder sector while encouraging the state farms. Farmers with larger plots were not able to get herbicide for all their fields and have to use family and/or hired labor for weeding. The coefficient for the extension variable suggests that farmers who have regular contact with the local extension office appeared to use herbicide. The variable DAVST90 has a significant and positive effect on the dependent variable. As in the case of fertilizer use, herbicide use is also enhanced by the use of fertilizer. Most farmers indicated that credit is used primarily for fertilizer purchase. The complementarity of the two inputs is confirmed by the positive effect of access to credit on herbicide use. More credit enables farmers to buy fertilizer and more fertilizer use will encourage farmers to adopt herbicides.

Family size was expected to be negatively affecting herbicide use as labor is a substitute for hand weeding. The labor shortage during critical periods of weeding and harvesting different crops that smallholders grow will not have a substitution effect on herbicide.

Table 6.13 Logit Analysis of Herbicide Adoption in Arssi, 1990/91.

Maximum Likelihood Estimates^a

<u>Variable</u>	<u>Coefficient</u> (t-ratio)
Constant	-3.0574 (0.8083)
AGEHCAT	0.46805 (0.279)
LVLEDHH *	0.2505 (1.470)
FMLSZ	0.5707 (1.172)
FARMSZHA ***	-0.4261 (-3.744)
OXNUM90 ***	0.3250 (2.697)
GETCRDT **	0.4527 (1.813)
FW90 **	1.1432 (2.302)
DAVST90 ***	0.9406 (3.018)

^aMultinomial Logit Model

LOGIT;LHS=APHBW90;RHS=X

2 Outcomes: APHBW9=0 APHBW9=1

Coefficients for APHBW9=0 set to ZERO.

(***, **, * indicate level of significance at the 1,5, and 10% levels, respectively)

The variable OXNUM90 has a positive relationship with herbicide use indicating the relationship between resource endowment and input use. In this particular analysis, the effects of land and labor did not conform to our theoretical expectation. The results of the analysis do not support the contention that farmers age negatively affect the use of herbicide. The model correctly predicts 78% of the cases and it is expected that an average farmer has only 19% probability to use herbicides given the mean values of the regressors. Herbicide use in the study area is very low as only 22 % of the sample farmers reported as users at one time or another.

6.3 Discriminant Analysis and Adopter Categories

Estimates of the discriminating variables for the five districts and for the region as depicted in Table 6.15, reveal the relative importance of the variables. A total of twelve variables are identified to discriminate the adopter categories. However, only seven of the variables are responsible for the difference among the categories for the region. Farmers' level of education, opinions about herbicide, use of hired labor and access to credit appeared to be most important in classifying the 426 sample farmers into different categories. The number of discriminating variables are three in Galema, four each in Chilalo and Ticho, five in Keleta and six in Gedeb district. Farm size and ownership of radio came out to be important in four of the five districts suggesting the critical role of farmers' resources and access to information in technology adoption. Level of education, access to credit, oxen number, knowledge about herbicide and farmers' attendance

of field days and demonstrations (ATFLDD) are relevant in two districts each while the rest of the five variables appeared to be important in only one of the five districts.

Table 6.15 Discriminant Estimates for Adopter Categories in Arssi Districts, 1990/91

	Keleta		Chilalo		Galema		Gedeb		Ticho		Arssi	
Discrim	Coeff	Lambd	Signf	Coeff	Lambd	Signf	Coeff	Lambd	Signf	Coeff	Lambd	Signf
AGECAT			.650	.921	.0586							
LVLEDHH						-.875	.949	.0912	.289	.889	.0194	
GETCRDI			.570	.851	.0263				-.353	.808	.0080	.316 .937
OXNUM90									-.424	.694	.0108	.420 .915 .1009
THKHBDAV	.377	.778	.0087						.672	.942	.0722	.376 .915
HIRLABR	.838	.926	.025									.339 .897
OMNRDIO			.055	.786	.0392	.672	.893	.034	.527	.718	.0071	.504 .867 .135
OFFRMJ												.267 .894
DAVST90	.581	.868	.0091									.246 .894
FARMSZHA	-.208	.831	.0072	-.569	.814	.0293	.401	.864	.0390	.484	.760	.0073
FMLSZ	-.091	.804	.0083									
ATFLDD							.452	.667	.0137	-.561	.893	.131

The accuracy of the classification procedure is measured by the per cent of correctly predicted cases in each group. Actual and predicted classification of farmers into fertilizer and herbicide users and three adopter categories is shown in Table 6.16. The actual and predicted number of farmers in each of the fertilizer and herbicide users and adopter category are converted to percent of farmers in each district and the total sample. Accordingly the actual figures show that 97 and 53 percent of the farmers use fertilizer and herbicide, respectively. For the same district the model predicted 90 and 74 percent of the farmers to apply fertilizer and herbicide respectively. The farmers in Keleta rank second in the use of these inputs. Farmers in Gedeb do not use herbicide at all.

Table 6.16 Discriminant Model Prediction and Actual Classification of Adopter Categories: Percent of Farmers.

	Keleta		Chilalo		Galema		Gedeb		Ticho		Arsi	
	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
Adoption Category												
Fertilizer users	87	70	97	90	86	76	87	69	74	57	86	57
Herbicide Users	48	67	53	74	4	2	0	0	8	7	23	17
Low Adopters	18	14	7	4	5	2	29	21	27	13	17	11
Moderate Adopters	53	18	43	27	39	18	49	22	47	22	46	14
Advanced Adopters	29	15	50	27	56	35	22	13	26	10	37	17

Ticho and Galema farmers are the least in fertilizer and herbicide use respectively. In terms of adoption category for the entire sample, the actual classifications indicate that about 17%, 46% and 37% of the sample farmers fail into low, moderate and advanced adopters categories, respectively. Galema farmers tend to use inputs more intensively as more than half of them are classified (35% predicted) as advanced adopters. About 40 to 50 % of farmers in each of the five districts and 46% in Arssi are classified as moderate adopters. Among the low adopters, Gedeb and Ticho farmers constitute the largest shares. The predicted figures are lower than the actual and this also suggests the problem in the predicting ability of the model. The per cent of correct predictions are better for the fertilizer and herbicide use classification. For example the model correctly predicted 90% and 74%; 72% and 71% of fertilizer and herbicide users in Chilalo and Keleta. The model predictions for the three adopter categories ranged from 46 to 62% for the districts and is only 41% correct predictions for the whole region. The implications of these classifications in the identification of important variables and ranking them based on their relative contribution in discriminating one group from the other group is critical in the design of research and extension strategy.

6.4 Summary

In chapter six, the profitability of wheat production technologies, econometric analysis of technology adoption and classification of adopter categories are examined and the results of the analysis are presented.

6.4.1 Profitability of Production Technologies

Partial budget and marginal rate of return analysis techniques are used to evaluate the profitability of wheat production technologies. The results are presented for three scenarios : a) farmers' production practices (Table 6.1), b) selected levels of input use (Table 6.3 and 6.4) and c) comparison of four alternative production packages (Table 6.7).

The variety Enkoy grown in all the districts generated a net benefit of EB 548/ha in Keleta, and EB 432/ha in Galema district followed by Dashen with EB 412/ha in Keleta. The third variety Bulk gave lower net benefits ranging from EB 135 to 182/ha.

The survey data suggest the suboptimal rate of fertilizer application. A fifth of the sample farmers in Arssi use less than 25 kg of fertilizer per hectare. Almost half of the respondents use 50 kg or less and the highest users are farmers in Galema and Chilalo (81 kg/ha). Results of the partial budget for the different levels of fertilizer use reveal that the 100 kg/ha rate gave a net benefit of EB 1531/ha and the 200 kg/ha level had EB 1476/ha. A move from 100 kg/ha to 150 kg/ha yields an MRR of only 33% which is not in the minimum acceptance range of 50-100%.

Four possible production practices under different levels of input use, i.e., Low input package (LIP), Limited Inputs Package (LMIP), Medium Inputs Package (MIP), High Inputs Package (HIP) are compared. Based on different prices and opportunity cost assumptions, gross benefits, variable costs, net benefits and marginal rate of returns are calculated for each alternative package. Prices, levels of fertilizer use, seed quality and source, use of herbicide and time of application have contributed to the apparent difference in the yields, costs and in the net benefits.

The HIP alternative yielded the highest net benefit per ha (1713 EB) while the minimum/low input LIP produced a net benefit of 1158 EB/ha. The MIP gave the highest MRR of 437% over the LMIP alternative and the HIP yielded 209% MRR (Table 6.7). Farmers' decision criteria to select any one of the alternative packages will be influenced by their access to resources. Farmers without a capital constraint to purchase inputs can choose the HIP package.

6.4.2 Econometric Analysis of Incidence and Intensity of Adoption

Descriptive statistics on adoption rates of the three wheat varieties, fertilizer (including proportion of farmers in different fertilizer application rates) and herbicide use by district are presented. The results indicate that the most popular variety Enkoy is adopted by farmers in the five districts. Galema farmers (88%) grow Enkoy while 41% of the farmers in Chilalo adopted the same variety. At the same time Dashen is grown by only 6 and 2% of the growers in Keleta and Galema. Despite its high yield, the incidence of disease has restricted the use of

Dashen to Chilalo. The variety Bulk is more adopted by farmers in Ticho (43%) and Gedeb (28%).

Logit Analysis: The logit maximum likelihood estimation procedure was used to obtain consistent, efficient and asymptotically normal estimators (Table 6.8). The coefficient for farmer's age category (AGEHCAT) has a negative sign implying that older household heads tend not to adopt fertilizer technologies. Level of education of household heads, family size (FMLSZ) and farm size (FARMSZHA) have positive effects on the probability of adoption. LVLEDHH and FARMSZHA are not statistically significant while FMLSZ is significant at the 5 % level in this specific analysis. The results suggest that access to credit (GETCRDT), herbicide use (APHBW90) and timely availability of fertilizer (GTFTML) variables are the most important determinants of fertilizer adoption. Farmers' knowledge of fertilizer use, number of oxen owned and extension contact have positive signs as expected but are not significant. The model correctly predicted the probability of adoption and no adoption for 85 per cent of the cases.

