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Adoption of improved *tef* and wheat production technologies in crop-livestock mixed systems in northern and western Shewa zones of Ethiopia

by

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DEDICATION

This work is dedicated to my late brother Bogale Gebtre Egziabher who made every effort to encourage me pursue my post-graduate studies valuing the opportunity he was not fortunate to have and my late niece Fasika Bogale for her unforgettable cares for me. They were eager to see me complete my study unfortunately they passed away during my study program which made my grief for their loss unbearable.

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Abstract

Since adoption is a dynamic process that involves learning about new technologies, static adoption models fail to adequately explore the effects of changes in farmers' perception and attitudes over time. This study analyzed the influences of farmers' learning and risk on the likelihood and intensity of adoption of improved *tef* and wheat technologies in Northern and Western Shewa zones of Ethiopia. The study employed Xtprobit and Xttobit and random effect models and panel data of the same farmers from 1997 to 2001. Separate samples were selected for wheat and *tef* and the study covers the same farmers from 1997-2001. Panel data are better suited to study dynamic changes and the random effect models control for unobserved variability and potential endogeniety.

Comparison of the main features of *tef* and wheat farmers revealed that wheat farmers are slightly younger, more educated, have slightly higher family size and significantly higher family labour than *tef* farmers. While average farm size is similar for *tef* and wheat farmers, farmers cultivated 60% and 30% of their land to *tef* and wheat, respectively. However, *tef* farmers allocated only 20% of their *tef* area to improved varieties due to shortage of desirable varieties whereas wheat farmers allocated 90% of their land to improved varieties from 1997 to 2001. Only three improved varieties were demonstrated and limited quantities of improved seeds were distributed to *tef* farmers whereas six improved wheat varieties were demonstrated and relatively sufficient quantities of improved seeds were distributed to wheat farmers during the study. Besides, similar levels of fertilizers and herbicide were used on *tef* and wheat. Wheat and *tef* were mainly grown for own consumption as less than half of the produce (48% of all wheat and 46% of all *tef*) was sold in the market.

The study provided evidence of the importance of learning in the adoption decision and area allocation to improved varieties. As farmer's gained more experience from growing the new varieties in previous years, they continued adoption and increased areas under these varieties. The study also revealed that adopters of wheat and *tef* technologies have increased their production by 20% and 39%, respectively, than non-adopters. Results of the analyses indicate that awareness, availability and profitability of the new improved *tef* and wheat varieties enhanced farmer's learning and farmer's experience had positive influence on the likelihood and intensity of improved seed adoption. Improved *tef* and wheat varieties were found more risky than the local varieties.

The study further revealed that younger age of farmer, farmers' learning from previous experience, availability of family labour and credit are key determinants of the likelihood and intensity of adoption of improved seed. Policies and strategies that contribute to timely availability of improved inputs and provision of credit enhance farmers learning from their own experience on adoption. Policies and strategies that focus on farmers' education and provision of insurance for crop failure to reduce risk would help the new extension program (NEP) achieve its objectives which give emphasis to raising smallholders' production and productivity.

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Abbreviations and Acronyms

ADLI	Agricultural Development Led Industrialization
ADAs	Assistant Development Agents
ADD	Agricultural Development Department
ADDP	Ada Development Program
AISCO	Agricultural Input Supply Corporation
AISE	Agriculture and Input Supply Enterprise
AMC	Agricultural Marketing Corporation
ARDU	Arsi Rural Development Unit
AUA	Alemaya University of Agriculture
CADU	Chilalo Agricultural Development Unit
CBD	Coffee Berry Disease
CEEPA	Center for Environmental Economics and Policy in Africa
CSA	Central Statistics Authority
CIMMYT	International Wheat and Maize Improvement Center
DA	Development Agent
DAP	Diammonium Phosphate
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
ECM	Error Components Model
EMTPs	Extension Management Training Plots
ESE	Ethiopian Seed Enterprise
ESIA	Ethiopian Seed Industry Agency
FAO	Food and Agriculture Organization
FEM	Fixed Effects Model
GDP	Gross Domestic Product
ha	Hectare
HYVs	High Yielding Varieties
IAR	Institute of Agricultural Research

IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Center
ILO	International Labour Organization
kg	Kilograms
km	Kilometer
LR	Likelihood Ratio
ML	Maximum Likelihood
masl	Meters Above Sea Level
MCTD	Ministry of Coffee and Tea Development
MEDAC	Ministry of Economic Development and Cooperation
MPP	Minimum Package Programs
MOA	Ministry of Agriculture
MSFD	Ministry of State Farm Development
mm	Millimeter
NEP	National Extension Program
NFIU	National Fertilizer Inputs Unit
NGOs	Non-Governmental Organizations
NPK	Nitrogen, Phosphorous and Potassium
OPVs	Open Pollinated Varieties
PAs	Peasant Associations
PADEP	Peasant Agricultural Development Program
PCs	Producers' Cooperatives
RELC	Research and Extension Liaison Committee
REM	Random Effects Model
SCs	Service Cooperatives
SFYP	Second Five-Year Plan
SMSs	Subject-Matter Specialists
TLU	Tropical Livestock Unit
T and V	Training and Visit
VIF	Variance Inflation Factor
WADU	Wolayta Agricultural Development Unit

Curriculum Vitae of the Candidate

Hailu Beyene Abera was born in Addis Ababa, Ethiopia on 20 January 1952. He obtained his first degree in Agricultural Economics in 1977 from Alemaya College of Agriculture, Ethiopia. He was employed as Assistant Research Officer in the Ethiopian Institute of Agricultural Research (EIAR) in 1978 in the Department of Socio-economics Research. In 1982, he was granted an FAO scholarship to pursue a Masters of Science in Agricultural Economics at the University of the Philippines. In 1985, he joined the EIAR and served as Reserch Officer until the end of 1999. He was promoted to Senior Researcher in August 2005. Mr Hailu was Division head and Department head of Socio-economic Research, project leader of Farming Systems Research, member of National task force for African Highlands Initiative and member of Research staff promotion committee. Mr Hailu has published 8 articles in proceedings and co-authored 3 articles in journals, 9 articles in books and 17 articles in different proceedings.

In 2000, he joined University of Pretoria to pursue a PhD in Agricultural Economics. The contribution of his dissertation was to add to literature that adoption is a dynamic process. The study employed a learning model and panel data set to analyze the effects of learning as a dynamic process using Xtprobit and Xttobit models, which are appropriate to analyze farmer's decisions over time. The results revealed that farmer's learning is one of the key factors in the adoption and intensity of use of improved *tef* and wheat technologies and increase production.

CHAPTER 1

INTRODUCTION

This chapter defines the nature of the research problem under investigation and motivates the significance of undertaking the present study. It also sets the objectives of the study and presents the approach and methods employed to achieve those objectives and how the study is organized.

1.1 Motivations and Setting

The economic development of Ethiopia is highly dependent on the performance of its agricultural sector. This is because agriculture contributes 50% of the country's gross Domestic Product (GDP), 90% of all exports (coffee, hides and skins, and oil seeds), and provides employment for 85% of the population directly or indirectly (World Bank, 1997). Agriculture also provides raw materials for 70% of industries in the country (MEDAC, 1999). Besides, the county has the biggest livestock herd in Sub-Saharan Africa (World Bank, 1997).

In spite of its tremendous potential, the performance of Ethiopian agriculture has been disappointing in the last three decades. Its performance has deteriorated from an average annual growth rate of 2.6% between 1965-75 to less than 1% between 1975-89. During the early 1990s, average agricultural growth was 1.5% per annum (World Bank, 1997). The 1994/95 agricultural outputs were 5% lower than the 1980/81 where as population increased by 40% over the same period (Croppenstedt et al, 1999). That means, food production lagged far behind population growth leading to food shortages. The poor performance of the agricultural sector coupled with recurrent unfavourable weather conditions resulted in serious food shortages, leading to three famines in 1973-74, 1984-85, and 1987-88 (Befekadu, 1988; Teressa, 1998). Consequently, Ethiopia received significant food aid and became highly dependent on food imports (Stroud and Mulugetta, 1992; Croppenstedt et al, 1999). The country received 12%-16% of its cereal production as food aid over the 1991-94 periods. In 1994, food aid together with total food imports of 928000 tons of cereals amounted to about 16.4% of total cereals production. Moreover, in 1995 FAO estimated that food imports will grow at 6% per year and will reach 2.5 million tons by 2010 (Takele, 1996). In general food insecurity has persisted in Ethiopia especially in rural areas (Diriba, 1995). The fact that Ethiopia has become increasingly dependent on external sources of food supply has become a major concern for policy makers and agricultural researchers. Therefore, the question of how to make Ethiopia self-reliant in food production has received major attention in recent years (EARO, 2000).

Improving agricultural production provides an important option for reducing reliance on food assistance and imports, and enhancing agricultural development (Block, 1975; Thomas, 1982; Herdt, 1984; Ruttan, 1986). The importance of improved agricultural production technology in achieving sustainable increases in food production in Sub-Saharan Africa is documented in many studies (Delgado et al., 1987; and Eicher, 1990). The green revolution model in Asia and Latin America where significant economic growth has been achieved through the introduction and adoption of improved agricultural production technologies, mainly improved seeds, fertilizers, pesticides and irrigation provides a good example for Africa (Traxler and Byrelee, 1993; Herath and Jayasuriya, 1996).

Low yield due to low adoption of improved agricultural technologies is believed to be the main factor that prevented agricultural production from coping with the rapid population growth in Ethiopia. Studies revealed that improved wheat cultivation is practiced on less than 10% of the cultivated land. Besides, the amounts of fertilizer and herbicide applied by most farmers in Ethiopia are below the recommended levels (Hailu et al., 1992; Legesse et al., 1992; Legesse, 1992). For instance, fertilizer utilization was very low (13.5 kg/ha) in cereals compared to 48 kg/ha in Kenya and 60 kg/ha in Zimbabwe (World Bank, 1995). Furthermore, the percentage of fertilizer applied to *tef* and wheat was 38.2% and 17.5%, respectively, of the total DAP and urea sold in 1995 (Croppenstedt et al, 1999).

According to previous research in Ethiopia, low adoption of improved production technologies was attributed to unavailability of appropriate technologies, unavailability and high cost of required inputs, lack of access to and high interest rates on credit, and policies that discourage improved technology adoption such as promotion of state farms[1] (Mulugeta et al, 1992; Hailu and Chilot, 1992; Bekle et al, 2000; Getahun et al, 2000).

Increasing the rates of adoption of improved production technologies is therefore considered critical for agricultural growth in Ethiopia. Currently, the agricultural policy of Ethiopia gives high priority to increasing food production through the promotion of improved production technologies among smallholders. Particularly promoting the adoptions of improved *tef* or wheat technology packages including improved seed, fertilizers and pesticides, being the main food crops, were given high priority among all cereals. However, there is currently limited information about farmers' learning from the demonstrations of improved t*ef* or wheat technologies, about the rate[2] and intensity of the use of improved t*ef* or wheat technologies after their introduction.

The majority of adoption studies conducted in Ethiopia in the past concentrated on addressing the question of why farmers do not adopt improved agricultural technologies using cross sectional data and static models. The results of these studies were sometimes contradictory with respect to the importance and influence of some explanatory variables.

The adoption decision is a dynamic process involving changes in farmers' perceptions and attitudes as acquisition of better information progresses and farmers' ability and skill improve in applying new methods (Ghadim and Pannell, 1999). In this study adoption of part of or the full package of improved *tef* or wheat technologies over time was analysed. The research questions addressed by this study included which *tef* or wheat technologies have been adopted and why they are still in use or already abandoned after introduction. The study accordingly identified factors that influence farmer's decision to continue to use new technologies or not and measure their influences over time.

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[1] During the Military Government (1974-1991), State farms received 40% of government expenditure on agriculture, 76% and 95%, respectively, of fertilizers and improved seeds while very little attention was given to smallholders who produced 95% of all grain crops (Legesse, 1998).

[2] Rate refers to percentage while intensity refers to level of use of a new technology (Feder et al., 1985).

1.2 Significance of the study

Understanding the factors that cause farmers to partially or fully adopt or discontinue the use of improved technological packages is crucial for improved design and transfer of the recommended practices. It is also important for researchers, extension workers and policy makers to know the pattern, intensity and dynamics of adoption and abandonment of improved packages. These information assist researchers for developing appropriate technologies that better fit the needs of smallholder farms. The generated information will also help extension to design appropriate strategies for removing barriers to higher adoption of improved production technologies by smallholders, and policy makers to increase food production in the country.