The marginal effects of the explanatory variables are calculated by substituting their values (0 or 1) and the results are reported in Table 6.9. Provisions of technical support (extension) and institutional support (access to credit, timely availability of fertilizer and herbicide) will increase the incidence of adoption to more than 90 per cent. Availability of the complete package of inputs and services will raise the use of fertilizer to 98 per cent. Farmers' resources of

land, labor and number of oxen owned appeared less important in determining the incidence of adoption.

Estimates of the logit model for herbicide use (Table 6.13) show that farm size has a negative effect on the adoption of herbicide in the study area. This is contrary to the previous literature on technology adoption. The coefficient for the extension variable DAVST90 which is significant suggests that farmers who have regular contact with the local extension office appeared to use herbicide. The complementarity of fertilizer and herbicide is suggested by the positive effect of access to credit on herbicide use. The expected substitution effect between labor and herbicide was not observed in this study.

The model correctly predicts 78% of the cases and it is expected that an average farmer has only 19% probability to use herbicides given the mean values of the regressors. Herbicide use in the study area is very low as only 22 % of the sample farmers reported being users at one time or another.

Probit Analysis: Ordered probit model was used for analyzing the factors influencing farmers' decisions to select any of the five rates of fertilizer levels (no use or less than 25 kg, 25 -50 kg, 50 -75 kg, 75 - 100 kg, greater than 100 kg/ha). The ordered probit estimates in Table 6.10 showed that farmers' knowledge of fertilizer recommended rates, educational levels, and ability to get fertilizer on time are critical variables (significant at 1 % level) influencing the decision to use higher rates of fertilizer per hectare. Age category and family size have a negative effect on the dependent variable. The results confirm that older farmers

and larger families tend to avert risk by not investing in higher rates of fertilizer.

The predicted probabilities for selecting any of the five levels for an average household are computed by substituting mean values of the explanatory variables into the regression equations. The predictions are very close to the actual frequencies of the data; the model correctly predicts 76 % of the cases. Given the mean values for the explanatory variables it is expected that only 4.2% of the farmers in the study area will use the recommended rate of 100 kg/ha and 26 % of the farmers will apply 75 - 100 kg/ha.

Tobit Analysis: The findings of the Tobit analysis revealed that resource endowments play a critical role in the intensity of fertilizer use. Variables FARMSZHA, OXNUM90, APHBW90, and DAVST90 have a significant effect on adoption and use of fertilizer (Table 6.11). According to these findings there is an 85.6% chance that an average farmer would apply fertilizer. These estimates also indicated that the average farmer who is a new adopter is expected to use 55 kg of fertilizer while those farmers who have already adopted will use 64 kg of fertilizer per farm. This expected rate of application would be less than 25 kg/ha given an average farm size of 2.7 hectares per household.

A Tobit decomposition approach was used to separate the two effects. For the study the total probability of adoption (i.e. 0.85) is decomposed to give a probability of 0.55 and 0.30 for new adoption and intensity of use, respectively. Table 6.12 presented the elasticity of decomposition for changes in the explanatory variables.

6.4.3 Adoption Categories

Classifying farmers into different adopter categories is undertaken by using the technique of discriminant analysis. Estimates of the discriminating variables for the five districts and for the region were depicted in Table 6.15. Twelve variables are identified to discriminate the adopter categories. However, only seven of the variables were responsible for the difference among the categories for the region. Farmers' level of education, opinions about herbicide, use of hired labor and access to credit appeared to be most important in classifying the 426 sample farmers into the low, moderate and advanced adopter categories.

CHAPTER 7

SUMMARY, CONCLUSIONS AND IMPLICATIONS

7.1 Introduction

7.1.1 Background of the Study

Ethiopia is one of the poorest countries in Sub Saharan Africa. The agricultural sector employs 86% of the population, and accounts for 45% of the GDP and 90% of the export earnings. While agriculture has significant potential, its performance has been dismal.

Ethiopia is the largest wheat producer in Sub Saharan Africa with 687,000 ha under wheat cultivation. The central, southeastern and northwestern highlands have favorable climatic conditions for wheat production. Wheat area, production and yield increased (0.4, 3.2 and 2.8% per annum, respectively) in the 1983-92 period due to the expansion of mechanized state farms and adoption of improved technologies by state farms and smallholders. However, production lagged behind the rapid increase in wheat consumption of nearly 3.5% per year. Average wheat yields are lower than in other countries in Southern and Eastern Africa. Since, Ethiopia is importing about half of its wheat requirements, it is important to increase wheat production and save vital foreign exchange.

Ethiopia is in a transition to a market economy and it needs to formulate new agricultural policies based on empirical studies. Although microeconomic studies

have been conducted for export crops and commodities, there are only a few studies on the economics of wheat production in Ethiopia. This study is designed to fill that gap.

7.1.2 Research Objectives

The general objective of the study has been to examine the social, economic, and institutional factors that influence the adoption of selected wheat production technologies in Arssi Region in the Southeastern Highlands of Ethiopia. Arssi is a major wheat and barley producing region and the home of the first integrated rural development project that was launched in 1968 with assistance from Sweden.

This study was undertaken in the Arssi Region in order to draw lessons from the experiences of technology adoption in the region. The region has 12 districts; the study was carried out in the five major wheat growing districts of Chilalo, Keleta, Galema, Gedeb and Ticho.

The components of the production package include high-yielding varieties (HYVs), chemical fertilizers and herbicides.

The specific objectives of the dissertation were to:

- 1) present descriptive information on wheat production by smallholders in Arssi region;
- 2) determine the profitability of smallholder wheat production;
- 3) generate quantitative estimates of the factors influencing the incidence and intensity of adoption of wheat production technologies;

- 4) identify constraints on the adoption of recommended technologies for wheat;
- 5) classify farmers by adopter categories based on adoption patterns and socioeconomic characteristics;
- 6) draw implications for agricultural research, extension, and policy changes needed to overcome the constraints on adoption.

7.1.3 Technology Adoption: An Overview

Studies of hybrid corn adoption in the United States in the 1930s and subsequent studies by many economists and sociologists have shown that the path of technology adoption approximates a cumulative normal distribution with an S-shaped curve. Studies in the Third World have shown that the factors responsible for adoption of technologies vary across countries, regions, farms and the type of enterprises.

The literature reveals that technology adoption is a function of various social and economic characteristics. Most studies have viewed adoption of a technological practice in isolation from other related practices, ignoring the interdependencies of different technological practices. Most studies have viewed adoption as a discrete choice which assumes farmers will eventually adopt a full range of technologies. Finally most studies have considered few explanatory variables and hence the models are underspecified.

This study takes these limitations into account and examines the interrelated technological practices of HYVs, fertilizer and herbicides and the incidence and

intensity of adoption of fertilizer. The study also includes a number of social, economic and institutional variables and adopters' perceptions of technologies.

A survey of 426 smallholders was conducted in the five major wheat-growing districts of Arssi from February to September 1991. Data were collected on farmer characteristics, farm resources, production practices, adoption of wheat varieties, fertilizer and herbicide and farmers' perceptions of recommended technologies. Partial budgets and marginal returns analysis were used to measure the profitability of technologies and alternative production packages identified. Econometric models (logit, probit and Tobit) were estimated and statistically significant variables were identified to measure the relative importance of the variables influencing farmers' adoption decisions.

7.2 Summary of Results

7.2.1 Household Characteristics

Farmers' decision making in adopting technologies is complex and is examined taking into account economic, social and institutional factors. **Family Size/Age:** The mean family size for the region is about 7.3 persons which is higher than the national average of 5 persons. This difference can be explained by the fact that the majority of Arssi families are moslems and practice polygamy. The mean household age is 45 years.

Educational Levels: The literacy rate in the Arssi region is the highest in the country. Seventeen percent of the sample were illiterate compared to 20-39% illiteracy level for the country. Chilalo and Galema districts have 11 and 16

percent illiteracy rates, respectively. About half of the respondents have 3-4 months of literacy education and 22 percent had elementary-level education.

Farm Sizes: The land reform of 1975 resolved the inequitable ownership of land and tenancy problems in most parts of Ethiopia. The mean farm size and arable area for Arssi are 2.7 and 1.9 ha., respectively. There is a significant difference in farm sizes across the study districts. The average farm size per household is 4.1 ha in Gedeb and 1.9 ha in Ticho. Forty percent of the households cultivate two ha or less and the other 45 percent have farm sizes between 2.1 - 4 ha. Only 13 percent of the farmers in Arssi own more than 4 hectares of farm land.

7.2.2 Profitability of Production Technologies

Partial budget and marginal rate of return analysis techniques are used to evaluate the profitability of wheat production technologies. The results are presented for three scenarios: a) farmers production practices, b) increased use of fertilizer only, and c) comparison of four alternative packages of improved inputs. The major findings from the profitability analysis are:

1. The wheat variety Enkoy, which was grown in each of the five surveyed districts, generated a net benefit of Ethiopian Birr (EB) 548/ha in Keleta, and EB 432/ha in Galema district. The Dashen variety generated a net benefit of EB 412/ha in Keleta. The Bulk variety generated net benefits ranging from EB 135 to 182/ha. The popularity and high net benefits of Enkoy reveal that small farmers' adoption decisions are influenced by profitability.

2. The survey revealed a suboptimal rate of fertilizer application. A fifth of the sample farmers in Arssi use less than 25 kg of fertilizer per hectare. Almost half of the respondents use 50 kg or less and the highest users are farmers in Galema and Chilalo (81 kg/ha). The partial budgets for the different levels of fertilizer use reveal that the 100 kg/ha rate gave a net benefit of EB 1531/ha and the 200 kg/ha level gave EB 1476/ha. An increase from 100 kg/ha to 150 kg/ha yields a marginal rate of return (MRR) of only 33% which is not in the minimum acceptance range of 50-100%.
3. Based on the results of the MRR analysis of fertilizer levels used in the study, we can conclude that given the 1991 season crop-fertilizer price relationship farmers' fertilizer application rates should not exceed the 100 kg/ha level.
4. The following four possible production practices under different levels of input use are identified for the comparative analysis:
 - a) Low input package (LIP): in which farmers use 50 or less kg/ha of fertilizer, own/retained wheat seeds, and relied on family labor for hand weeding;
 - b) Limited input package (LMIP): use of 50 - 75 kg/ha of fertilizer, purchased wheat seeds and hand weeding using family labor;
 - c) Medium input package (MIP): 75 - 100 kg/ha of fertilizer, purchased seeds and herbicides;

- d) High input package (HIP): greater than 100 kg/ha of fertilizer, purchased seeds and herbicides.

The HIP alternative yielded the highest net benefit per ha (1713 EB) while the LIP produced a net benefit of 1158 EB/ha. The MIP gave the highest MRR of 437% and the HIP yielded a 209% MRR. Farmers' decision criteria about the alternative packages will be influenced by their access to resources. Farmers without a capital constraint are able to purchase inputs and can adopt the HIP package. This is different from the above recommendation (3) which was based on fertilizer use only and did not include other package components (improved seed, herbicide).

7.2.3 Analysis of Farmers' Production Practices and Technology Adoption

The initial benefits of the integrated rural development project in the Arssi region went largely to the land-owning class in Arssi, but the radical land reform of 1975 gave the small farmers access to land and improved production technologies. The results of the study reveal that compared to farmers in other regions of Ethiopia, farmers in Arssi:

- a) have high rates of fertilizer adoption (87%),
- b) apply an average of 71 kg fertilizer per ha for wheat,
- c) fertilize 55% of the cultivated area per household, and
- d) have more than 15 years of awareness and knowledge about fertilizer use.
- e) wheat has become an important food and cash crop (an average household markets about half its wheat production).

In terms of fertilizer application rates, there was considerable variation across the five districts. Almost half of the sample farmers in the region use 50 kg or less of fertilizer per ha. About 60% of farmers in the districts of Ticho and Gedeb apply 50 kg or less fertilizer per ha while the same proportion of farmers in Chilalo and Galema use relatively higher rates (75-100 kg/ha).

Wheat Varietal Adoption and Herbicide Use: Enkoy is grown in all the districts and is the highest yielder except in Ticho. Enkoy, which is grown throughout different zones of the region, has a yield gap of 45% between research station and on-farm trials, and a 30% yield gap between on-farm trials and farmers' reported yields. Wheat gets priority in the use and allocation of purchased farm inputs. In Chilalo and Keleta, 52 and 48% of the farmers reported using herbicides.

Adopters' Perceptions of Technologies: Recent studies identify three paradigms for technology adoption: a) innovation-diffusion, b) economic constraints and c) adopters' perceptions. The surveyed farmers reported that unavailability, late delivery and high prices are the major reasons for not using fertilizer, herbicide and HYVs in Arssi. Wheat varieties are preferred by farmers for their specific attributes. For instance, 75 and 84 and 55% of the respondents reported that yield is the most important criterion in selecting the three most popular varieties: Dashen, Enkoy and Bulk. Other factors such as grain color, grain price, taste in preparing local foods, resistance to lodging and diseases are listed as important criteria in varietal preference by farmers.

7.2.4 Econometric Analysis of Incidence, Intensity and Determinants of Adoption

Farmers' adoption decisions are analyzed using qualitative response models, which constrain the estimated probabilities of adoption to a range between 0 and 1. The two most popular are the logit and probit models.

Logit Analysis: The logit is used to model yes/no adoption decision of farmers. The logit analysis results suggest that access to credit, herbicide use and timely availability of fertilizer variables are the most important determinants of fertilizer adoption. Their coefficients have the expected positive signs and are statistically significant at the 1% and 5% levels. The model correctly predicted the probability of adoption and no adoption for 85 per cent of the cases. Farmers' knowledge of fertilizer use, number of oxen owned and extension contact have positive signs as expected but are not significant. The coefficient for farmer's age category has a negative sign implying that older household heads tend not to adopt fertilizer technologies. Level of education of household heads, family size and farm size have positive effects on the probability of adoption. Family size is significant at the 5 % level in this analysis.

The marginal effects of the binary regressors are calculated by substituting their values in the estimated logit model. Since farmers in the region have been aware of improved production technologies since 1967/68, it is not surprising that the average farmer has an 88% probability of using fertilizer. Farmers without access to extension service and no knowledge of the recommended rates of

fertilizer and herbicides are expected to have a 73% probability of using fertilizer. Results of the logit analysis further indicate that subsequent provisions of technical support (extension) and institutional support (access to credit, timely availability of fertilizer and herbicide) will increase the incidence of adoption to more than 90 per cent. If the complete package of inputs and services is available, fertilizer adoption will increase to 98 per cent.

Farmers' decisions to use fertilizer are related to herbicide use because these inputs are complementary in crop production. Farmers' resources of land, labor and number of oxen owned appeared less important in determining the incidence of adoption. Estimates of the logit model for herbicide use show that farm size has a negative effect on the adoption of herbicides in the study area. Farmers reported that they were unable to buy herbicides in the market. Local extension officers rationed herbicides to cooperative members only.

Most farmers indicated that credit is used to purchase fertilizer. The complementarity of fertilizer and herbicide is suggested by the positive effect of access to credit on herbicide use. Credit enables farmers to buy fertilizer and more fertilizer use will encourage farmers to adopt herbicides. Family size was expected to negatively affect herbicide use since labor can be used for hand weeding. Labor shortage during critical periods of weeding and harvesting of different crops is a major constraint. Farmers use both labor and herbicide to control weeds.

Ordered probit analysis: Farmers have a choice of using different levels of fertilizer application. The ordered probit model was used for analyzing the factors influencing farmers' decisions to select one of the five levels of fertilizer. The probit estimates showed that farmers' knowledge of fertilizer recommended rates, educational levels, and ability to get fertilizer on time are critical variables (significant at 1 % level) influencing the decision to use higher rates of fertilizer per hectare. Age and family size have a negative effect on the dependent variable. Older farmers and larger families tend to avert risk by not investing in higher rates of fertilizer. The predicted probabilities for selecting any of the five levels for an average household are computed by substituting mean values of the regressors into the regression equations. The predictions are very close to the actual frequencies of the data; the model correctly predicts 76 % of the cases. Given the mean values for the explanatory variables it is expected that only 4.2% of the farmers in the study area will use the recommended rate of 100 kg/ha and 26 % of the farmers will apply 75 - 100 kg/ha.

Tobit Analysis: The Tobit model measures not only the probability that a farmer will adopt the new technology, but also the intensity of use of the technology once adopted.

The results of the logit and ordered probit models identified the importance of institutional variables in explaining adoption. The findings of the Tobit analysis, however, reveal that resource endowments play a critical role in the adoption and intensity of fertilizer use. Farm size, number of oxen owned,

herbicide use and visit by extension agent variables have a significant effect on adoption and use of fertilizer. According to these findings there is an 86% chance that an average farmer would apply fertilizer. These estimates also indicated that the average farmer who is a new adopter is expected to use 55 kg of fertilizer while those farmers who have already adopted will use 64 kg of fertilizer per farm. This expected rate of application would be less than 25 kg/ha given an average farm size of 2.7 hectares per household for the region.

Elasticity of Adoption: The results of the Tobit model were also used to identify the effects of changes in an explanatory variable on the adoption and intensity of use. A Tobit decomposition approach was used to separate the two effects: a) changes due to likelihood of new adoption and b) expected changes in intensity of adoption by those who have already adopted. For the study the total probability of adoption (i.e. 0.85) is decomposed to give a probability of 0.55 and 0.30 for new adoption and intensity of use, respectively.

Farm size has the highest impact on the use intensity and probability of adoption with a total elasticity value of 0.42. This value is divided into 0.24 and 0.18 for intensity and adoption probability, respectively. These estimates are useful in evaluating proposed policy changes affecting technical and institutional variables used in this study. For example, a 10% increase in farm size is expected to result in about a 4.2% increase in adoption and use of fertilizer.

7.2.5 Adoption Categories

Discriminant analysis was used to classifying farmers into different adopter categories. Twelve variables are identified to discriminate the adopter categories, but only seven were responsible for the difference among the categories for the region. Farmers' level of education, opinions about herbicide, use of hired labor and access to credit helped classify the 426 sample farmers into the low, moderate and advanced adopter categories. The number of discriminating variables is three in Galema, four each in Chilalo and Ticho, five in Keleta and six in Gedeb district. Farm size and ownership of a radio were important in four of the five districts, suggesting the critical role of farmers' resources and access to information.

In terms of adoption category for the entire sample, 17%, 46% and 37% of the sample farmers are low, moderate and advanced adopters, respectively. More than half of the Galema farmers are classified as advanced adopters. About 40 to 50% of farmers in each of the five districts and 46% in Arssi are classified as moderate adopters. Among the low adopters, Gedeb and Ticho farmers constitute the largest proportion.

7.3 Policy Implications

7.3.1 Implications for Agricultural Research

The descriptive information on wheat producers and the subsequent econometric analysis of technology adoption shed some light on the crucial role of agricultural research and the availability of appropriate technology. The following major implications emerge from the results of the analysis:

1. Although farmers in the study area are aware of the recommended technologies, particularly fertilizer, HYVs and herbicides, they are using suboptimal levels of these inputs because of the unavailability of inputs, high input prices relative to grain prices, or farmers' own reservations about the technologies.
2. Since 20% of the farmers use less than 25 kg fertilizer per ha, it is imperative to develop low input technologies. Agricultural researchers have to focus on refining the fertilizer recommendations so that they can tailor their recommendations for different farming systems and for farmers with different levels of resources.
3. The three most popular varieties have their specific attributes that farmers demand. The most widely used variety, Enkoy, gives a stable yield and has disease resistance. Dashen is susceptible to disease and Bulk has a lower yield. Future crop improvement programs have to consider the specific attributes of varieties that influence farmers' decisions.

4. The IAR has recently incorporated adopters' perceptions of specific characteristics of technology into its research agenda. This research should be expanded. A demand-driven agricultural research program requires feedback from the users.