1.3 Research Objectives

The overall objective of the study is to analyse determinants of patterns[3] and intensity of improved technology adoption by smallholder producers of *tef* or wheat in Ethiopia, especially the dynamics of learning in the adoption decision. Specifically, the study will pursue the following objectives:

1. Estimate the rate and intensity of improved t*ef* or wheat technology adoption over time;
2. Determine the effects of experience and risk as well as other factors on the decision to continue or discontinue use of improved *tef* or wheat production technologies over time;
3. Analyse the adoption of improved t*ef* or wheat technologies using panel regression models.

1.4 Approach and methods of the study

To achieve the stated objectives, this study was undertaken in *tef* and wheat based farming systems of the Northern and Western Shewa Zones of the Oromiya Regional State of Ethiopia, which respectively, represent medium and high potential *tef* and wheat production regions in the

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[3] Pattern refers to the cumulative percentage of users of a new technology over time (Griliches, 1957).

country. Northern and Western Shewa zones are located in the central highlands of Ethiopia, which stretch about 115 and 185 km respectively, to the north and west of the capital city Addis Ababa. The study covered the 1997-2001 agricultural seasons.

This study included farmers who were exposed to improved *tef* or wheat technologies in Northern and Western Shewa Zones. Data for the intended analysis was collected from farmers' surveys in high and medium potential areas of *tef* or wheat production. Unlike many adoption studies, straw yield and its value was considered in the data collection. A component or a package approach was employed to *tef* or wheat growers who have been using these technologies over time after exposure. The study adopted panel regression models such as Xtprobit and Xttobit to estimate random-effects probit models and random-effects tobit models, respectively, in the adoption of improved *tef* or wheat technologies over time. Farmers' decisions to continue or discontinue using the new technology and intensity of adoption change depending on their learning in using the new technology in the previous years.

1.4. Organization of the study

The study is organized into seven chapters. Chapter one presents the motivation and objectives of the research project and defines the approach and methods to be used. Chapter two provides background information on the importance of the agricultural sector to the economy at large and to food security in Ethiopia. It further gives an overview of the status of agricultural research and extension systems in Ethiopia. The theoretical and empirical literature of relevance are reviewed in Chapter 3 out of which the conceptual framework to be employed in subsequent analysis are defined. Chapter 4 develops in full detail the analytical approach and empirical methods used to conduct the analysis. Results of the economic analysis of improved *tef* and wheat technologies, and the pattern and sequence of adoption of components of improved *tef* and wheat technologies over time are presented in Chapter 5. Chapter 6 presents the results of empirical analyses of panel data regression models (Xtprobit and Xttobit) on the adoption of improved *tef* or wheat technologies. Finally, Chapter 7 brings together the major findings, draw conclusions and make recommendations to improve smallholders' agricultural productivity through the adoption of improved *tef* or wheat technologies in the study areas.

CHAPTER 2

AGRICULTURE, IMPROVED TECHNOLOGY AND FOOD SECURITY IN ETHIOPIA

The purpose of this chapter is to provide background information on the role of agriculture in economic development, technology development and dissemination, and food security in Ethiopia. The first section describes agricultural production systems and government policies that have direct bearing on agricultural technology adoption. Smallholders are the most important agricultural producers in terms of area cultivated and production, and therefore, more attention was given to describing their production system and policies that are particularly important to them. However, other production systems have also been briefly analysed. Ethiopian agriculture has lived through major political changes during the past three decades (imperial, socialist and the current regimes). The policies of each of the mentioned governments to increase agricultural productivity and their impact on agricultural technology adoption are discussed. The second part of the chapter gives an overview of the status of agricultural research and extension systems in Ethiopia. It describes the constraints encountered in developing and disseminating technologies suitable for smallholder farmers and identifies problems that exist between research and extension that hindered the dissemination of improved agricultural technologies. Food availability, consumption, and food self-sufficiency issues, which are dependent on agricultural productivity, are discussed in the third part of the chapter.

2.1 Agriculture and the national economy

Agriculture is the most important sector of the Ethiopian economy. It contributes about 50% of the Gross Domestic Product (GDP), the bulk of which comes from cultivation of crops (80%) and the rest (20%) from livestock (Abinet et al, 1991). These shares did not significantly change over the years. The industrial sector is small in size contributing, on average, only about 16% of the GDP. Figure 2.1 shows the contribution of agriculture to GDP and its growth rate between 1981 and 1998 (MEDAC, 1998). The rate of growth of agriculture was negative in seven out of 17 years. This was mainly due to severe weather fluctuations including drought in 1984 and 1987, inappropriate economic policies, low rate application of improved technologies and prolonged civil war. Apparently, this negative growth of agriculture had contributed to the reduction of GDP during that same period.

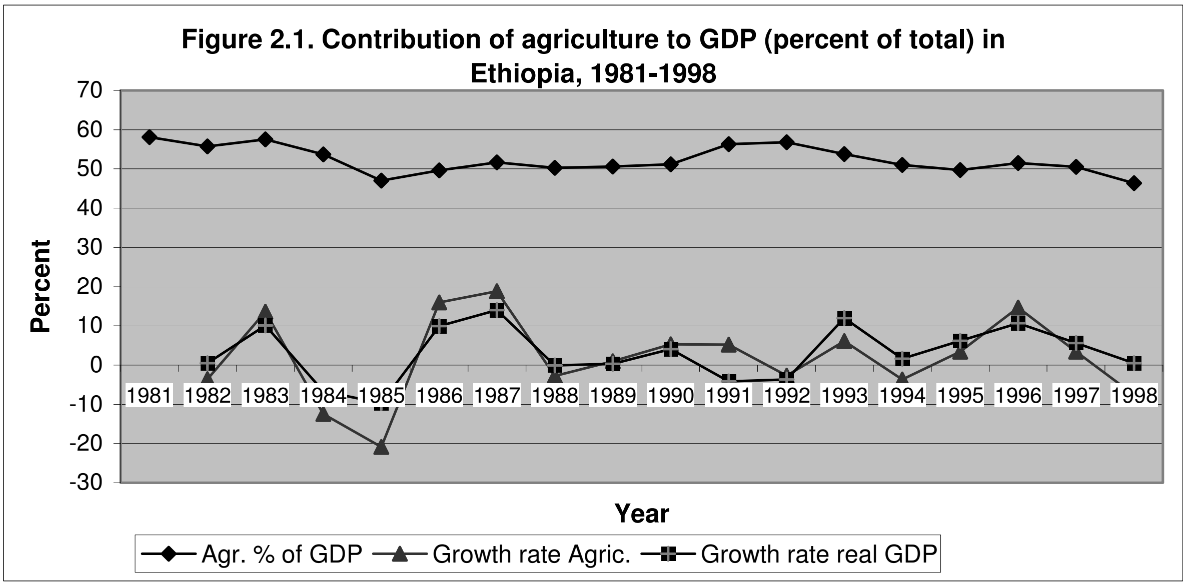
Figure 2.1. Contribution of agriculture to GDP (percent of total) in Ethiopia, 1981-1998

Source: MEDAC, 1998

In spite of the low productivity of agriculture, the economy of Ethiopia remains heavily dependent on agricultural exports for foreign currency. Agriculture is the major source of export revenue and accounts for 82% of the total value of exports of the country. Coffee is the major agricultural export contributing about 70% of the volume of agricultural exports and more than 58% of the total value of exports. Chat[1], hides and skin ranked second and third accounting for, on average, 8% and 7% of total exports, respectively, from 1993-2000 (National Bank of Ethiopia, 2000; Ministry of Trade & Industry, 2000). Oil seeds and pulses account for about 4% and 3% of the value of exports, respectively, but contributed better than cereals in terms of export earnings (Figure 2.2). Coffee, hides and skin have been the dominant agricultural export of the country since the 1950s. These export earnings are mainly used to finance the import of capital goods for the development of the sectors of the economy including agriculture (National Bank of Ethiopia, 2000; Ministry of Trade & Industry, 2000). Generally, sufficient efforts have not been made to diversify the

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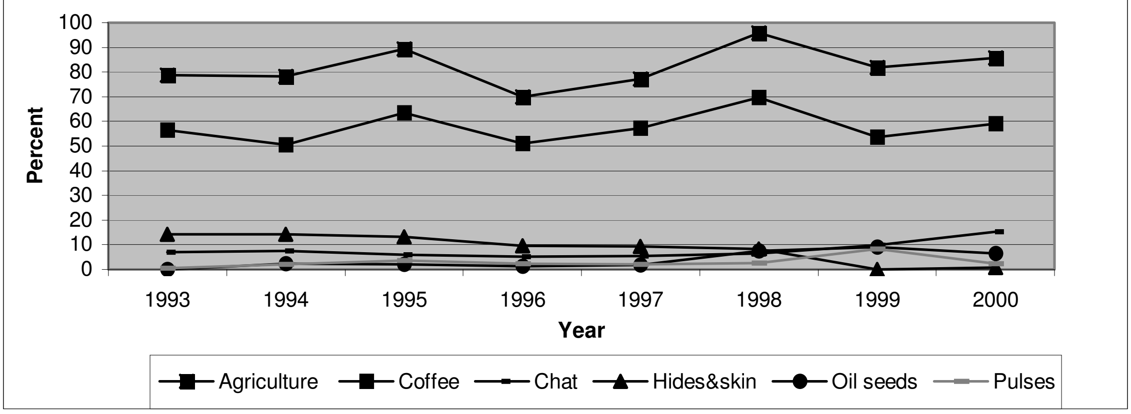
[1] *Catha edulis* (Celastraceae), a bush the leaves of which are chewed as a stimulant (Bezabih Emana and Harmen Storck, 1992).

agricultural exports and the country is always at the mercy of other countries that have similar export (coffee).

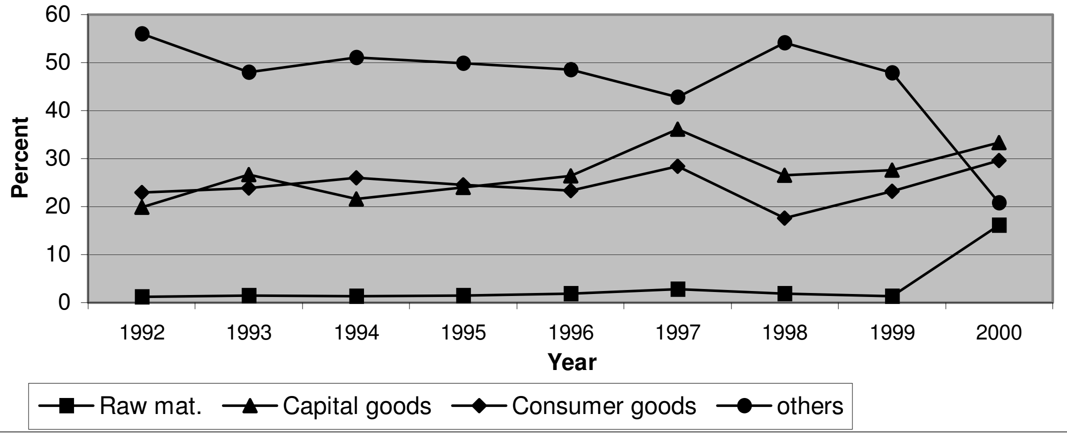
Figure 2.2. Value of Ethiopia's exports (percent of toatl) by source (1993-2000)



Source: National Bank of Ethiopia, 2000; Ministry of Trade and Industry, 2000

On the other hand, imports of capital goods were dominant from 1992 to 1999 except for the years 1992, 1994 and 1995 where imports of consumer goods accounted for a larger share (National Bank of Ethiopia, 2000; Ministry of Trade and Industry, 2000). The share of imports of raw materials was quite insignificant during the whole period (Figure 2.3).

Figure 2.3. Value of Ethiopia's imports (percent of total), 1992-2000

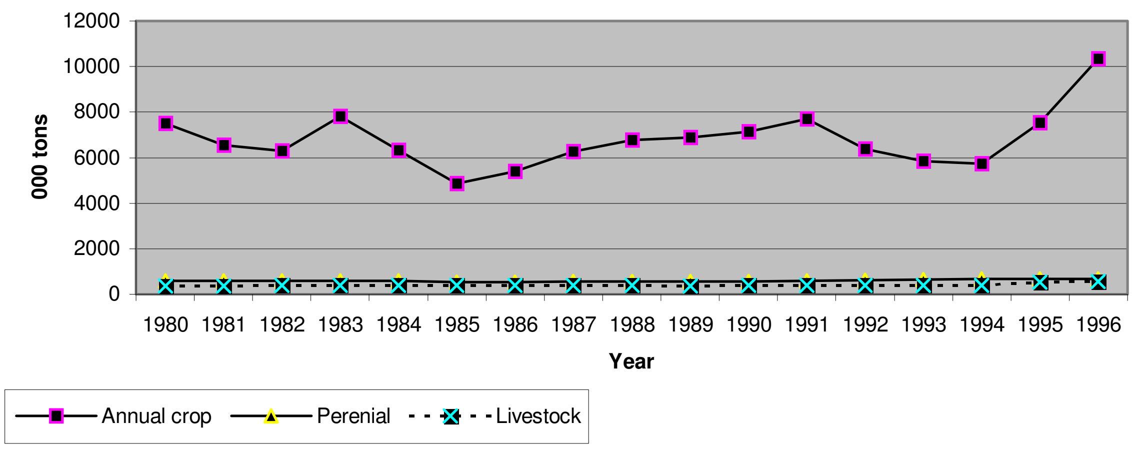


Source: National Bank of Ethiopia, 2000; Ministry of Trade and Industry, 2000

Agriculture is also the major source of employment for 90% and 89% of male and female labor, respectively, in the country. The industrial sector employs only 2% while the services sector employs 8% and 10% of the male and female population, respectively. (ILO, 1996). Employment figures include full as well as part time workers.

Another contribution of agriculture is that it is the only source domestic food production for the growing population where about 95% of the food production comes from the smallholders' production system. Almost all of the domestic food production comes from annual crops (87%), perennial crops (8%) and livestock (5%). Figure 2.4 shows the sources of domestic food production over the years.

Fiure 2.4. Domestic food production (ooo tons) in Ethiopia, by source, 1980-1996.



Source: Adapted from Debebe, 1997

2.2 The Agricultural potential of Ethiopia

Ethiopia has an area of 1.12 million square kilometres and is the ninth largest country in Africa. About 66% of the total land is potentially arable out of which only 22% is currently under cultivation and only 4% of the land suitable for irrigation is currently utilized (EARO, 2000).

Ethiopia lies within the tropics but enjoys tropical, sub-tropical, and temperate environments because of the significant altitudinal variations. Originally, Ethiopia was divided into three major agro-climatic zones:

kola, representing the warm climate zone, less than 1500 meters above sea level (masl);

weinadega, representing a moderate climate (1500 masl to 2500 masl); and *dega*, which represents a cool climate, greater than 2500 masl (Stroud and Mulugetta, 1992).

Recently, the country was divided into 18 major agro-ecological zones and 48 sub-zones based on altitude, rainfall and length of the growing period (EARO, 2000). Crops and livestock production are concentrated between 1500 masl and 3500 masl where the temperature ranges from moderate (*weinadega)* to cool (*dega*).

The country is endowed with enormous water resources. The water resources of the country comprise 10 big rivers and their tributaries, and 11 lakes with sizes ranging from 20 km^2 to 3600 km^2. The irrigation potential of the country is over 3.5 million ha (FAO, 1986; Legesse, 1998). However, there are barriers, at least in the short run, to exploiting this potential. In particular, potentially irrigable lands are located in sparsely populated lowland areas where infrastructure is poorly developed.

Ethiopia has a bimodal rainfall defining two seasons. The main rainy season occurs between the months of June to September, while a shorter season with lesser amount of rain falls between February and mid-May. Crop production is mainly carried out during the main rainy season. The major crop production areas receive on average 800 mm to 1200 mm of rainfall in normal years and produce 95% of the total crop production of the country (FAO, 1986). In some parts of the highlands, shortages and uneven distribution of rainfall occur approximately once in 3 to 5 years when the amount of rainfall received may fall below 400 mm and be unevenly distributed. In general, the reliability of rainfall decreases from South to North and from West to East. The arid and semi-arid parts of the country suffer from shortages and from erratic rainfall.

With regard to its livestock population, Ethiopia stands first in Africa and tenth in the world (Pickett, 1991). According to the Ministry of Agriculture (MOA), Livestock and Fishery Resource Development Department, there are about 28 million cattle, 24 million sheep, 18 million goats, 7 million equine (horses, donkeys and mules), 1 million camels and 52 million poultry (Legesse, 1998). Unfortunately, this great potential is not well exploited.

2.3 Agricultural production systems in Ethiopia.

There are two main production systems in Ethiopia: the pastoral-nomadic system, and the mixed crop production system. The pastoral livestock production system dominates the semi arid and arid lowlands (usually below 1500 masl). These regions cover a vast area of land with a small livestock population. The crop production system can be classified into smallholders' mixed farming, producers' cooperative (PCs) farms, state farms, and private commercial farms based on their organizational structure, size, and ownership. As this study focuses only on smallholder crop agriculture, no further discussion of other systems (pastoral-nomadic and private commercial activities) is provided.

The smallholders' production system was the most dominant and accounted for more than 90% of cultivated area and production from 1980 to 1995 (Table 2.1). The major objectives of smallholder farmers' production are to secure food for home consumption and to generate cash to meet household needs (clothing, farm inputs, taxes etc). The PCs were established as a result of the past socialist government during the 1970s and 1980s to collectivise land, speed up the use of improved agricultural technologies to increase food production in the country, and provide higher income to PCs' members. The PCs mainly produced for their own consumption and to a minor extent for the market. PCs had priority to get improved inputs on credit and extension agents were based in the PCs to demonstrate improved agricultural technologies on their farms. However, despite such generous government support to PCs, their progress was very slow due to weak services offered by extension agents and PCs' leaders due to lack of experiences. Moreover, PCs did not offer higher income to their members as envisaged. Thus, there was strong resistance from smallholders to join the PCs. There were only 3741 PCs with a membership of 321,324 households or 4% of all rural households by 1989 (Stroud and Mulugetta, 1992). From 1980 to 1995, PCs cultivated 2% of the total cultivated area and produced only 1.6% of the total crop production in the country, which was the lowest of the three production systems (Table 2.1).

The state farms are the third production systems set up by the socialist regime to manage nationalized commercial farms (70,000 hectares) in 1975. Since then the government has expanded the size and number of state farms by clearing forests and grabbing farmers' grazing lands. In 1979, the socialist government established two ministries [the Ministry of State Farm Development (MSFD) and the Ministry of Coffee and Tea Development (MCTD)] to manage state-owned farms. State farms ranged in size from 500 ha to 15,200 ha. However, in 1980 the total area cultivated by state farms ranged from 214,000 to 240,000 ha. As shown in Table 2.1 state farms cultivated only about 2% of the total land under crops and accounted for 3% of total production. State farms practiced mono cropping, were major users of improved production technologies (improved seed, fertilizers, pesticides and mechanization). The state farms have been producing for both the domestic and export markets.

Table 2.1 Crop production in Ethiopia: area and production by crop category and mode of production (1980-1995).

	Area ('000 ha)			
Crop category	**Smallholders**	**State farms**	**Cooperatives**	**All farms**
Cereals	9449.35	198.04	190.82	9838.21 (82)
Pulses	1632.92	6.3	29.93	1669.15 (14)
Oil seeds	458.81	17.32	14.17	490.30 (4)
Total	**11541.08 (96.2)**	**221.66 (1.8)**	**234.92 (2)**	**11997.66 (100)**
		Production	**('000t)**	
Cereals	10163.03	360.52	169.655	10693.21 (87)
Pulses	1356.665	3.49	17.045	1377.20 (11)
Oil seeds	221.166	7.006	3.989	232.161 (2)
Total	**11740.185 (95.4)**	**371.016 (3)**	**190.689(1.6)**	**6173.776 (100)**

Source: Estimated from CSA data (1980-1995); Figures in parentheses are percentages

2.4 Crop production in Ethiopia

The major crops in Ethiopia include cereals, pulses and oil seeds. Cereals accounted for more than 80% of the total cropland and total production between 1980 and 1996 (Table 2.2). *Tef (Eragrostis tef)* and wheat occupied 44% of the total area under major crops and contributed about 37% of the total crop production in the country from 1980 to 1996. Pulses and oil seeds accounted for the remainder.

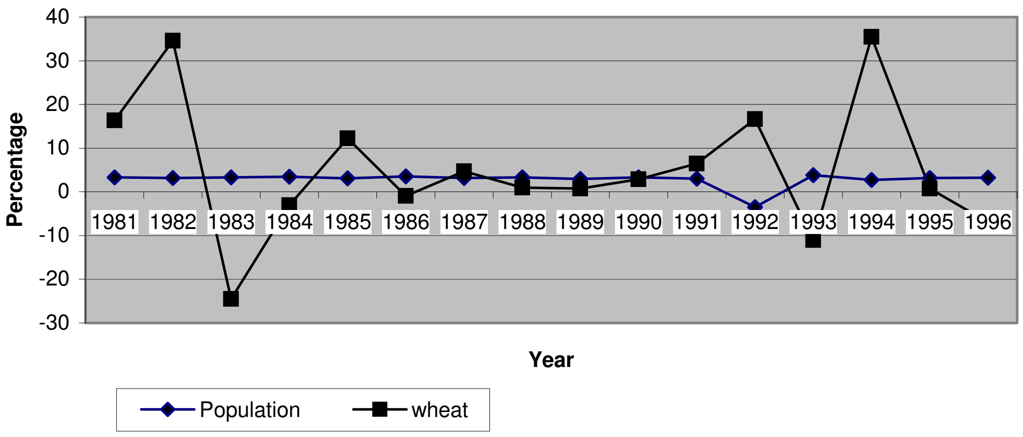
Table 2.2 Total area harvested and production of major crops in Ethiopia, 1980-1996.

Major crops	**Area, 000 ha**	**Percentage share**	**Production, 000 ton**	**Percentage Share**
Cereals	5399.481	83.19	6588.3274	88.49
Tef	1467.497	31.22	1292.5586	23.08
Wheat	615.280	13.12	750.4897	13.46
Barley	717.156	15.42	840.7215	15.46
Maize	878.229	18.68	1475.9414	25.95
Sorghum	793.265	15.40	1048.8008	18.28
Pulses	934.489	14.48	736.1408	10.75
Oil seeds	147.330	2.32	54.6700	0.76
Total	**6481.30**	**100**	**7379.1382**	**100**

Source: FAO and CSA

Ethiopia is the largest wheat producing country in Sub-Saharan Africa (Hailu et al., 1991). It used to produce a surplus and export wheat in the 1960s and 1970s (EARO, 2000). However, currently Ethiopia produces 65% of its wheat requirements since production could not cope up with population growth. For instance, wheat yield increased by only 18% while population increased by 56% from 1980-1996. Figure 2.5 presents population growth and wheat production growth rates for the same period (1980-1996). As it is clearly indicated, wheat production growth was slower than population growth in some years (1986, 1988-1989, 1995) and even negative during the drought of 1983-1984, 1993 and 1996.

Figure 2.5. Wheat production and population growth (percent of the previous year) in Ethiopia, 1980-1996



Source: Adapted from Debebe, 1997

The use of improved inputs such as improved seed, fertilizers and pesticides is generally low in Ethiopia. For instance, about 39%, 3.6% and 5.0% of the land cultivated in 2000/01 was applied fertilizers, improve seed and pesticide, respectively (CSA, 2001/02). Moreover, only about 1.3% of the area under t*ef* and only 5.4% of the wheat area was under improved varieties from 1991-2000 (Table 2.3). In terms of area fertilized and pesticide applied, wheat had a better share than t*ef* for the same period (Table 2.3).

Table 2.3 Area under improved seed, pesticide and fertilizer (000 ha), Ethiopia, 1991- 2000.

Crop type	Total area,	Improved seed		Pesticide		Fertilizer	
		Area planted	Percent	Area applied	Percent	Area	Percent
Tef	9488.04	122.67	1.29	8129.77	11.72	4857.56	51.19
Wheat	4104.03	221.11	5.39	987.97	27.4	2487.95	60.62

Source: CSA, 2001/02

Smallholders applied relatively higher rates of fertilizer on wheat (about 74 kg/ha) than on t*ef* from 1991-2000 (Table 2.4). However, these figures significantly change when the government had improved inputs use promotion programs. For instance, Table 2.5 presents area planted to improved seeds in Ethiopia in 1996 crop season where there was a strong input promotion program (Abdisa et al., 2001).

Table 2.4 Quantity of fertilizer applied on crops by smallholders in Ethiopia, 1991 -2000.

Crop type	Total area, 000 ha	Area fertilized, 000 ha	Rate, kg/ha
Cereals	6888.56	2501.98	35.3
Tef	2167.77	1175.65	53.7
Wheat	772.23	443.69	73.6

Source: CSA

Table 2.5 Area planted to improved and local varieties of major food crops in Ethiopia, 1996/1997.