7.3.2 Implications for Agricultural Extension

The major duties of the extension agents are input distribution, organizing and managing demonstration sites and field days, and organizing and promoting agricultural cooperatives. The implications of the study for the agricultural extension service are summarized below.

1. In the past 17 years, the extension service was preoccupied with promoting collective agriculture, leaving little time for assistance to smallholders. The study reveals that since the adoption of new technology is influenced by the frequency of extension contact, the extension service needs to design a cost-effective way of reaching the smallholders who are located in the remote rural areas of the country.
2. The role of the extension service in creating the link between farmers and researchers is critical in technology development and transfer. The study found that farmers are not using the recommended packages of technologies. With feedback from farmers, extension agents will be in a better position to understand what factors are contributing to the suboptimal use of recommended inputs. Extension feedback will also

contribute to the design of effective technology development and transfer policies.

3. The study has demonstrated that higher levels of education of farmers contributed to increased rates and intensity of adoption. The extension program has to design technical training programs to provide farmers the required skills.

7.3.3 Implications for Agricultural Development Policy

The challenges facing Ethiopia in the 1990s are the achievement of food security, agricultural growth and sustainable development. Our findings in this study reveal that smallholders are responsive to economic incentives and that the smallholder road to development should form the centerpiece of agricultural policy. The government should consider investing a higher percentage of its resources in the smallholder sector while reducing the allocation for producer cooperatives and state farms. Government resources are needed to strengthen and expand agricultural research and extension services to enhance technology generation and transfer.

Farmers in the study districts are not using the recommended levels of inputs because of the physical unavailability of inputs, and the lack of credit and high input prices. The lack of rural credit and input delivery institutions has been identified as a major constraint on technology adoption. The current government or project run input distribution system has not been effective. There is a need to

design an alternative input delivery system. The role of the private sector in input delivery should be explored.

7.4 Limitations of the Study and Recommendation for Further Research

The main objective of the study was to examine the social and economic factors influencing technology adoption in Arssi region. The ultimate goal of this study was to contribute to the knowledge base on technology adoption by smallholders. The limitations of this study are associated with the data. The data were collected during the political upheaval in 1991. In this insecure atmosphere, the author and the enumerators were unable to travel to some of the selected villages. Farmers were hesitant in responding to questions related to past and present yields, prices, wages, farm size and farmers' opinions on government institutions. These issues were found to be sensitive in the prevailing political situation.

Time series data on farmers' awareness and use of different varieties, and quantities produced and used for home consumption and seed, are important in analyzing adoption over time. Since this study used cross sectional data from one season, the conclusions are only indicators of the technology adoption process and the factors responsible for enhancing or constraining adoption in the study area.

Several related issues were beyond the scope of this study and merit additional investigation:

1. The results of the econometric analysis of this study suggest that institutional factors influence adoption decisions more than economic and

technical factors. Ethiopian agriculture is characterized by weak research- extension linkage, marketing and input delivery systems. Further research is needed on institutional innovations for smallholders.

2. This study provided evidence on the rates and intensity of adoption. The results can be used to design future research on impact assessment to strengthen technology development and transfer efforts. A follow-up rate of return study on wheat research in Ethiopia is needed to formulate a policy on agricultural research resource allocation.
3. Ethiopia is importing about half of its wheat requirements. Since the profitability of wheat production is influenced by macro prices (wage, exchange rate and interest rate) that are set by the government, a study of the entire wheat sub sector will improve the empirical basis for appropriate policy formulation.
4. There is a potential to increase wheat acreage and irrigated wheat production. An in-depth economic analysis of irrigated wheat production and other alternative/competing enterprises would assist policy makers and agricultural researchers in formulating priorities for wheat research and development.

APPENDICES

APPENDIX I

Institute of Agricultural Research

Dept. of Agricultural Economics

Questionnaire on the Economics of Smallholder Wheat Production and
Technology Adoption in Southeastern Ethiopia.

Principal Investigator: Mulugetta Mekuria, Ph.D candidate,

Dept of Agricultural Economics, Michigan State University, East Lansing

Farmer's Name _____

PA _____

Awraja: Keleta-1, Chilalo-2, Galema-3, Gedeb-4, Ticho-5

AWRAJA _____

FNUMB _____

ENUM _____

Farmer Number _____

Enumerator _____

Date _____

Instruction to the Enumerator

Please introduce yourself before starting questioning the farmers by name location, the institute you are working for and its purpose and objective. Please ask each question patiently until the farmer gets the point. Please fill up the questionnaire according to the type of question. For open question fill the farmer response in short and for closed one indicate by ticking (v). or encircling (1).

QUESTIONNAIRE

I HOUSEHOLD CHARACTERISTICS

1. Household head:

1.1 Male _____ 1 Female _____ 2 SEXHH _____

1.2 Age _____ years. AGEHH _____

1.3 Level of formal education: Illiterate _____ 0 LVLEDHH

Literacy campaign _____ 2 Elementary ed. _____ 3

Secondary ed. _____ 4.

1.4 If female, where is the husband not relevant-0dead-1, soldier-2, divorced-3, other-4

LOCHUSB _____

1.5. How long have you been farming? _____ years.

2. Household Members

2.1. Number of adults living in household FMLSZ _____

over 17. _____ ADT 17+ _____

2.2. Number of children 14-17 _____ CHD 14-17 _____

2.3 Number of children less than 14 _____ CHD 14- _____

2.4 Number working and living off farm _____ NWLOFFM _____

3. Land

3.1 Total farm size _____ timad FARMSZ _____

3.2 Arable/cultivated area _____ timad ARBLAREA _____

3.3 Grazing area _____ timad GRZAREA _____

3.4 Fallow _____ timad FALWAREA _____

3.5 Other(specify) _____ timad OTHERAREA _____

4. Land tenure of farmer

1. Own	YES	___ 1	NO	___ 2	LDTNOWN_____
2. Family	YES	___ 1	NO	___ 2	LDTNFAM_____
3. Own/family	YES	___ 1	NO	___ 2	LDTNOWF_____
4. Share cropping	YES	___ 1	NO	___ 2	LDTNSHR_____
5. Rent	YES	___ 1	NO	___ 2	LDTNRNT_____
6. Borrow	YES	___ 1	NO	___ 2	LDBRW_____
7 If share cropping, area _____				timad	SHRAREA_____
8 If renting, area _____				timad	RNTAREA_____
9 If borrowing, area _____				timad	BRWAREA_____

5. Fertilizer

5.1 Did you apply fertilizer on the following crops in the 1990 and 1991 crop season?

	<u>1990</u>		<u>1992</u>		
	<u>Yes</u>	<u>No</u>	<u>Yes</u>	<u>No</u>	
Wheat	1	2	1	2	FW90__ FW91__
Barley	1	2	1	2	FB90__ FB91__
Faba bean	1	2	1	2	FFB90__ FFB91__

5.2 If No. reasons

Not heard of fertilizers/never tried before_____	1	RNNOFAP_____
Too expensive _____	2	
Unavailable _____	3	
Late delivery _____	4	
Farmer believes that fertilizer doesn't increase yield_____	5	
Other (specify) _____	6	

5.3. If yes amount used

	<u>1990</u>		<u>1991</u>	
CROP	Amount (kg)		Amount (kg)	
	DAP	Area Urea Area	DAP	Area Urea Area
Wheat	_____			
Barley	_____			
Faba bean	_____			

5.4 Do you know the recommended fertilizer rate? KWRFTRT_____

by IAR or MOA Yes ___ 1 No ___ 2

5.5 If yes, what are the recommended rates for 1990/91?

	DAP (kg/ha)	Urea (kg/ha)
Wheat	_____	_____
Barley	_____	_____
Faba bean	_____	_____

5.6 If the recommended rate is higher than what the farmer had used
(Refer. Q. 8.3) ASK. Why the farmer did not apply more fertilizer?

	RLFTAP_____
Too expensive_____1	
Unavailable_____2	
Late delivery_____3	GTFTTML_____
Higher rates damage the crop_____4	
Other (specify)_____5	

5.7 Do you get fertilizer on time? Yes_____1

No _____2

- 5.8 How far do you travel to buy fertilizers? **FTDSTKM**_____
- Distance in km_____
- 5.9 Number of kilometers to the nearest market_____ **NRMKKM**_____
- 5.10. What is the length of time since you **FTAWYR**_____
- first heard about fertilizers? _____
- Years (No.years since the farmer was aware)
- 5.11 How many years have you been **FTUSYR**_____
- using fertilizers? _____
- 5.12 Have you been using fertilizer every **USFTYRL**_____
- year or discontinued using for some
- reason? Use every year_____1
- Have not used every year_____2
- 5.13 According to your view, what are the **ADVFT**_____
- advantages of fertilizers?
- Increase grain yield_____1 **ADVFT**_____
- Increase straw yield_____2
- Improves the quality of the crop_____3
- Other (specify)_____4
- 5.14 Do you think fertilizers have
- disadvantages? Yes_____1 **THKFTDA**_____
- No_____2
- 5.15 If yes, what are the disadvantages
- associated with fertilizer use? **DADVFT**_____
- Favors weed growth_____1 **DADVFT**_____
- Burns/damages the crop_____2
- Doesn't increase grain yield_____3

Expensive/unaffordable_____4

Other (specify)_____5

6. Weed control

6.1 How many times did you weed the following crops?

	1989	1990	1991
Wheat	<u>NWDWH89</u>	<u>NWDWH90</u>	<u>NWDWH91</u>
Barley	<u>NWDB89</u>	<u>NWDB90</u>	<u>NNDB91</u>
Faba bean	<u>NWDFB89</u>	<u>NWDFB90</u>	<u>NWDFB91</u>

6.2 How many weeks after planting do you normally weed your crop?

	Wheat	Barley	Faba bean
Three weeks after planting	<u>3</u>	<u>3</u>	<u>3</u>
Four weeks after planting	<u>4</u>	<u>4</u>	<u>4</u>
Five weeks after planting	<u>5</u>	<u>5</u>	<u>5</u>
Six weeks after planting	<u>6</u>	<u>6</u>	<u>6</u>
Other(specify)	<u></u>		