Crops	Harvested area ('000 ha)	Area under improved varieties ('000 ha)	Quantity of improved seed used ('000 t)	Area planted to	
				local varieties (%)	improved varieties (%)
Tef	2396.9	92.7	2.78	96.1	3.9
Bread wheat	855.1	770.0	115.50	10.0	90.0
Durum wheat	571.1	22.8	2.28	96.0	4.0
Barley	1370.1	23.0	2.53	83.2	16.8
Maize	1951.1	1170.7	35.12	40	60
Sorghum	1750.1	420.0	4.20	76	24
Oats	71.3	71.3	71.3	0.0	100.0
Finger millet	442.0	0.0	0.0	100.0	0.0
Total cereals	**9407.7**	**2570.5**	**169.54**	**72.7**	**27.3**
Faba beans	510.4	5.1	1.02	99.0	1.0
Field peas	245.0	1.2	0.18	99.5	0.5
Chickpeas	229.2	0.5	0.04	97.6	2.4
Haricot beans	174.8	131.4	19.66	25.0	75.0
Other	247.2	0.0	0.0	100.0	0.0
Total pulses	**1406.6**	**138.2**	**20.90**	**90.2**	**9.8**
Niger seed	250.5	0.2	.002	99.0	1.0
Linseed	148.2	0.16	.004	98.0	2.0
Rape seed	21.4	0.83	.001	85.0	15.0
Ground nuts	17.4	0.63	0.005	80.0	20.0
Others	41.0	0.0	0.005	1000.0	0.0
Total oil seeds	**478.5**	**1.82**	**0.012**	**99.6**	**0.4**
Total	**11292.8**	**2710.5**	**190.45**	**76.0**	**24.0**

Source: Abdisa et al., 2001

Crop production depends on rainfall. However, the state farms either use supplementary irrigation or totally depend on irrigation for about 25% of the land under crop production. Due to unreliable amount and distribution of rainfall during the crop season and low use of improved inputs, crop yields are generally low, e.g. less than 1.2 t/ha on average (Hailu et al., 1992). Wheat and t*ef* rank the third and fifth, respectively, in terms of yield among the cereals (Table 2.6). There is a large difference between on-farms' and research centers' yields that indicates research results have not yet been achieved by producers. This is why yields of cereals, pulses and oil seeds did not exhibit remarkable growth on-farm from 1980 to 1996. However, wheat gave better yield than *tef* both on-farm and on research center farms (Table 2.6) due to better availability and utilization of more improved varieties (Table 2.5).

Table 2.6 Yield of major crops in Ethiopia, 1980-1996.

Major crops	**Yield, t/ha**	**Minimum, t/ha**	**Maximum, t/ha**	**Research centers' yield, t/ha**
Cereals	1.223	0.8806	1.4485	
Tef	0.8848	0.7042	1.4291	2.4
Wheat	1.2212	0.9578	1.5929	5.3
Barley	1.1877	0.9642	1.5151	5.5
Maize	1.6667	1.1254	1.9897	9.0
Sorghum	1.3228	0.6704	1.5802	5.0
Pulses	0.816	0.0892	1.0975	2.0
Oil seeds	0.379	0.3147	0.5190	1.3

Source: FAO and CSA

Earlier it is indicated that yields are generally low in Ethiopia due to low adoption of improved technologies. However, smallholders are relatively more productive than the other two production systems particularly in the production of pulses and oil seeds (Table 2.7). Smallholders have long experience in growing crops particularly pulses and oil seeds. In terms of cereals, small holders were more productive than producers' cooperatives and less productive than state farms due to high utilization of inputs by state farms during the period. For instance, of the total fertilizer, improved seed and agricultural credits about 50%, 79% and 85%, respectively, were directly allocated to state farms and PCs while smallholders received the remaining balance (Legesse, 1998).

Table 2.7 Yields of cereals, pulses, and oil crops by mode of production in Ethiopia, 1979/80- 1994/95.

Category	**Smallholders**	**Producers Cooperatives**	**State farms**
Cereals	11.50	8.60	18.05
Pulses	9.10	5.66	5.76
Oil seeds	4.84	2.97	4.54
Weighted average	10.89	7.89	16.54

Source: Estimated from CSA Statistical Bulletin (1981-1996).

2.5 Smallholders' mixed farming system

As indicated earlier smallholders dominate the agricultural production system and the total number of smallholder farmers is estimated at about seven million (MEDAC, 1999). The smallholder production system is characterized by small and fragmented land holdings, and a mixed crop-livestock production. For instance, about 62% of the smallholder households had land holdings of less than one hectare in 1996 (Table 2.8).

Table 2.8 Distribution of number of households (HH), total cropland and land area per household by size of holding in Ethiopia, 1996.

Size of holding, ha	Number of (HH), 000	Percentage of HH	Total crop land, 000 ha	Percentage of cropland	Average cropland area per HH
less than 0.1	514.01	5.92	30.10	0.34	0.06
0.1 – 0.50	2637.80	30.38	787.82	8.93	0.30
0.51 – 1.0	2260.99	26.04	1664.47	18.86	0.74
1.01 – 2.0	2159.15	24.87	3073.89	34.83	1.42
2.01- 5.0	1059.22	12.20	2950.66	33.44	2.79
5.01 – 10.0	48.75	0.56	288.82	3.27	5.92
Total	**8682.13**	**100**	**8825.06**	**100**	**1.02**

CSA: (1998)

In smallholders' production system livestock is mainly kept to supply draft power. Livestock is fed on crop residues as their main feed. Types of livestock kept on the farm include cattle, sheep, goats, horses, donkeys, mules and poultry. Cattle are kept on farms mainly for food (milk and meat), manure, and immediate cash need in addition to draft (plowing, planting and threshing). Small ruminants are frequently sold for immediate cash needs and cattle during crop failure and other unforeseen problems. Animal products are also sold to generate cash income whenever there is excess over households' self use. Pack animals (donkeys, mules and horses) are major means used to transport inputs, produce and humans in rural areas.

Farming systems' studies carried out by Hailu and Chilot (1992), Legesse et al. (1992) and Tilahun et al. (1992) revealed that smallholders give priority to staple food crop production in allocation of resources. For smallholders, food crops generally serve a dual purpose as food and cash crops. Some food crops are mainly grown for the market. Examples include t*ef* which is grown for cash in other major crop farming system (e.g., maize), and particularly white t*ef* is grown for cash while red and mixtures are grown for food in major t*ef* producing areas. The degree of the dominance of subsistence and market objective varies with location. It is clear from the above explanations that the market objectives play a key role in resource allocation in areas which are closer to big urban markets. Thus, both subsistence and market objectives of farmers have implications for technology adoption. Subsistence objectives may discourage adoption of risky technologies.

With regard to farm tools for crop production, smallholders use traditional tools and implements to perform different farm operations. For instance, land preparation is done by oxen-drawn wooden plow with a single metal chisel at the tip, *maresha*. Land preparation commences at the onset of rains, which vary from January to April. Farmers have to wait for the rains to soften the soil. Otherwise the soil is too hard to be broken by the local plough. The number of plowing depends on the type of crop grown, soil type, and number and condition of oxen during the dry season.

Most crops are planted from June to July and all crop seeds and fertilizers are broadcasted on the soil manually and covered by oxen-drawn plow. However, t*ef* is left uncovered since the seed is very small. Chickpea and rough pea are planted with the residual moisture at the end of the rainy season. The use of modern agricultural technologies on smallholders' production system is minimal with the exception of fertilizer, and to some extent herbicide in *Shewa* and *Arsi* zones. Generally, farmers use less than the recommended rate of fertilizers for all cereals. For instance, smallholders apply 26% less than the recommended rate of 100 kg/ha of DAP for wheat regardless of the location and soil type. A smaller number of farmers use improved varieties of crops in very limited areas. These technologies are either not available in sufficient amounts or on time. Most farmers feel that seeds of improved varieties are expensive, and hence hesitate to purchase the limited amount made available to them at their locality. Some farmers also have doubts about the performance and colour of some of the improved varieties. For instance, improved wheat varieties such as *Bulk* and *Enkoy* have brown grain colour, which is not preferred by consumers for bread making and fetches lower prices.

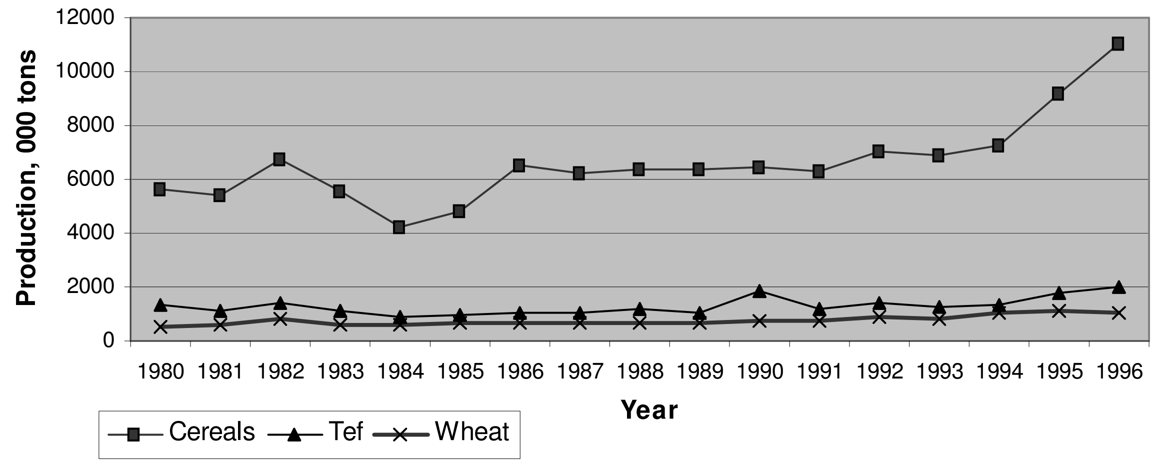
Hand weeding and use of post emergence herbicides (2,4-D) are common weed control practices in crop production. However, herbicides are sprayed only on cereals mainly on t*ef* and wheat. Pulses are rarely weeded due to overlapping of activities. Crop harvesting is from November to end of December depending on planting date and crop type. Harvesting is also done manually with a sickle and harvested sheaves are pilled near homestead until threshing. Threshing is done mainly using oxen to trample on the crops on small threshing ground, a hard surface plastered with cow dung and sun-dried. Of all the crops t*ef* is the most labour-intensive, especially for its highly demanding plowing, planting, weeding, harvesting and threshing operations.

Land is generally fallowed during the dry season and grazed. Most crop residues are fed to animals or used as building materials or fuel and hence very little is returned to the soil. Forage conservation is generally not practiced and the availability of natural grazing areas varies with altitude, rainfall and soil types. Overgrazing in some densely populated and intensively cultivated areas has contributed to soil erosion.

2.6 Trends in crop production

As indicated above, crop production generally remained almost the same for most of the years mainly due to low adoption of improved technologies. For instance, cereals, pulses and oil seeds production remained stagnant from 1986 to 1994 and increased after 1994 mainly due to increased cultivated land. Figure 2.6 depicts this trend for cereals, *tef* and wheat for the same period. The lowest production in 1984 was due to drought in that year.

Figure 2.6. Trends of cereals, *tef* and wheat production (ooo tons) in Ethiopia, 1980 - 1996



Source: CSA and FAO

2.7 Agricultural policies and their impact on agriculture

Ethiopian agriculture has lived through major political changes during the past three decades. The monarchy and feudalism era, which ended by the 1974 revolution, was replaced by a centrally planned economy (socialist regime). Consequently, rural and urban land, and large industries transferred from private, community, and church ownership to public ownership. In 1991, the present government adopted a new economic policy that promised a move away from centralized planning towards a market-oriented system in which private ownership will prevail in most sectors. Since then an adjustment and privatization programme has been underway. Moreover, Agricultural Development-Led Industrialization (ADLI) strategy was adopted to enhance food self-sufficiency and increase foreign exchange earnings, and supply of raw materials to industries (EARO, 2000). The emphasis of ADLI is on accelerating growth through increased use of improved agricultural technologies such as improved seeds and fertilizers throughout the country. The agricultural sector affected most by each of the mentioned governments' policies and the effects of these policies particularly in the adoption of improved agricultural technologies are presented in the following sections.

2.7.1 Agricultural policies during the imperial period (1950 -1973)

During the imperial period, economic policies were implemented under three consecutive five-year development plans. The First Five Year Plan (1957-1962) concentrated on infrastructure development (roads and communications) to lay the base for industrialization, while the Second Five Year Plan (1963-1968) focused on the development of manufacturing, power and improved infrastructures. With regard to agriculture, the First Five Year Plan aimed at accelerating agricultural development by promoting large-scale commercial farms where as the Second Five Year Plan (SFYP) focussed changing the predominant agricultural economy to an agro-based industry (Sisay, 1994). The SFYP in particular emphasized on diversification through commercial farming and the introduction of modern processing methods. During this period, development policies neglected the agricultural sector. For instance, during the SFYP agriculture received only 6% of the total investment expenditure and only 1% of the total investment expenditure was earmarked for the peasant sector (Cohen and Weintraub, 1975).

During the imperial period, the church[2], royal families, landlords, governors, and powerful civil and military officials owned most of the productive land. Peasants were victims of insecure tenure, exploitation and corrupt administrative and unjust judicial system. Before 1975, about 50% of farmers were share tenants and had to pay about 50% of their total production as land rent to landlords (Cohen and Weintraub, 1975). Moreover, the tenants had to provide free labour for the landlord or his local agent. There was no legal protection for tenants and they often had to bribe the landlords' agents in order to stay on the land.

To accelerate agricultural production during the First and Second Five Year Plans (1957 to 1967), the country trained about 120 extension workers (Robinson and Yamazaki, 1986), and these extension agents provided extension services only to commercial farms.

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[2] The Ethiopian Orthodox church was an extensive landholder. But the size of land held by the church is not known. A study by Cohen and Weintraub (1975) estimated that up to 20% of the agricultural land of the country belonged to the church. Another study by Dessalegn (1984) estimated a figure of 10% to 12% for the period before 1975.

During the Third Five Year Plan (1968-1973), an agricultural policy aimed at improving and expanding large commercial farms and supporting agriculture of smallholders was adopted. However, policy makers still considered large commercial farms as the key to agricultural development and this bias had negative implications for technology development and adoption on smallholder farms.

2.7.2 Agricultural policies during the socialist period (1974-1990)

The 1974 Ethiopian revolution overthrew the imperial regime and replaced the military government (*Derg*) that follow socialist ideology to bring changes in the rural economy and the lives of farmers. Following the revolution the economy was restructured to create a more efficient, modern agriculture and increase production. Thus, compared with the previous regime, attention was given to agricultural development; and government expenditures on agriculture increased, and a number of policies were formulated to bring changes in the agricultural sector. However, most of these ideologically and politically driven policies were not able to bring the expected changes. Most of the policies formulated on land redistribution; development of producers' cooperatives (PCs) and state farms; villagization and resettlement; price control; and interregional trade regulations were inappropriate and resulted in distorted resource allocations. Under Ethiopian conditions, there were several policies that acted against the interests of smallholders. The impacts of these policies on smallholders are given below.

2.7.2.1 The land reform policy

During the socialist regime, there was a land reform policy in 1975 that abolished all previous land tenure systems[3], the landlord-tenant relationship and ownership of private land. The policy granted user-rights of land up to 10 ha to any individual who wanted to cultivate land (Dessalegn, 1984). This policy increased freedom of individual farmers particularly tenants and farm labourers. The land reform policy was implemented through

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[3] The land tenure system during the imperial period included kinship (communal) tenures, village tenures, private tenures, church tenures, and state tenures (Cohen and Weintraub, 1975; Dessalegn, 1984).

Peasant Associations (PAs)[4] that were responsible for redistributing land according to the new principles[5] of land reform.

To what extent the land reform policy has increased agricultural production is not well known. However, from the overall agricultural performance and food shortages crisis in Ethiopia, it might be inferred that its effect was marginal. At least three factors were responsible for the failure of the land reform policy to increase agricultural production. First, in spite of being the most important economic force in the country, smallholder farmers were not given the necessary incentives to expand production. For instance, some 50%, 79% and 85%, of total fertilizer, improved seeds and agricultural credit, respectively, were directly allocated to state farms and PCs while smallholders, which produced more than 90% of total crop output received the remaining balance (Legesse, 1998). Such policies discouraged the incentives of smallholders to increase production and might have undermined the effect of land reform policy. Second, with increased population pressure, land redistribution created a new type of insecure land tenure in rural areas. In PAs where PCs were organized, relatively fertile fields were given to PCs members. This might have affected farmers' interest in investing in maintenance of land and the use of improved agricultural technologies. Third, even though tenants and farmers who have insufficient land showed greater interest in innovations to improve their production after the land reform, improved technologies were not available to them in sufficient quantity (packaging) and at reasonable prices. A study by Dessalegn (1984) indicated that the prices of fertilizers considerably increased as compared to output prices in the early 1980s. Thus, the unavailability of inputs and increments in prices might have affected the productivity of land and compromised the effect of land reform policy.

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[4] PAs were organized on an average of 800 ha each. In addition to their responsibilities in land distribution, they served and still serve as grass root level organizations through which government involves the rural population in political, social and economic affairs. PAs greatly facilitate technology transfer and on-farm research activities.

[5] Land was to be allocated according to family size for individuals living in the PAs.

2.7.2.2 Producers' cooperatives expansion policies

The Ten Year Perspective Plan issued in 1984/85 indicates that the government's plan was to put 50% of total cultivated land under PCs by the end of the plan period (1994). However, the transformation of smallholder farms to PCs was much slower than envisaged in the plan. The PCs received preferential treatment in terms of access to formal credit and to modern agricultural technologies once registered under the Ministry of Agriculture (MOA). PCs used to pay 10% less for 100 kg of fertilizers and tax per hectare as compared to fertilizer prices and taxes paid by smallholders. PCs also had access to free labour as individual farmers were obliged to work up to two days per week on PCs' farms during peak agricultural periods (Kassahun et al., 1992). Moreover, PCs received preferential treatment in extension services as a development agent (DA) was assigned to PCs to render better extension services. Thus, the rate of technology adoption on the farms of PCs was relatively higher than on individual smallholdings. For instance, a study by Legesse and Asfaw (1988) in Bako area of western Ethiopia indicated that all PCs farms used fertilizer and improved maize varieties while only 34% and 50% of smallholders used improved maize variety and fertilizer, respectively, during the same period.

The most negative impact of producers' cooperative promotion policy production of the smallholder sector was when a PC was formed in a peasant association or when the number of PC members had increased, the PC members had priority in allocation of the best land as well as access to irrigation. This implies that fertile land was transferred from private smallholders to PC members and the individual farmers were allocated poor quality land. Hence, the formation of PCs had intensified the land insecurity problem for private smallholders. This might have restricted conservation and other forms of land improvement measures in the area (Legesse, 1998).

2.7.2.3 Marketing and pricing policies

Marketing and pricing policies adopted during the socialist period had a great effect on overall agricultural development and the adoption of new agricultural technologies by smallholders. The socialist government established the Agricultural Marketing Corporation

(AMC) to purchase and distribute agricultural products in 1976. The AMC was responsible to enforce uniform producer and consumer prices through out the country, provide production incentives by reducing marketing margins, and ensure adequate food supplies at reasonable prices. Grain quotas were set for individual farmers, different administrative regions and *weredas* (districts) to deliver to AMC. Interregional trade regulations were introduced and prices of grains were pan-territorially fixed by government and kept constant over time (Stroud and Mulugetta, 1992). Moreover, the activities of licensed grain traders were partially or totally taken over by AMC in most surplus-producing areas. However, the policy allowed grain traders to participate in grain marketing provided they sell 50% of their purchase to AMC at a price margin of 15% to 20% over the prices paid to farmers. At that time, the market prices were substantially higher than the fixed prices and the 15% to 20% margin was not adequate to attract traders in the light of opportunities foregone in the parallel markets. Thus, many traders inclined not to participate in legal (licensed and paying tax) marketing (Legesse, 1998).

The implications of marketing and pricing policies on the production and income of small farmers and thereby on their technology adoption decisions were negative. It is assumed that an increase in the agricultural product price increases farmer’s income and raises the incentive for technology adoption, which in turn leads to higher production per unit area of land or labour. Information on the effect of different grain prices on new technology adoption is limited and the findings of these studies converge to the same conclusion. A study by Cohen and Isaksson (1988) showed that the marketing policy had a negative impact on smallholders' production and income. Another study by Franzel et al. (1992) examined the impact of fixed AMC prices and average annual market prices of output using data from on-farm fertilizer experiments. Their study showed that on average there were 63% (ranging from 21% to 140%) and 72% (ranging from 0% to 172%) responses to fertilizer use on maize and wheat, respectively. However, at AMC fixed prices, application of fertilizer was not profitable at 82% of the trial sites due to the fact that the fixed AMC price was so low that the marginal value of production even did not cover the marginal cost of fertilizer application. The study further noted that at annual average market prices of maize and wheat, application of fertilizer became profitable at 78% of the sites (Table 2.9).

Table 2.9 Impact of AMC and market prices of output on profitability of fertilizer in Ethiopia, 1984-1987.

Crop	No. of trial sites	Sites at which fertilizer is not profitable to farmers	
		At AMC fixed Price	At local market price
Maize	35	34(97%)	10(28%)
Wheat	28	16(57%)	6(21%)
Tef	9	9(100%)	0(0%)
Total	72	59(82%)	16(22%)

Source: Adapted from Franzel et al. (1992

The study concluded that the fixed low prices reduced farmers' incomes and incentives to use new technologies (Franzel et al, 1992). Another study by the World Bank (1987), assuming fixed AMC prices and based on rough estimates of fertilizer responses, indicated that the benefit-cost ratio for fertilizer use was too low to provide adequate incentives for farmers, except for maize and wheat in some areas.

In the mid 1980s, a strategy was developed to make the country self-sufficient in food production. The strategy was to concentrate resources and technology on grain-surplus-producing *weredas* (districts) and more than 100 surplus producing *weredas* were selected to implement the strategy. Technologies such as improved varieties and fertilizer were made available on credit and extension activities were strengthened in those surpluses producing *weredas*. The results of these concerted efforts were encouraging since production and yield increased in the selected *weredas*. Besides, at the aggregate level, total production was also increased in the years 1986 and 1987. However, the marketing policy in place during that time compromised the gain from these efforts. Grain trade restrictions resulted in lower prices in surplus-producing *weredas* as surpluses could not moved out to deficit *weredas*. From this analysis, it is obvious that the policy had a negative effect on the use of improved technologies in grain-surplus-producing *weredas* of the country as a decline in output price result in reduction of benefits from the technology.

2.7.2.4 Villagization and resettlement policies

During the socialist regime, villagization and resettlement programmes were undertaken in the 1980s. These programmes moved peasants from their old settlements to new sites and regions. The villagization programme moved people who typically lived scattered throughout into a village. The objectives of the villagization program were to conserve natural resources by promoting a better land-use plan, enhance extension services, give greater access to public services, and strengthen security and self-defence (Stroud and Mulugetta, 1992). By the villagization programmes, 35% to 40% of farmers were forced to move to new villages (Hansson, 1994). Potential problems with villagization were the wastage of working time in travelling to and from fields, increased attacks of crops by livestock and wildlife because of the distance of the fields from the house, overgrazing near the villages aggravated erosion and more pressure on water supplies and tree resources. Moreover, the government has lacked resources to provide the necessary services such as water. The extension workers who were used to transfer agricultural technology were assigned to implement this programme and an unhealthy relationship was created between farmers and extension workers since the programme was undertaken without consulting farmers.

On the other hand, the resettlement programme moved rural people from drought-prone areas to the western, south-western and southern part of the country, where rainfall was reliable. Initially the World Bank recommended resettlement as a solution to overcrowded areas where the resource base could no longer support the population (World Bank, 1987a). 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, 1987a). In 1984/85 an estimated half a million people were resettled (Sisay, 1994). As the resettlement programme was not based on detailed studies; it failed at least due to four factors. First, farmers were moved and resettled against their will and because of these forceful measures they were not interested in the resettlement scheme. Second, the implementation of the programme involved many resettles and incurred high costs, and the government failed to provide adequate supports. Third, the government had the intention of developing the resettles' farms into PCs farms, but the resettles had no interest in collective farming. Fourth, resettles had limited participation in decisions concerning their farms. Technologies such as improved variety, fertilizer, and tractors were used on resettles' farms. However, the magnitude of participation of resettles in decision-making particularly concerning what to produce and the type and level of input to use was minimal. The authorities responsible for the implementation of the programme mainly made such decisions. Hence, the application of modern agricultural technologies was not considered as adoption decisions made by resettle farmers.

2.7.3 The post economic reform policies (1990-1995)

Towards the end of the socialist regime several reform measures have been undertaken since 1990, particularly the abolition of the compulsory grain quota and fixed price, and the lifting up of inter-regional trade regulations were of great importance for smallholders. Recurrent land redistribution was stopped and indefinite user right and the rights to transfer to legal heirs were given to farmers (Hansson, 1994). To make producer cooperatives and state farms viable economic units restructuring guidelines were developed. Above all, discrimination against smallholder farmers was terminated. The present government, which took power in 1991 enforced new economic reform (free market) in 1991.