6.3 Did you apply herbicides on the following crops in the 1990 and 1991 crop seasons?

	<u>1990</u>		<u>1991</u>		
	<u>Yes</u>	<u>No</u>	<u>Yes</u>	<u>No</u>	
Wheat	1	2	1	2	<u>APHBW90</u>
					<u>APHBW91</u>
					<u>APHBB90</u>
Barley	1	2	1	2	<u>ABHBB91</u>
					<u>ABHBB90</u>
Faba bean	1	2	1	2	<u>ABHBB91</u>

6.4 If yes, area sprayed in timad and cost

	<u>1990</u>		<u>1991</u>	
	<u>Area</u>	<u>Birr</u>	<u>Area</u>	<u>Birr</u>
Wheat	WTARSP90_____	WHBCO90_____	WTASP91_____	WTHBCO91_____
Barley	BARSP90_____	BHBCO90_____	BARSP91_____	BHBCO91_____
Faba bean	FBARSP90_____	FBHBCO90_____	FBARSP91_____	FBHBCO91_____

6.5 If the farmer had used herbicide, what are the advantages of herbicides?

Saves labor to do other tasks _____ 1 **ADVHBUS**_____

Reduce weeding labor requirement _____ 2

Controls weeds better than hand weeding _____ 3

Increase yield_____ 4

Gives more time to rest_____ 5

Other (specify) _____ 6

6.6. Do you think herbicides have disadvantages? **THKHBDV**_____

Yes _____ 1 No _____ 2

6.7. If yes, what are the disadvantages **DADVHB**_____

associated with herbicides use?

Too expensive_____ 1

Risk of not working if little moisture_____ 2

Unavailability of sprayers_____ 3

May burn or damage the crop_____ 4

Lack of technical knowledge on use_____ 5

Don't control weed adequately_____ 6

Other (specify)_____ 7

6.8. If the farmer did not use herbicides in both **RNOHBVS**_____

years, why did he not use herbicide?

Not heard of herbicides_____1

Expensive/unavailable_____2

Herbicides do not solve the weed problem __3

Farmer has enough labor_____4

Other (specify)_____5

7. Seed:

7.1 What kind of seed (variety) did you plant in the 1990 and 1991 crop seasons?

	1990		1991		
	Improved	Local	Improved	Local	
Wheat1	1	2	1	2	WIMPS90 _____
_____					WIMPS91 _____
Barley	1	2	1	2	BIMPS90 _____
_____					BIMPS91 _____
Faba bean	1	2	1	2	FIMP90 _____
_____					FIMP91 _____

7.2 If the farmer had planted improved varieties, what are the varieties? (list)

Crop	Variety	1990		1991	
		Area	Amount	Area	Amount
Wheat	Dashen	_____	_____	_____	_____
	ENKOY	_____	_____	_____	_____
	BULK	_____	_____	_____	_____
	K6295 4A	_____	_____	_____	_____
	Other	_____	_____	_____	_____
Barley	Variety	Area	Amount	Area	Amount
		_____	_____	_____	_____
		_____	_____	_____	_____
		_____	_____	_____	_____
Faba bean	Variety	Area	Amount	Area	Amount
		_____	_____	_____	_____

7.3 If the farmer had planted more than one variety of each or any of the crops, which variety has he liked best?

Crop	Variety	Main reason for liking the best:	
Wheat	1 _____	_____	RVRPREF ₁ _____
	2 _____	_____	RVRPREF ₂ _____
	3 _____	_____	RVRPREF ₃ _____
	4 _____	_____	
Barley	1 _____	_____	
	2 _____	_____	
Faba bean	1 _____	_____	
	2 _____	_____	

LIST OF CRITERIA FOR VARIETY PREFERENCE:

High yield 1 Resistance to disease 2 Resistance to lodging 3
 Earliness 4 Seed size 5 Seed color 6 Weed competition 7 Taste in
 injera 8 Taste in bread 9

7.4 What was your source of seed ?

<u>Source</u>	<u>Wheat</u>	<u>Barley</u>	<u>Faba bean</u>
Received from MOA	1	1	1
Received from Research Team	2	2	2
Purchased	3	3	3
Retained from own harvest	4	4	4
Other (specify)	5	5	5

7.5 If purchased, what was your source of purchase?

	<u>Wheat</u>		<u>Barley</u>		<u>Faba bean</u>	
<u>Source</u>	<u>Amount</u>	<u>Cost</u>	<u>Amount</u>	<u>Cost</u>	<u>Amount</u>	<u>Cost</u>
Service coops	_____	_____	_____	_____	_____	_____
Local Market	_____	_____	_____	_____	_____	_____
Producer Coops	_____	_____	_____	_____	_____	_____
Neighbor	_____	_____	_____	_____	_____	_____
Relatives	_____	_____	_____	_____	_____	_____
Others	_____	_____	_____	_____	_____	_____

7.6 If purchased, how far must you travel to buy improved seed?

Distance in km. _____ DBYISD _____

7.7. Quantity of improved seed harvested and disposed in 1990

Crop variety	Harvested(qt)	Sold(qt)	Price/qt.	Retained(qt)
Wheat				
Dashen	_____	_____	_____	_____
ENKOY	_____	_____	_____	_____
K6290 Bulk	_____	_____	_____	_____
K62954A	_____	_____	_____	_____
Barley	_____	_____	_____	_____
Faba bean	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____

7.8 Did you plant all offield to improved seed?

	1990				1991			
	Yes			No	Yes			No
	All	Half	One-third		All	Half	One-third	
Wheat	10	12	13	20	10	12	13	20
Barely	10	12	13	20	10	12	13	20
Faba bean	10	12	13	20	10	12	13	20

7.9. If No, why did you not plant all of your

RNPIMPS_____

land to improved seed?

Too expensive _____ 1

Unavailability of seed _____ 2

Lack of fertilizer _____ 3

Not aware of it _____ 4

Because of previous bad experience ____ 5

Other (specify) _____ 6

7.10 If you have a question about improved varieties,

fertilizers or herbicides, whom do you ask first? SRCINFO_____

MOA development agent _____ 1

Research team _____ 2

Producer cooperative executive member____ 3

Service cooperative _____ 4

Contact/Model farmer _____ 5

Neighbor _____ 6

Other _____ 7

James G. Gentry

7.11. If the farmer has not used improved varieties of the three crops, ask him/her why he did not plant improved varieties?

Not heard of improved varieties_____1 RNOUSIV_____

Very expensive seed price _____2

Improved varieties unavailable _____3

Improved varieties are not better than local cultivars_____4

Lack of fertilizer_____5

Other (specify)_____6

8. Access to Credit:

8.1. Do you get credit for your farming

operations? Yes_____1 GETCRDT_____

No_____2

8.2 If yes: Purpose: To purchase fertilizers__1 PRPCRDT_____

To purchase improved seed____2

To buy oxen_____3

To buy herbicides_____4

Other(specify)_____5

8.3 Source of credit :

MOA_____1 SRCCRDT_____

Scs_____2

Bank_____3

Neighbor or relative_____4

Local money lender_____5

Other (specify)_____6

8.4. Have you ever been disqualified from getting

credit because of lack of cash for credit down payment?

Yes _____ 1 DISQCRD _____

No _____ 2

9. Do you hire labor? Yes _____ 1 HIRLABR _____

No _____ 2

9.1 If yes for which operations?

	Wheat	Barley	Faba bean
Plowing	1	1	1
Planting	2	2	2
Weeding	3	3	3
Harvesting	4	4	4
Other(specify)	5	5	5

9.2 If no, why?

I have enough labor	1	RNOHIRL _____
Too expensive	2	
No labor available for hiring	3	
Other(specify)	4	

10. Livestock:

10.1 Would you please tell me the number of livestock you have?

Type	1990		1991	
	Number	Value(Birr)	Number	Value(Birr)
Oxen				
Cows				
Male calves				
Female calves				
Horses				

DonkeysMulesSheep

10.2 Are your oxen enough for your farm operations?

ENOXFOP_____

Yes_____1

No_____2

10.3 If No, how do you get additional oxen

SRCADOX_____

when you need them?

Makanajo system_____1

Hire from someone_____2

Borrow from friend or relative_____3

Other (specify)_____4

11. Off-farm activities

11.1 do you have a job off your farm?

OFFARMJ_____

Yes_____1

No_____2

11.2 If yes, Type of work_____

TYPOFJB_____

Type of work_____

11.3 Annual Income earned from off-farm work_____ INCOFJB_____

11.4 Does any one else in the family living with you have job off the
farm?

FAMOFJ_____

Yes_____1

No_____2

11.5. If yes, type of work_____

JYPOFFJ_____

11.6. Annual income earned_____

11.7. Do you have family member(s) living and working LIVOFWK_____

off-farm? Yes_____1

No_____2

11.8 If yes, annual remittance received from family ANREMRC_____

members living and working off-farm ____ (birr)