Well-focused studies are not available to examine the impact of the post economic reform policies at macro as well as at micro level. To highlight the possible impact, some preliminary studies and secondary data from Central Statistics Authority (CSA) were used to compare the situations in area cultivated, production, and availability of inputs before and after the reform. A study by Hansson (1994) showed that peasant farmers increased the cultivated area by 12% to 20%[6] and agricultural production by 6% one year after the 1990 reform. As shown in Figures 2.7 and 2.8, on average, the area cultivated by smallholders increased from 93% in the pre-reform period to 99% of the total cultivated land after the reform. The area increment was mainly due to the shift from cooperative farms to private smallholder farms. Similarly, crop production increased from 93% to 98%, on average,

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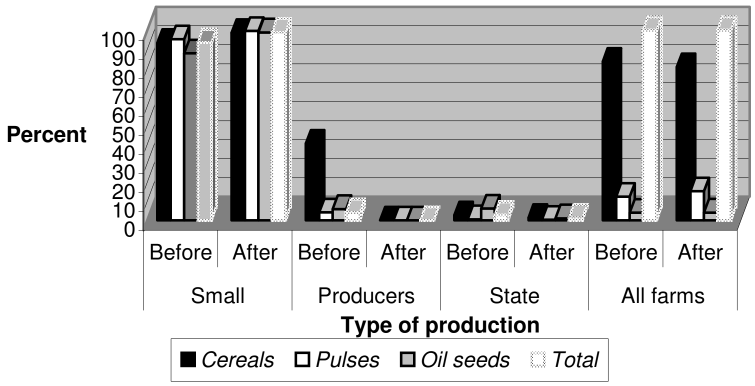
[6] The figures reported by Hansson (1994) do not look realistic in line with the national data reported by CSA. Using CSA data average growth rate of cultivated land over the period 1991 to 1994 was 9%.

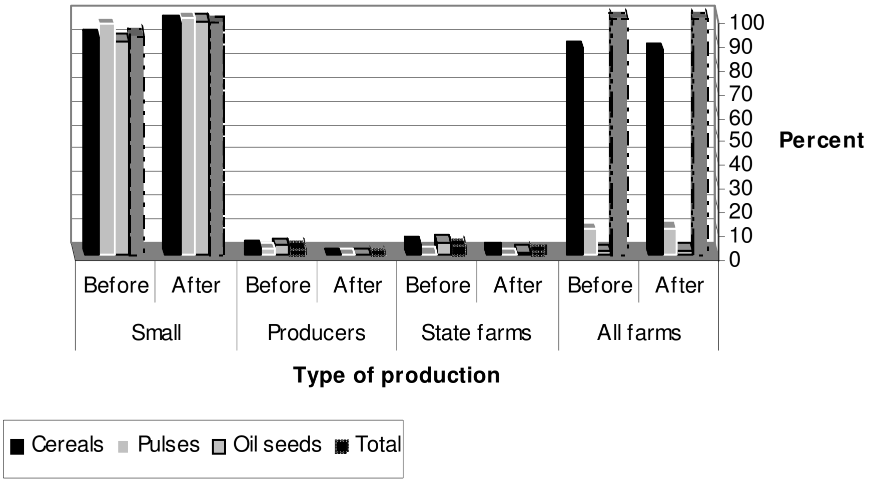
after the reform. On the other hand, the area cultivated and the amount of outputs produced by state farms dropped to 1% and 2%, respectively, in 1995. Moreover, the productivity of these farms was even worse than on smallholder farms. For instance, cereals yield of PC was 25% less than the yield obtained by smallholders. Nevertheless, a study by Eshetu (1994) showed that the performance of agriculture was greatly influenced by the weather. The study concluded that the country had two consecutive years of good rain and this may account for the considerable improvement in the performance of the agricultural sector after the reform.

Figure 2.7. Area of cereals, pulses and oil seed before and after the 1990 reform by type of production (percent of total) in Ethiopia.



Source: CSA

Figure 2.8. Crop production in Ethiopia before and after the 1990 reform by type of production (percent of total) in Ethiopia.



Source: CSA

Of the improved technologies, the availability of fertilizer and improved seed increased considerably after the reform. At the national level, the availability of fertilizer almost doubled over the period 1989 to 1995. For instance, fertilizer increased from 109,301 tons in 1989 to 210,420 tons in 1995 with an average annual growth rate of 11% (Table 2.10).

Table 2.10 Availability of fertilizer and improved seeds to smallholder farmers before and after the 1990 economic reform in Ethiopia.

Selected year	**Fertilizer ('000 ton)**	**Improved Seed ('000 ton)**	**Proportion of improved seed by sub-sector**	
			State farm	**Smallholder**
1975	13979	NA	NA	NA
1980	43287	1922	NA	NA
1984	46884	3193	80	20
1989	109301	9273	51	49
1993	135146	15586	22	78
1994	202325	17191	20	80
1995	210420	12456	23	77

Source: AISE and ESE; NA = Data not available.

Compared to the pre-reform period, the amount of improved seeds made available to farmers increased from 9,273 tons in 1989 to 12,456 tons in 1995 with an average annual growth rate of 5% due to favourable policy towards smallholders after the reform. Besides, the quantity of improved seed supplied to peasant farmers increased from around 15% in 1982 to more than 70% in 1995. Much of the seed distributed during the post-reform period, particularly after 1991, was done through safety net and rehabilitation programmes and projects. Thus, improved seed was distributed to farmers either free of charge or on loan through a revolving fund scheme with a recovery period of 3 to 5 years (Legesse, 1998).

Another change that took place after the economic reform was decentralization of extension activities and devolution of power. Approximately 3,000 to 5,000 assistant development agents (ADAs), who can speak the local language were trained and deployed over three years. This was a big achievement when compared to the number of DAs deployed in the pre-reform period. However, the quality of ADAs was weak due to the greater emphasis attached to political outlook[7] of an individual rather than his potential technical capability in recruiting individuals for the job (Legesse, 1998).

2.8 Agricultural research and extension in Ethiopia

This section gives an overview of the status of agricultural research and extension systems in Ethiopia. It describes the process in developing and disseminating agricultural technologies; constraints encountered in developing suitable technologies for smallholder farmers and identify weak links, which exist between research and extension systems that limit the adoption of improved agricultural technologies.

2.8.1 Agricultural research in Ethiopia

To develop improved crop varieties with their cultural practices agricultural research was initiated by the Institute of Agricultural Research (IAR) currently Ethiopian Institute of Agricultural Research (EIAR). The Alemaya University of Agriculture (AUA), Addis Abeba University, Awasa College, units of the Ministry of Agriculture (MOA) and Ministry of State Farms, Coffee and Tea Development, and Regional State Agricultural Research Bureaus also undertake different types of agricultural research. IAR was a semi-autonomous public institution established in 1966 to coordinate and perform agricultural research in the country. In 1997, Ethiopian Agricultural Research Organization (EARO) was formed and it included more institutions involved in agricultural research other than ex-IAR. The mandate of EARO is to generate new technologies; to improve indigenous knowledge; to adapt foreign technologies; and to develop new scientific knowledge and information in order to increase the production and productivity of agricultural resources and ultimately improve the living standards of the farm population of the country (EARO, 2003). Since the establishment of the IAR a number of crops varieties including t*ef* and wheat, were developed and released with their respective agronomic recommendations.

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[7] The assistant development agents were recruited by *wereda* administrators (elected politicians) with very little and passive participation of the responsible agricultural office and were trained for 6-9 months.

EIAR (renamed from EARO), AUA, Addis Abeba University and regional state agricultural research centers develop and release varieties. Although Pioneer Hi-Bred International has been involved in some varietal development (maize), all plant breeding has been virtually performed by the public institutions. The research programs emphasized increased *tef* or wheat production by concentrating on improved varieties with a package of cultural practices. This included the use of national and international nurseries to identify desirable genotypes, the execution of an extensive national and regional variety testing programs, the development of varieties through breeding, the coordination and execution of agronomic and crop management studies, and the multiplication and distribution of breeder and basic seed (Hailu, 1991). Special breeding, selection and crop, soil and water management programs have been designed for selected production problem areas. The areas of research included the development of varieties and crop management practices for drought and frost-prone areas, water logging vertisols and low soil fertility, specific disease or pest problems (Hailu, 1991). The target groups of the research results are producers (small-scale, private, subsistence, and resource poor farmers, medium to large-scale commercial private farmers, and the large-scale state farms) and users such as grain traders, the milling and food industry, and consumers. Before a variety is recommended for release, it must be evaluated in farmers' fields for its productivity, stability, disease resistance, and food quality. Varieties are officially released by National Variety release Committee (currently National Seed Industry Agency) after on–farm evaluation and verification. However, this procedure was sometimes violated. For instance, in 1991 Pioneer tried to produce 144 ha of hybrid maize seed and 60 ha of sunflower using improved seed that had not been evaluated and officially released in Ethiopia. As a result, the company harvested only 71.1 tons of maize seed and the sunflower even did not set seed (Hailu, 1992).

The *tef* and wheat research programs are handled by a multidisciplinary team of experts from different research and development institutions. The development of a minimum critical mass of work force, infrastructure and research facilities at major research centers has been the major efforts of the programs. Unfortunately, this is not achieved especially in the case of trained staff due to a serious brain drain and staff departure for a better pay.

The relationship between research and extension was not formal at the beginning. The first linkage between research and extension started in 1974 in the form of IAR/EPID joint research program and discontinued in 1977. It resumed in 1980 as IAR/ADD joint research and extension program and continued until 1987. In 1985, Research and Extension Liaison Committee (RELC) were formed at the national and zonal levels to create a strong and effective linkage between research and extension (Adugna et al., 1991) and still functional.

The Ethiopian Seed Enterprise (ESE), which was established in 1979 to produce, process and market seed after release. Initially, ESE only supplied seed to state farms and producers cooperatives during the socialist regime. Now it has been given autonomous status to function as a profit making enterprise. It was the only seed enterprise in Ethiopia until December 1990, when it entered partnership with Pioneer Hi-Bred International[8] (Hailu, 1992).

ESE usually receives breeder and basic seeds from EIAR and AUA and multiplies them on its farms. It also produces seed under contractual arrangements with state farms and private producers. The enterprise maintains five processing plants, from which it distributes seed. From 1980-1998, ESE produced and distributed an average of 19,948 tons of seed per year (Hailu, 1992; Abdisa et al., 2001). Of the total seed produced, wheat has the largest share of 70.2%, maize 19%, barley 5.2%, and *tef* and sorghum each 2.8%. Figure 2.9 presents seed distribution over the years. Total seed distribution, particularly wheat was more before than after the 1990 reform. From 1980-1990, ESE distributed an average of 24,289 tons of seed while 13,980 tons was distributed from 1991-1998 which is 42% less than previously distributed seed. The reduction in seed distribution occurred when producers' cooperatives dissolved and state farms number reduced after the fall of socialist regime. Figure 2.9 also depicts that wheat seed distribution decreased from 79% to 55% after the 1984 drought while maize seed distribution increased from 8% to 34% of total seed distributed. Since 1993, ESE has increased its seed supply because of the present government's effort to promote improved seed through its extension management training plots (EMTPs). During 1995-1998, ESE distributed 55% of its seed to EMTPs, about 15%

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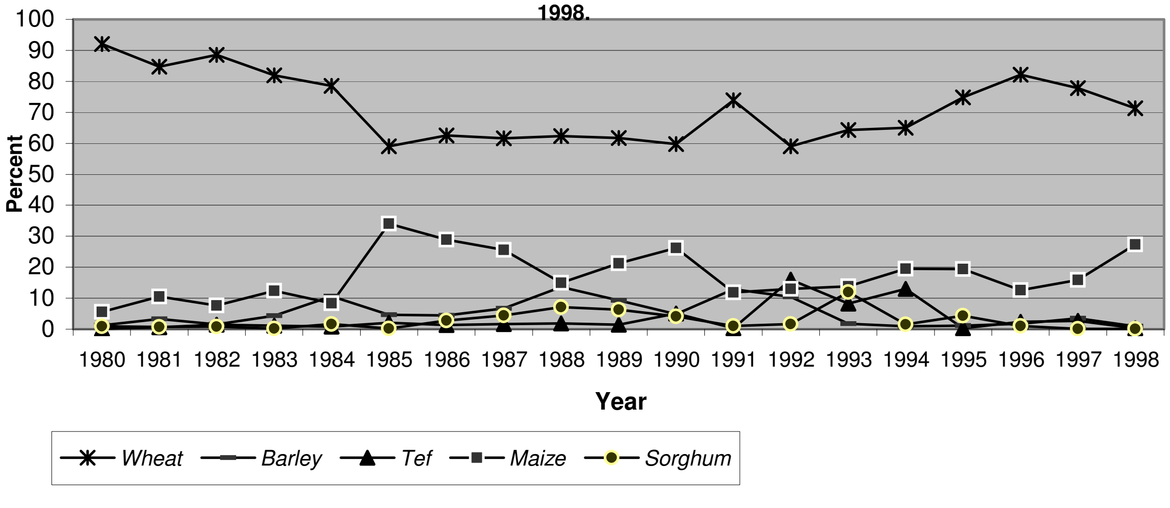
[8] The joint venture was terminated in December 1995 as part of the reform to liberalize the economy (Regassa et al., 1998).

to state farms, and about 30% to others including smallholders. In 1998, of the seeds distributed 71.3% was wheat, 27.4% maize, 0.9% barley and the remaining other crops including *tef*.

Figure 2.9. Seed distribution (percent of toatal) by the Ethiopian Seed Enterprise, 1980-1998.



Source: Adapted from Abdisa et al., 2001

Other public agencies like *Arsi* Rural Development Unit (ARDU) of the Ministry of Agriculture (MOA) and the Ministry of State Farm Development (MSFD) had also undertaken a limited amount of seed production and distribution since the late 1960s. ARDU produced different kinds of seed for peasant farmers in *Arsi* where as MSFD produced seed to meet its own requirements.

ESE is also responsible for importing seed, to meet the local demand. Between 1986 and 1991, ESE imported nearly 3,000 tons of seed, mostly hybrid maize, malting barley and sunflower (Hailu, 1992). After establishing a joint venture with Pioneer Hi-Bred International in 1990, ESE imported more seed (Abdisa et al., 2001). Increasing seed imports may have a negative impact on national effort to develop adapted, high-yielding varieties and hybrids, on creating a sustainable seed supply that would foster self-sufficiency, and on conservation and sustainable use of indigenous germplasm (Hailu, 1992). Moreover, increased imports reflect inability of ESE to meet domestic seed demand (Abdisa et al., 2001).

ESE used to distribute seed to farmers through Agricultural Input Supply Corporation, AISCO, currently Agricultural Input Supply Enterprise (AISE). AISE distributes seed to farmers through service cooperatives (SCs[9]) and PAs through the bureau of agriculture at regional, zonal and district level. There has always been some discrepancy between the amount of seed ordered and purchased by AISCO. For instance, between 1985/86 and 1990/91, AISCO ordered about 24,688 tons of seed from ESE and purchased only about 21%, which left ESE with a large residual seed stock every year. Moreover, AISCO actually distributed only 60% of what it had purchased. This problem of seed production and distribution to farmers was caused by problems in demand assessment, the seed distribution mechanism, seed quality, and the seed price and credit system (Hailu, 1992). At present ESE distributes seed directly to SCs through district agricultural development offices. In this case the seed price of ESE should be lower than AISE because of less service costs of ESE. Formerly, AISCO charged 20 *Birr*[10] (Ethiopian currency) per 100 kg seed above the price it paid to ESE for its services (Hailu, 1992).

With regard to seed quality, there is no independent national seed quality control and certification scheme although ESE has its own internal quality control facilities. As a result, none of the commercial seed distributed by ESE is certified by independent organization. Some times farmers and development agents have disputed the purity and quality of seed supplied by ESE (Hailu et al., 1998). Besides, very few improved varieties recommended and released by the research systems have reached farmers mainly due to poor seed dissemination mechanism (Adugna et al., 1991).

The National Seed Industry Agency (NSIA) was established in 1993 to strengthen the seed industry in Ethiopia. The objective of NSIA is to increase the flow of improved seed to farmers. Generally, the contribution of the formal sector in supplying improved seed has been very low although it is improving now. As a result, most seed in the peasant sector is still produced by the farmers themselves (Hailu, 1992). Seed distributed by national and

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[9] SCs were established (one for every 3-10 PAs) to sell farm inputs, purchase locally produced cereals and pulses, give loan at fair interest rates, provide storage and saving services, supply basic consumer goods, educate members in socialist philosophy, supply tractor services, collect self-help contributions, provide flour milling services and promote cottage industries (Stroud and Mulugetta, 1992).

[10] 1 US$=8.5 *Birr*

regional research centers through on-farm testing, demonstrations and through the Plant Genetic Resources Center and community level land race conservation initiatives is minimal. However, these efforts have contributed to the distribution of recently released varieties through farmer-to-farmer seed exchange, although the distribution is limited to the immediate vicinity of the research centers (Legesse, 1998).

The most common form of seed exchange in Ethiopia is from farmer to farmer (informal seed sector). This system has a number of advantages to farmers over the formal seed sector. First, it uses indigenous structures for information flow and exchange of seeds, and this makes it more flexible than the formal sector. Second, it operates at the community level between households within a small number of communities, so farmers have easy access to seed and often know the farmer from whom they have obtained the seed. Availability is further enhanced by wide variety of exchange mechanisms such as cash, exchange in kind, barter, or transfers based on social obligations (free of charge) that are used to transfer seed between individuals and households. This is especially important for households that have limited resources to purchase seed. Third, a further benefit of the informal exchange system is that farmers are able to acquire seed in the quantities they want (Cromwell, 1996). Although farmers have access to credit, they rarely make use of this opportunity due to lack of information, unavailability, and the complicated bureaucratic procedures required to access credit.

Ethiopian farmers have been participating in seed selection and preservation for centuries and the bulk of the national seeds requirement is still met through this informal system. Of the total annual seed requirement (about 0.42 million tons), only 15% is produced by the formal sector as improved seed stock, whereas 85% is produced by the informal farmer-to-farmer exchange system as local varieties (NSIA, 1998). In 1996, of the total area under crops, 76% was planted to local varieties while 24% was under improved varieties (Table 2.5).

2.8.1.1 Improved t*ef* and wheat production technologies

To improve t*ef* and wheat production, research has been going on for more than 30 years in Ethiopia. EIAR had adopted the farming system approach to develop more appropriate technologies to farmers in 1984 (Mulugetta et al., 1992). Based on research results (on-station and on-farm), a number of recommended t*ef* and wheat technologies with their respective agronomic practices were developed and released by the EIAR and the AUA since the 1950s (EARO, 2000). These improved t*ef* and wheat technologies were demonstrated to farmers since 1986 (Adugna et al., 1991).

2.8.1.1.1 Improved t*ef* and wheat varieties

Ten improved t*ef* varieties have been released and recommended for farmers at the time of the study (Seyfu, 1993; EARO, 2000). Of these five were developed through mass selection from farmers' varieties, and the other five were obtained from the crossing program. Out of the ten varieties, *DZ-01-354, DZ-01-196* and *DZ-Cr-37* were demonstrated to farmers and were being cultivated in the study areas (Table 2.11).

Table 2.11 Improved *tef* varieties presently in use in Ethiopia.

Variety	Year released	Maturity (days)	Altitude (m)	Rainfall (mm)	Yield (t/ha)	
					on center	on-farm
DZ-01-354	1970	85-130	1600-2400	300-700	3.0-4.0	1.7-2.2
DZ-0!-99	1970	85-130	1400-2400	300-700	2.8-3.0	1.7-2.2
DZ-01-196	1978	80-113	1800-2400	300-700	2.5-3.0	1.4-1.6
DZ-01-787	1978	90-130	1800-2500	400-700	2.7-3.0	1.7-2.2
DZ-Cr-37	1984	82-90	1860-2000	134-500	2.8-3.0	1.4-1.6
DZ-Cr-44	1982	125-140	1800-2400	300-700	2.5-3.0	1.7-2.2
DZ-CR-82	1982	112-119	1700-2000	300-700	2.8-3.0	1.7-2.2
Gibbe	1993	74-98	1520-1750	550-850	2.5-3.0	1.4-1.8
DZ-01-974	1970	75-137	1500-2200	500-700	2.4-3.4	2.0-2.5
DZ-Cr-358	1995	75-137	1820-2400	350-700	2.1-3.6	2.0-2.5

Source: EARO, 2000

On the other hand, a total of 44 improved bread wheat varieties have been recommended for release at the time of this study. Of these, 14 bread wheat varieties were recommended for release between 1967 and 1974 and 36 bread wheat varieties from 1974 to 2001(Hailu et al., 1991; EARO, 2000). However, there were 15 bread wheat varieties (Table 2.12) that were in use in addition to several obsolete varieties that tend to stay with the farmers longer (EARO, 2000). Among the obsolete varieties *6290 Bulk, 6295-4A*, and *Enkoy* are the major ones. ET-13.A2 and out of the varieties released after 1990s*, Kubsa (HAR-1685), Galema (HAR-604),* and *Wabe (HAR-710)* have been widely demonstrated to farmers with their associated cultural practices in the study areas. Under normal climatic conditions, bread wheat improved packages on the average yield 2.5 t/ha under on-farm conditions while the traditional varieties give a yield of 1.3 t/ha (Adugna et al., 1991).

Table 2.12 Bread wheat varieties presently in use in Ethiopia.

Variety	Year released	Maturity (days)	Altitude (m)	Rainfall (mm)	Yield (t/ha)	
					on center	on-farm
Dereselign	1974	144	1650-2200	300-700	na	na
K6290 Bulk	1977	128-131	1800-2200	300-700	4.0-6.0	3.0-4.0
K6295-4A	1980	128-131	1900-2400	300-700	3.5-5.5	3.0-4.0
ET-13A2	1981	107-149	2200-2700	400-700	4.0-6.0	3.0-4.5
Pavon-76	1982	120-135	750-2200	134-500	3.0-4.0	2.0-3.0
Mitike	1993	125-135	2000-2600	300-700	4.5-5.5	3.0-4.0
Wabe	1994	120-140	<2200	300-700	4.5-5.5	2.5-3.5
Kubsa	1994	120-140	2000-2600	550-850	4.5-6.0	3.0-45
Galema	1995	120-155	2200-2800	500-700	4.5-6.5	na
Abola	1997	128-131	2200-2700	na	na	na
Magala	1997	113-124	<2200	na	na	na
Tusie	1997	125-130	2200-2500	na	na	na
Tura	1999	120-149	2200-2700	na	na	na
Katar	1999	110-134	2000-2400	na	na	na
Shinna	1999	100-120	1800-2500	na	na	na

Source: EARO (2000); Tesfaye et al (2001); na = information not available at the time of the study.

2.8.1.2.2 Fertilizers

Of the several ways to increase agricultural productivity such as widespread use of improved cultural practices, efficient use of organic fertilizers and pest management techniques, the promotion of commercial fertilizer use has been the most plausible option in Ethiopia. Commercial fertilizer plays an important role in increasing yield even without improved seeds and bridging the gap between food production and population growth. Research results show that each kg of nutrient applied can increase grain yield by more than 5 kg (ADD/NFIU, 1992). The amount of fertilizer currently applied in Ethiopia is too low to cause major ecological degradation. In fact, increased use of fertilizer reduces the expansion of cultivation of fragile lands (IFDC, 1995). However, the use of commercial fertilizer is constrained by a number of factors. For instance, technical and marketing problems have reduced the return and efficient use of commercial fertilizers. The profitability of fertilizer use is affected by three interrelated factors of yield response, fertilizer price, and output prices.

A study by Asnakew et al. (1991) on sources of nutrients showed that the best sources are urea for N and DAP for phosphorus. Fertilizer response trials have been carried out since 1966 on red and black soils. Based on several years of experimentation, 60 k g of N and 60 kg of P_2O_5 have been recommended for t*ef* and wheat (Seyfu, 1993;). However, the Bureau of Agriculture still demonstrates 64/46 kg of N/ P_2O_5 per hectare for cereals.

2.8.1.2.3 Weed control

Weeds are one of the major crop production problems in Ethiopia. To control weed damage weeding is usually done by hand. Use of herbicide is limited since herbicides have not been readily available by public agencies. The government believes there is sufficient labour on farm, which can be used for weeding although there is a shortage during peak period. Consequently, timely weeding is one of the major problems of farmers (Hailu et al, 1991). Yield losses due to weeds were 36% for wheat and 52% for t*ef* (Rezene, 1985; Birhanu, 1985). Moreover, the critical period of weed competition for wheat and t*ef* was found to be during the early crop establishment period. Optimum yield was obtained from two-hand weeding; hence, two-hand weeding (30-35 and 50-55 days after crop emergence) was recommended for t*ef* and wheat cultivation (Rezene, 1985; Birhanu, 1985).