12. Access to Information:

12.1 Have you ever attended a field day or ATFLDD_____

demonstration trial? Yes_____1

No_____2

12.2 Have you ever attended a farming ATFTRNG_____

training course? Yes_____1

No_____2

12.3 Do you have a radio? Yes_____1 OWNRDIO_____

No_____2

12.4 If yes, do you listen to any agricultural

education program? Yes_____1

No_____2

LSNAGED_____

12.5 If yes, is the coverage or content of the AGEDCNT_____

program satisfactory? Yes_____1

No_____2

13. Did extension agent visit you last year? DAVST90_____

Yes_____1

No_____2

13.1. Did extension agent visit you this year? DAVST91_____

Yes_____1

No_____2

13.2. If yes, what time of the year or during which operation?

Plowing_____1_____ No.of visit_____

Planting_____2_____ No. of visit_____

Weeding_____3_____ No.visit_____

Harvesting_____4_____ No.visit_____

14. Have you ever lived out side your village? LVDOVLG_____

Yes_____1_____

No_____2_____

14.1. If yes, for how long? _____years. LVDOVYR_____

14.2. How far is your house from the nearest town? _____Km.

APPENDIX II

REGRESSION RESULTS OF LIMDEP PROGRAM

```

TOBIT; LHS=WDPKG90;RHS=X1$
Limited Dependent Variable Model - CENSORED regression
Maximum Likelihood Estimates
Log-Likelihood..... -1968.510
Threshold values for the model: Lower= 0.0000 Upper=+Infinity
Variable Coefficient Std. Error t-ratio Prob|t|>zx Mean of X Std.Dev.of X
Constant -3.6448 12.49 -0.292 0.77048 2.8615 0.91114
AGEHCAT -4.6776 3.098 -1.510 0.13113 1.2535 0.85766
LVLEDHH 4.1675 3.220 1.294 0.19560 1.2535 0.85766
FMLSZ 0.64187 0.9125 0.703 0.48181 7.3310 2.9202
FARMSZHA 9.9668 1.790 5.569 0.00000 2.7124 1.4324
OXNUM90 8.6339 2.190 3.943 0.00008 1.8920 1.1489
GFTML 0.65634 5.052 0.130 0.89664 0.32160 0.46764
GETCRDT 5.0806 4.730 1.074 0.28276 0.43897 0.49684
KWRFTRT 5.5388 3.574 1.550 0.12121 0.80282 0.64614
APHBW90 17.810 5.775 3.084 0.00204 0.22770 0.41984
DAVST90 14.557 6.820 2.135 0.03280 0.14319 0.35068
σ 46.413 1.783 26.027 0.00000

```

1. Matrix -> β1=PART(B,1,11)

```

<<<< β1
1
ROW 1 -3.64485
ROW 2 -4.67760
ROW 3 4.16749
ROW 4 0.641874
ROW 5 9.96683
ROW 6 8.63389
ROW 7 0.656344
ROW 8 5.08063
ROW 9 5.53879
ROW 10 17.8099

```

```

ROW 10 17.8099
ROW 11 14.5569

```

```

3. Matrix -> XB1=MEAN(X1)
<<<< XB1 >>>> COLUMN

```

```

1
ROW 1 1.00000
ROW 2 2.86150
ROW 3 1.25352
ROW 4 7.33099
ROW 5 2.71244
ROW 6 1.89202
ROW 7 0.321596
ROW 8 0.438967
ROW 9 0.802817
ROW 10 0.227700
ROW 11 0.143192

```

```

Calculating ->  $\sigma = S$ 
>>>  $\sigma$  = 46.41346 <<<

```

```

Calculating ->  $BXS = DOT(\beta_1, XB1) / \sigma$ 
>>> BXS = 1.062136 <<<

```

```

Calculating ->  $MU = N01(BXS) / PHI(BXS)$ 
>>> MU = 0.2651609 <<<

```

```

Calculating ->  $P = PHI(BXS)$ 
>>> P = 0.8559130 <<<

```

```

Calculating ->  $P1 = P * (1 - BXS * MU - MU^2)$ 
>>> P1 = 0.5546768 <<<

```

```

Calculating ->  $P2 = N01(BXS) * BXS + N01(BXS) * MU$ 
>>> P2 = 0.3012362 <<<

```

Multinomial Logit Model

Maximum Likelihood Estimates

Log-Likelihood..... -156.8410

Restricted (Slopes=0) Log-L. -174.9653

Chi-Squared (10)..... 36.24866

Significance Level..... 0.7628123E-04

Variable	Coefficient	Std. Error	t-ratio	Prob> t	Mean of X	Std.Dev. of X
Constant	0.52023	0.7863	0.662	0.50824		
AGEHCAT	-0.31515	0.1921	-1.641	0.10086	2.8615	0.91114
LVLEDHH	0.58499E-01	0.2022	0.289	0.77235	1.2535	0.85766
FMLSZ	0.11317	0.5981E-01	1.892	0.05847	7.3310	2.9202
FARMSZHA	0.75586E-01	0.1178	0.642	0.52094	2.7124	1.4324
OXNUM90	0.16007	0.1484	1.079	0.28079	1.8920	1.1489
CTFTML	0.63381	0.3424	1.851	0.06416	0.32160	0.46764
GETCRDT	0.99576	0.3243	3.071	0.00213	0.43897	0.49684
KMRFTRT	0.10336	0.2685	0.385	0.70025	0.80282	0.64614
APHBW90	1.2758	0.5029	2.537	0.01118	0.22770	0.41984
DAVST90	0.26411	0.5237	0.504	0.61408	0.14319	0.35068

Frequencies of actual & predicted outcomes
 Predicted outcome has maximum probability.

		Predicted		
Actual		0	1	TOTAL
0		1	60	61
1		0	365	365
TOTAL		1	425	426
1. Matrix -> XB=MEAN(X1)				
<<<< XB		>>>>		COLUMN
		1		
ROW	1	1.00000		
ROW	2	2.86150		
ROW	3	1.25352		
ROW	4	7.33099		
ROW	5	2.71244		
ROW	6	1.89202		

```

ROW 7 0.321596
ROW 8 0.438967
ROW 9 0.802817
ROW 10 0.227700
ROW 11 0.143192

```

```
Calculating -> P=LGP(DOT(XB,B))
```

```
>>> P      =      0.8890911      <<<
```

```
Calculating -> F=P*(1-P)
```

```
>>> F      =      0.9860815E-01 <<<
```

```
Calculating -> K=ROW(B)
```

```
>>> K      =      11.00000      <<<
```

```
1. Matrix -> DELTA=F*B
```

```
<<<< DELTA >>>> COLUMN
```

```
1
```

```

ROW 1 0.512992E-01
ROW 2 -0.310767E-01
ROW 3 0.576850E-02
ROW 4 0.111592E-01
ROW 5 0.745340E-02
ROW 6 0.157841E-01
ROW 7 0.624990E-01
ROW 8 0.981898E-01
ROW 9 0.101917E-01
ROW 10 0.125806
ROW 11 0.260430E-01

```

```
1. Matrix -> DELTA=F*B
```

```
<<<< DELTA >>>> COLUMN
```

```
1
```

```

ROW 1 0.512992E-01
ROW 2 -0.310767E-01
ROW 3 0.576850E-02
ROW 4 0.111592E-01
ROW 5 0.745340E-02
ROW 6 0.157841E-01

```

```

ROW 7 0.624990E-01
ROW 8 0.981898E-01
ROW 9 0.101917E-01
ROW 10 0.125806
ROW 11 0.260430E-01

```

```

1. Matrix -> G=F*IDEN(K)&((1-2*P)*F)*B|XB'
1. Matrix -> G=F*IDEN(K)&((1-2*P)*F)*B|XB'

```

```

Calculating -> (1-2*P)*F
>>> Result = -0.7673510E-01 <<<

```

3. Matrix -> STAT(DELTA,VARDELTA)

Matrix Statistical results: Coefficients=DELTA Variance=VARDELTA

Variable Coefficient Std.Error t-ratio Prob|t|>=x Mean of X Std.Dev.of X

```

-----
DELTA_1 0.51299E-01 0.7781E-01 0.659 0.50971
DELTA_2 -0.31077E-01 0.1887E-01 -1.647 0.09963
DELTA_3 0.57685E-02 0.1995E-01 0.289 0.77246
DELTA_4 0.11159E-01 0.5866E-02 1.902 0.05714
DELTA_5 0.74534E-02 0.1157E-01 0.644 0.51942
DELTA_6 0.15784E-01 0.1453E-01 1.086 0.27727
DELTA_7 0.62499E-01 0.3352E-01 1.864 0.06226
DELTA_8 0.98190E-01 0.3081E-01 3.187 0.00144
DELTA_9 0.10192E-01 0.2647E-01 0.385 0.70025
DELTA_10 0.12581 0.4633E-01 2.716 0.00661
DELTA_11 0.26043E-01 0.5146E-01 0.506 0.61282

```

MODEL COMMAND:
LOGIT;LHS=APHBW90;RHS=X1\$
Multinomial Logit Model
2 Outcomes: APHBW9=0 APHBW9=1
Coefficients for APHBW9=0 set to ZERO.
Maximum Likelihood Estimates
Log-Likelihood..... -205.8361
Restricted (Slopes=0) Log-L. -228.5412
Chi-Squared (8)..... 45.41021
Significance Level..... 0.3070050E-06
Variable Coefficient Std. Error t-ratio Prob>|t|>zx Mean of X Std.Dev. of X

Constant -3.0732 0.8079 -3.804 0.00014 2.8615 0.91114
AGEHCAT 0.48002E-01 0.1677 0.286 0.77474 1.2535 0.85766
LVLEDHH 0.25499 0.1701 1.499 0.13387 7.3310 2.9202
FMISZ 0.57003E-01 0.4874E-01 1.170 0.24217 2.7124 1.4324
FARMSZHA -0.42616 0.1139 -3.743 0.00018 1.8920 1.1489
OXNUM90 0.32828 0.1203 2.729 0.00636 0.43897 0.49684
GETCRDT 0.45640 0.2496 1.828 0.06752 0.85681 0.35068
FW90 1.1397 0.4966 2.295 0.02174 0.14319 0.35068
DAVST90 0.94117 0.3117 3.019 0.00254 0.14319 0.35068

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

		Predicted		TOTAL
Actual		0	1	
0	321	8		329
1	86	11		97
TOTAL	407	19		426

1. Matrix -> XB=MEAN(X1)

```
<<<< XB      >>>> COLUMN
1
ROW 1 1.00000
ROW 2 2.86150
ROW 3 1.25352
ROW 4 7.33099
ROW 5 2.71244
ROW 6 1.89202
ROW 7 0.438967
ROW 8 0.856808
ROW 9 0.143192
```

```
Calculating -> P=LGP(DOT(XB,B))
>>> P      = 0.1944153 <<<
```

```
Calculating -> F=P*(1-P)
>>> F      = 0.1566180 <<<
```

```
Calculating -> K=ROW(B)
>>> K      = 9.000000 <<<
```

1. Matrix -> DELTA=F*B

```
<<<< DELTA  >>>> COLUMN
1
ROW 1 -0.481321
ROW 2 0.751803E-02
ROW 3 0.399358E-01
ROW 4 0.892776E-02
ROW 5 -0.667442E-01
ROW 6 0.514151E-01
ROW 7 0.714807E-01
ROW 8 0.178490
ROW 9 0.147404
```

```

Matrix -> STAT(DELTA,VARDELTA)
Matrix Statistical results: Coefficients-DELTA      Variance=VARDELTA
Variable  Coefficient  Std. Error  t-ratio  Prob|t|>zx  Mean of X  Std.Dev. of X
-----
DELTA_1  -0.48132      0.1194      -4.031  0.00006
DELTA_2   0.75180E-02  0.2628E-01   0.286  0.77483
DELTA_3   0.39936E-01  0.2655E-01   1.504  0.13250
DELTA_4   0.89278E-02  0.7612E-02   1.173  0.24084
DELTA_5  -0.66744E-01  0.1701E-01  -3.924  0.00009
DELTA_6   0.51415E-01  0.1843E-01   2.790  0.00527
DELTA_7   0.71481E-01  0.3885E-01   1.840  0.06580
DELTA_8   0.17849      0.7523E-01   2.372  0.01767
DELTA_9   0.14740      0.4878E-01   3.022  0.00251

```

Ordered Probit Model
Maximum Likelihood Estimates
Log-Likelihood..... -625.0310
Restricted (Slopes=0) Log-L. -641.2945
Chi-Squared (4)..... 32.52697
Significance Level..... 0.1492110E-05

Cell Frequencies for Outcomes

Cell	Count	Rel.Freq.
0	90.	0.21127
1	117.	0.27465
2	80.	0.18779
3	117.	0.27465
4	22.	0.05164

Variable	Coefficient	Std. Error	t-ratio	Prob t >=x	Mean of X	Std.Dev. of X
Constant	0.12798	0.1358	0.943	0.34592		
LVLEDHH	0.27122	0.6189E-01	4.383	0.00001	1.2535	0.85766
OXNUM90	0.10563	0.4284E-01	2.465	0.01368	1.8920	1.1489
GETCRDT	0.20753	0.1066	1.947	0.05154	0.43897	0.49684
GTFTML	0.24457	0.1131	2.163	0.03053	0.32160	0.46764
MU(1)	0.80673	0.6631E-01	12.166	0.00000		
MU(2)	1.3124	0.7776E-01	16.877	0.00000		
MU(3)	2.5288	0.1192	21.213	0.00000		

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted					
Actual	0	1	2	3	4	TOTAL
0	23	42	0	25	0	90
1	15	59	0	43	0	117
2	6	35	0	39	0	80
3	6	50	0	61	0	117
4	1	8	0	13	0	22
TOTAL	51	194	0	181	0	426

```

Calculating -> BX=B(1)+B(2)*XBR(LVLEDHH)+B(3)*XBR(OXNUM90)+B(4)*XBR(GETCRDT
) +B(5)*XBR(GETFTML)
>>> BX      =      0.8375649      <<<

Calculating -> D0=D0-N01(-BX)
>>> D0      =      -0.2809170      <<<

Calculating -> D1=N01(-BX)-N01(B(6)-BX)
>>> D1      =      -0.1178356      <<<

Calculating -> D2=N01(B(6)-BX)-N01(B(7)-BX)
>>> D2      =      0.4234854E-01 <<<

Calculating -> D3=N01(B(7)-BX)-N01(B(8)-BX)
>>> D3      =      0.2609436      <<<

Calculating -> D4=N01(B(8)-BX)-0
>>> D4      =      0.9546046E-01 <<<

1. Matrix -> BETA=PART(B,1,5)

<<<< BETA      >>>> COLUMN
1
ROW 1 0.127976
ROW 2 0.271224
ROW 3 0.105628
ROW 4 0.207532
ROW 5 0.244570

2. Matrix -> PDP0DX=D0*BETA
<<<< PDP0DX      >>>> COLUMN
1
ROW 1 -0.359508E-01
ROW 2 -0.761914E-01
ROW 3 -0.296728E-01
ROW 4 -0.582993E-01
ROW 5 -0.687038E-01

```

3. Matrix -> PDP1DX-D1*BETA

```
<<<< PDP1DX >>>> COLUMN
1
ROW 1 -0.150802E-01
ROW 2 -0.319598E-01
ROW 3 -0.124468E-01
ROW 4 -0.244547E-01
ROW 5 -0.288190E-01
```

4. Matrix -> PDP2DX-D2*BETA

```
<<<< PDP2DX >>>> COLUMN
1
ROW 1 0.541961E-02
ROW 2 0.114859E-01
ROW 3 0.447321E-02
ROW 4 0.878868E-02
ROW 5 0.103572E-01
```

5. Matrix -> PDP3DX-D3*BETA

```
<<<< PDP3DX >>>> COLUMN
1
ROW 1 0.333946E-01
ROW 2 0.707742E-01
ROW 3 0.275631E-01
ROW 4 0.541541E-01
ROW 5 0.638189E-01
```

6. Matrix -> PDP4DX-D4*BETA

```
<<<< PDP4DX >>>> COLUMN
1
ROW 1 0.122167E-01
ROW 2 0.258912E-01
ROW 3 0.100833E-01
ROW 4 0.198111E-01
ROW 5 0.233467E-01
```

REFERENCES

- Adesina, Akinwumi A. and Moses M. Zinnah. 1993. "Technology Characteristics, Farmers' perceptions and Adoption Decisions: A Tobit Model Application in Sierra Leone." Agricultural Economics, 9:297-311.
- ADD/NFTU/MOA/FAO.1991. Results of Fertilizer trials conducted on Major Cereal Crops(1986-1989). Addis Ababa: MOA.
- Akinola, Amos A. 1987. "An Application of Probit Analysis to the Adoption of Tractor Hiring Services Scheme in Nigeria." Oxford Agrarian Studies 16:70-82.
- Akinola, Amos A. and Trevor Young. 1985. "An Application of the Tobit Model in the Analysis of Agricultural Innovation Adoption Processes." Oxford Agrarian Studies 14:26-51.
- Amemiya, T., 1981. "Qualitative Response Model: A Survey." Journal of Economic Literature, 19:1483-1536.
- Amemiya, T., 1984. "Tobit Models: A Survey." Journal of Econometrics, 24:3-61.
- Audi, Patrick O., and Dale Colyer. 1993. "Adoption of New Technologies by Smallholder Farms in Semi-Arid Areas of Kenya." Paper presented at the Annual Meeting of the American Agricultural Economics Association, Orlando, Florida, August 1-4.
- Bekure, Solomon. 1992. "Priming the Pump of Economic Growth: A Strategy for Agricultural Development in Ethiopia." Paper presented at Symposium on Economic Development in Ethiopia: Economic Policy During the Transition Period. January 15-18.
- Beyene, Hailu., Steven Franzel, and Wilfred Mwangi. "Constraints to Increased Wheat Production in Ethiopia's Smallholder Sector." In Steven Franzel and Helen van Houten (eds). Research with Farmers: Lessons from Ethiopia. C.A.B International.
- Boughton, Duncen., Eric Crawford, Mark Krause, and Bruno Henry de Frahan. 1990. "Economic Analysis of On-Farm Trials: A Review of Approaches and Implications for Research Program Design."

Staff Paper No. 90-78. East Lansing: Dept. of Agricultural Economics, Michigan State University.

- Byerlee, Derek and Steven Franzel. 1993. "Institutionalizing the Role of Economists in National Agricultural Research Institutes." CIMMYT Economics Working Paper No. 93-01. Mexico, D.F.: CIMMYT.
- Byerlee, Derek and Edith Hess de Polanco. 1986. "Farmers' Stepwise Adoption of Technological Packages: Evidence From the Mexican Altiplano." American Journal of Agricultural Economics 68: 520-527
- CIMMYT Economics Program 1992. "The Adoption of Agricultural Technology: A Guide for Survey Design." CIMMYT Economics Working Paper (Draft). Mexico, D.F.: CIMMYT.
- Cleaver, Kevin M., 1993. "A Strategy to Develop Agriculture in Sub-Saharan Africa and a Focus for the World Bank." World Bank Technical Paper Number 203 Africa Technical Department Series. Washington D.C.: The World Bank.
- Debela, Seme and Sentayehu G. Mariam. 1990 "A Review of the Status of Agricultural Research, Extension and Training in Ethiopia." Prepared for IGADD as part of the Agricultural Research Planning Project, Addis Ababa.
- Delgado, Christopher L., John W. Mellor, and Malcolm L. Blackie. 1987. "Strategic Issues in Sub Saharan Africa" In John W. Mellor, Christopher L. Delgado, and Malcolm J. Blackie (eds) Accelerating Food Production in Sub-Saharan Africa Baltimore: John Hopkins Press.
- Eicher, Carl K., 1990. "Building African Scientific Capacity for Agricultural Development." Agricultural Economics. 4:117-143.
- Eicher, Carl K., 1992. "Revitalizing The CGIAR System and NARSs in the Third World." Staff Paper No. 92-73. East Lansing: Dept. of Agricultural Economics, Michigan State University.
- Eicher, Carl K., 1994. "Zimbabwe's Green Revolution: Preconditions for Replication in Africa." Staff Paper No. 94-1. East Lansing: Dept. of Agricultural Economics, Michigan State University.

- Feder, Gershon., Richard E. Just, and David Zilberman. 1985. "Adoption of Agricultural Innovation in Developing Countries: A Survey." Economic Development and Cultural Change, 33:255-298.
- Fischer, G.W and M.M. Shah. 1990. "Ethiopian Agriculture: Crop Yield Response and Fertilizer Policies". Addis Ababa: FAO Fertilizer Program, Project GCPE/ETH/039/ITA, National Fertilizer and Inputs Unit.
- Green, D.A.G. and D.H. Ng'ong'ola. 1993. "Factors Affecting Fertilizer Adoption in Less Developed Countries: An Application of Multivariate Logistic Analysis in Malawi." Journal of Agricultural Economics, 44(1):99-109.
- Green, William H., 1990. Econometric Analysis. New York: Macmillan Publishing Co.
- Griliches, Zvi. 1957. "Hybrid Corn: An Exploration in the Economics of Technological Change." Econometrica 25:501-522.
- Hassan, Rashid M and Hamid Faki. 1993 "Economic Policy and Technology Determinants of the Comparative Advantage of wheat Production in Sudan." CIMMYT Economics Paper No.6. Bangkok, Thailand.: CIMMYT
- Henery, Micheal C. 1988. "Risk, Uncertainty and Adoption of New Agricultural Technology: An Empirical Application of Expected Utility Maximization." "Oxford Agrarian Studies 17:78-94.
- Henery, Micheal C. 1983. "Factors in the Adoption of New Farm Technology in a Less Developed Country with Special Reference to Guyana." Oxford Agrarian Studies 12:163-176
- Herd, Robert W. 1988. "Increasing Crop Yields in Developing Countries: Sense and Nonsense." paper presented at the American Agricultural Economics Association Annual Meeting, Knoxville.
- Herd, Robert W. 1984 "Differing Perspective of the World Food Problem : Discussion." American Journal of Agricultural Economics 66:186-187.
- Institute of Agricultural Research. 1988. " Recommended Research Results" IAR Publication (in Amharic): Addis Ababa

- Jarvis, L.S. 1981. "Predicting the Diffusion of Improved Pastures in Uruguay." American Journal of Agricultural Economics. 63:495-502.
- Jansen, Hans G.P, Thomas S. Walker, and Randolph Barker. 1990. "Adoption Ceilings and Modern Coarse Cereal Cultivars in India." American Journal of Agricultural Economics 72:655-663.
- Judge, George W., R. Carter Hill, William E. Griffiths, Helmut Lutkepohl and Tsoung-Chao Lee. 1988. Introduction to the Theory and Practice of Econometrics 2nd. Edition New York: John Wiley.
- Kebede, Yohannes, Kisan Gunjal and Garth Coffin. 1990. "Adoption of New Technologies in Ethiopian Agriculture: The Case of Tegulet-Bulga District, Shoa Province" Agricultural Economics. 4:27-43.
- Kennedy, Peter. A Guide to Econometrics Cambridge: MIT Press, 1992
- Kmenta, Jan. Elements of Econometrics 2nd. Edition, New York: Macmillan Publishing Company, 1988
- Maddala, G.S. Limited-Dependent and Qualitative Variables in Econometrics. Cambridge University Press, 1983
- Manning, Mervyn H. "Future Technology and Foreign Competition." Agricultural Engineering
- Maredia, Mywish K., 1993. "The Economics of the International Transfer of Wheat Varieties." Unpublished Ph.D Dissertation, East Lansing, Department of Agricultural Economics, Michigan State University.
- McDonald, J.F. and Robert A. Moffitt. 1980. "The Uses of Tobit Analysis." The Review of Economics and Statistics, 62:318-321.
- Mekuria, Mulugetta. 1992, " Building Sustainable NARSs: The Ethiopian Experience" unpublished paper, East Lansing: Dept of Agricultural Economics, Michigan State University
- Mekuria, Mulugetta., Hailu Beyene and Steven Franzel. 1989. " Farming Systems Research: Challenges and Issues in the IAR." IAR Research Report No.10 IAR: Addis Ababa.

- Mekuria, Mulugetta., Steven Franzel and Hailu Beyene. 1992. "Farming Systems Research in Ethiopia: Evolution, Development and Organization." In Steven Franzel and Helen van Houten (eds). Research with Farmers: Lessons from Ethiopia. C.A.B International.
- Mekuria, Mulugetta and Steven Franzel. 1987. "Farming Systems Research in Ethiopia: Evolution, Impact and Issues" Research Report No.7. Institute of Agricultural Research, Department of Agricultural Economics and Farming Systems Research: Addis Ababa.
- Mellor, John W. 1982. "Third World Development: Food, Employment and Growth Interaction." American Journal of Agricultural Economics 64:304-310.
- Mellor, John W., Christopher L.Delgado and Malcolm J.Blackie. 1987. "Priorities for Accelerating Food Production Growth in Sub Saharan Africa". In John W. Mellor, Christopher L.Delgado and Malcolm J.Blackie (eds) Accelerating Food Production in Sub-Saharan Africa Baltimore: John Hopkins Press.
- Mirotchi, Mesfin and Daniel B. Taylor. 1993. "Resource Allocation and Productivity of Cereal State Farms in Ethiopia." Agricultural Economics 8: 187-197.
- MOA/NFIU. 1991. Crop-Wise Fertilizer Usage. Planning and programming Dept. Addis Ababa:MOA.
- Morris, Micheal L. 1989. "Wheat Policy Options in Sub-Saharan Africa: The Case of Zimbabwe" Agricultural Economics 3:115-129.
- Morris, Micheal and Derek Byerlee. 1993. "Narrowing The Wheat Gap in Sub Saharan Africa: A Review of Consumption and Production Issues" Economic Development and Cultural change, 737-761.
- Norris, P.E and Sandra S. Batie. 1987, "Virginia Farmers' Soil Conservation Decisions: An Application of Tobit Analysis." Southern Journal of Agricultural Economics, 19:79-89.
- Norusis, Marija J., 1990. SPSS/PC+ Advanced Statistics 4. SPSS Inc.

- Oehmke, James F., and Eric W. Crawford. 1993. "The Impact of Agricultural Technology in Sub-Saharan Africa: A synthesis of Symposium Findings." Staff Paper Number 93-63. East Lansing: Dept. of Agricultural Economics, Michigan State University.
- O'Mara, Gerald T. 1971. "A Decision-Theoretic View of the Microeconomics of Technique Diffusion in a Developing Country." Unpublished Ph.D. dissertation. Stanford University.
- ONCCP, Government of Ethiopia. 1989. Towards a Food and Nutrition Strategy for Ethiopia. ONCCP: Addis Ababa.
- Paolino, Leonard and John W. Mellor. 1984. "The Food Situation in Developing Countries: Two decades in Review." Food Policy, 291-303.
- Polson, Rudolph A. and Dunstan S. C. Spencer. 1991. "The Technology Adoption Process in Subsistence Agriculture: The Case of Cassava in Southwestern Nigeria." Agricultural Systems, 36(1):65-78.
- Rahm, M.R. and Huffman, W.E., 1984. "The Adoption of Reduced Tillage: The Role of Human Capital and Other Variables." American Journal of Agricultural Economics. November: 405-413.
- Rahmato, Dessalegn. 1992. "The land Question and Reform Policy: Issues for Debate." Paper presented at Symposium on Economic Development in Ethiopia: Economic Policy During the Transition Period. January 15-18.
- Rauniyar, Ganesh P., 1990. "An Econometric Model of Rate of Adoption of Technology for Developing Countries." Unpublished Ph.D Dissertation, Department of Agricultural Economics and Rural Sociology, The Pennsylvania State University.
- Rogers, Everett M. 1983. Diffusion of Innovations. 3rd edition. New York: The Free Press.
- Ruttan, Vernon M. 1986 "Assistance to Expand Agricultural Production" World Development 14:39-63.
- Schultz, T.W. 1975. "The Value of the Ability to Deal with Equilibrium." Journal of Economic Literature 13: 827-846.

- Shakya, P.B. and Flinn J.C. 1985. " Adoption of Modern Varieties and Fertilizer Use on Rice in the Eastern Terrai of Nepal". Journal of Agricultural Economics. 36:409-419.
- Shire, Saad Ali 1986."The role of Prices in Agricultural Supply: A Household Production Systems Approach for Smallholders in Ethiopia." Unpublished Ph.D Dissertation, The Pennsylvania State University.
- Stoneman, Paul. 1983. The Economic Analysis of Technological Change. New York: Oxford University Press.
- Strauss, John. Mariza Barbosa, Sonia Teixeira, Duncan Thomas and Raimundo Gomes Junior. 1991. "Role of Education and Extension in the Adoption of Technology: A study of Upland Rice and soybean Farmers in Central-West Brazil." Agricultural Economics 5:341-359.
- Stroud, Ann and Mulugetta Mekuria. 1992. "Ethiopia's Agricultural Sector: An Overview." In Steven Franzel and Helen van Houten (eds). Research with Farmers: Lessons from Ethiopia. C.A.B International.
- Sureshwaran, S., S.R. Londhe, P. Frazier, and N.P. Pascual. 1992. "A Tobit Analysis of Factors Affecting the Intensity of Adoption of a Soil Conservation Technology." Paper presented at the annual meeting of The American Agricultural Economics Association, Baltimore.
- Tanner, Douglas G., Amanuel Gorfu, and Kassahun Zewde. 1991. "Wheat Agronomy Research in Ethiopia." In Hailu Gebre-Mariam, D.G. Tanner and Mengistu Hulluka, (eds.). Wheat Research in Ethiopia: A Historical Perspective. Addis Ababa: IAR/CIMMYT.
- Tanner, Douglas G. and Giref Sahile. 1991. "Weed Control Research Conducted on Wheat in Ethiopia." In Hailu Gebre-Mariam, D.G. Tanner and Mengistu Hulluka, (eds). Wheat Research in Ethiopia: A Historical Perspective. Addis Ababa: IAR/CIMMYT.
- Tanner, Douglas G., Amanuel Gorfu, Lemma Zewdie and Asefa Taa. 1992. "Developing Technologies to Improve Soil Fertility, Weed Control and Wheat Varieties." In Steven Franzel and Helen van Houten (eds). Research with Farmers: Lessons from Ethiopia. C.A.B International.

- Thomas, John W. 1982. "Food Problems and Emerging policy responses in Sub-Saharan Africa: Discussion." American Journal of Agricultural Economics, 64:907-908.
- Tobin, J., 1958. "Estimation of Relationships for Limited Dependent Variables." Econometrica, 26:29-39.
- Yirga, Chilot., Hailu Beyene., Lemma Zewde and Douglas G. Tanner. 1992. "Farming Systems of the Kulumsa Area." In Steven Franzel and Helen van Houten (eds). Research with Farmers: Lessons from Ethiopia. C.A.B International.