With regard to the use of herbicides, different broad-leaf and grass herbicides (a total of 15) have been recommended to farmers. However, only 2-4,D and MCPA 50% each at the rate of 1 l/ha were recommended to control broad leaf weeds in t*ef* and wheat production (Rezene, 1985; Birhanu, 1985).

2.8.2 Overview of extension activities

There was no formal extension service in Ethiopia prior to 1950s and new technologies were introduced through missionaries and the agricultural institutes in Jima and Ambo In 1952, formal agricultural research and extension were institutionalized under the auspices of the then Alemaya College of Agriculture (ACA). The responsibility of agricultural extension was transferred to the Ministry of Agriculture in 1963 (Tennassie, 1985). In Ethiopia research and extension are under different organizations. The Ministry of Agriculture (MOA), and the Ministry of State Farms' Coffee and Tea Development have been providing extension services to smallholders. The role of extension agents in Ethiopia includes demonstrating technologies, distributing inputs, carrying out soil and water conservation projects, villagizing farmers and promoting afforestation.

Different agricultural extension activities were undertaken in the past. The activities started as an educational service approach in the 1950s by Alemaya College of Agriculture and the service was fairly adequate particularly in the vicinity of the extension college. In the 1960s the community development approach was initiated as part of the First Five-Year plan (1958-62). Towards the end of 1960s and the beginning of 1970s the Comprehensive Package approach to rural development was introduced (e.g., CADU, WADU, ADDP). The early assessment of the comprehensive projects necessitated the development of a nationally replicable approach such as the Minimum Package Programs (MPPI and MPPII). MPPI was launched in 1971 under the Extension Project Implementation Department of the MOA. The package included limited inputs, credit and extension advices, and model farmers were used to demonstrate agricultural technologies. The MPPI was replaced by MPPII in 1980, which used peasant associations to distribute inputs and credit. Development agents (DA) in collaboration with trained farmers demonstrated the new technologies to members of peasant associations (Tennasie, 1985).

Before the termination of the MPPII in 1985, the Training and Visit (T and V) extension system was initiated in 1983. The T and V approach focused on the regular visit of contact farmers by DAs, monthly training of DAs by subject-matter specialists (SMSs) and every three months training of SMSs by researchers. From the experience of MPPI and MPPII, the Peasant Agricultural Development Program (PADEP) was launched in 1988. The objective of PADEP was to increase food production and improve farmers' productivity. This program utilized the modified T and V extension system and concentrated its programs in surplus producing *woredas* (Adugna et al., 1991).

The Sasakawa Global (SG-2000) extension approach started in Ethiopia in 1993. This program focused on demonstration of improved technologies, unlike earlier extension approaches, on larger plot size (half a hectare), timely availability of technological packages, financial self-reliance of farmers, and training of grass root level extension agents, supervisors and subject mater specialists in selected areas (Habtemariam, 1997). Following the "success" of SG-2000 Project, the government of Ethiopia launched the national extension package program, extension management training plots (EMTPs) in 1995 all over the country with more extension packages (post harvest, livestock and high income value crops). Farmers participate for a maximum of two years in the EMTPs and graduate. During their participation they get improved seed, fertilizers and herbicide on credit and on time, and technical advise from extension agents. Since the launching of EMTPS significant efforts have been made to raise the level of adoption of technological packages of t*ef* and wheat and other crops.

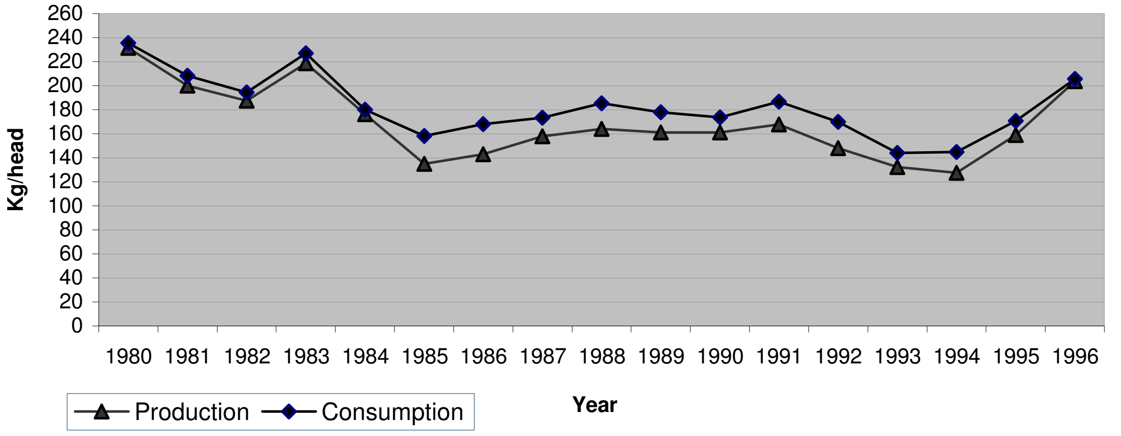
One of the problems that limited the development of agriculture in Ethiopia is the historically weak linkage between agricultural research and extension. This is because the two organizations are not under one umbrella, thus, are not obliged to work together. The EARO is a semi-autonomous and administered by a board whereas the extension is under the MOA. Their relationship is always on cooperation basis. Thus, extension workers are not formally involved in research. The number of forums where research information is passed to extension agents has been limited. This implies that appropriate research results may not be passed to extension agents and problems of farmers with the improved technologies may not be also communicated to researchers as feedbacks. There have been few efforts made by researchers and extension agents to improve the linkage by creating a liaison committee, Research and Extension Liaison Committee (RELC). RELC also tried to improve the linkage between researchers, extension agents and farmers. However, the outcome is not satisfactory and varies from region to region which indicate there is no clear guidance and responsibility sharing obligations. Besides, although there have been efforts to strengthen the extension units in the past, it was not adequate to establish efficient technology transfer system. Frequent reorganization, little in-service training for development agents, frequent transfer and few incentives including lack of pay raise and transportation to do their jobs have resulted in a generally unmotivated staff (Stroud and Mulugetta, 1992).

2.9 Food security in Ethiopia

In Ethiopia, food security has become an issue since the 1970s and has received considerable attention since then (Melaku, 1997). Maxwell and Frankenberger (1992) defined food security at the household level as "access to adequate food by households over time." The World Bank gave a more comprehensive definition of food security as the "access by all people at all times to enough food for an active and healthy life" (World Bank, 1986). The availability and accessibility of food to meet individual food needs should also be sustainable (Melaku, 1997). There is a difference between the concept of food security and self-sufficiency in food production. Food security implies physical and economic access to basic food at all times while food self-sufficiency is based on the need for greater independence and control of own food supply, non-tradability of some staple foods and the problems of dependence on one export crop (Hassan et al, 2000).

For a country like Ethiopia, food security is a high priority. However, domestic food production and supply have consistently been below the requirements mainly due to low productivity of the agricultural system resulted from insufficient use of improved technologies such as improved seeds, fertilizers, and herbicide. Consequently, Ethiopia is not able to feed its rapidly growing population. Figure 2.10 presents per capita production and consumption based on 225 kg/head/year, which is equivalent to 2100 kilocalorie (Kcal) recommended for an average individual (Debebe, 1997). The production was estimated without considering yields losses both at the field and storage due to lack of data. As it is clear from Figure 10, domestic food supply from agriculture (crop and livestock) was not sufficient to feed the population. In fact, it was only in 1980 where production meets the required consumption. The situation was particularly bad during the drought years of 1984-87 and 1993-94. For instance, in 1985, per capita food production dropped by 23% due to the drought while population increased by 3.1% from 1984. This forced per capita consumption to fall below the required level due to unavailability of food. The 1985 and 1993 consumption level (158 and 144 kg/head/year, respectively) was even lower than the minimum recommended level (182 kg/ head) for an average individual.

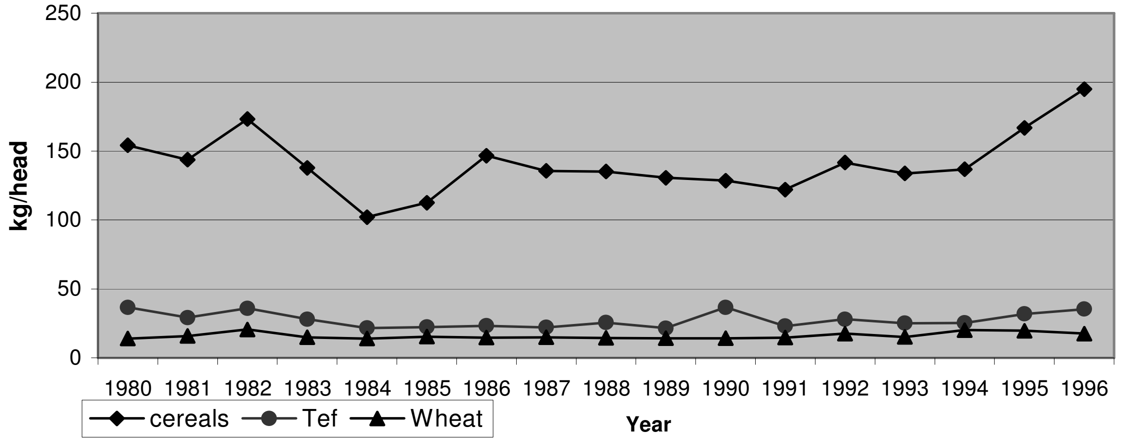
Figure 2.10. Food production and consumption (kg/head) in Ethiopia, 1980 - 1996.



Source: Adapted from Debebe, 1997.

Cereals are the major staple food accounting for 69% of the calories in Ethiopian diet (Stroud and Mulugetta, 1992). *Tef (Eragrostis tef)* is the main staple food (Seyfu, 1987). *Tef* and wheat contribute 20% and 11%, respectively, of per capita cereals consumption (Debebe, 1997). The average per capita cereals, t*ef* and wheat consumption were 141 kg, 28 kg and 16 kg per head per year, respectively. The shares of cereals, *tef* and wheat in food self-supply during 1980-96 were 87%, 16% and 9%, respectively. Figure 2.11 shows per capita consumption of cereals, t*ef* and wheat over the years.

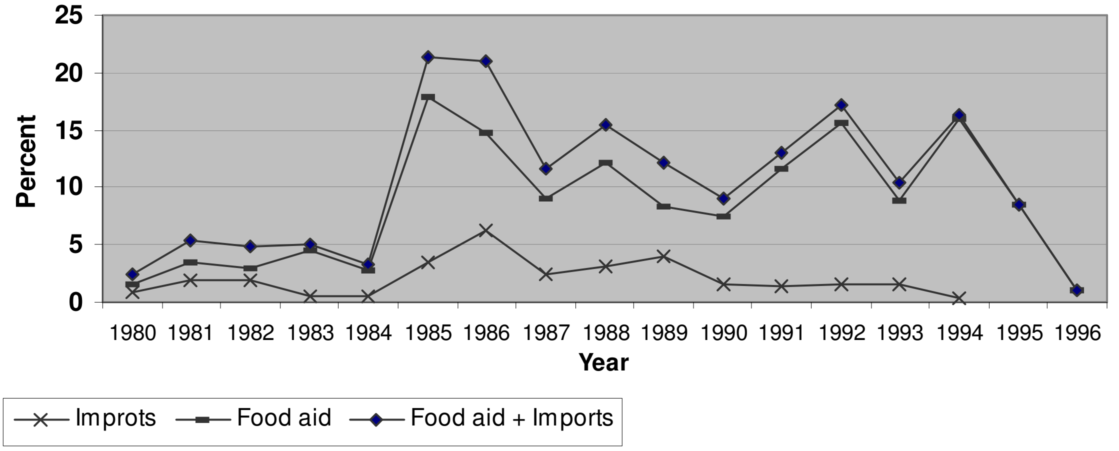
Figure 2.11. Per capita consumption (kg/head) of cereals, tef and wheat, 1980-1996



Source: Adapted from Debebe, 1997

It is clear from Figure 2.10 that the country had to import food to feed its growing population when it has the foreign exchange and look for food aid otherwise. Food aid has been the most important source of households' food security in rural Ethiopia. Annual food aid varies from 200,000 to 1,200,000 metric tons since 1980. The number of people who received food aid also increased from 2.5 million in 1987, 7.85 million in 1992, and 7.7 million in 2000 (Devereux, 2000) to 14 million in 2003. Ethiopia had imported up to 6% of its domestic food production from 1980 up to 1996 and received up to 16% of its domestic food production as food aid (Debebe, 1997). Food imports and food aid reached up to 21% of Ethiopia’s agricultural production especially after the drought years (Figure 12).

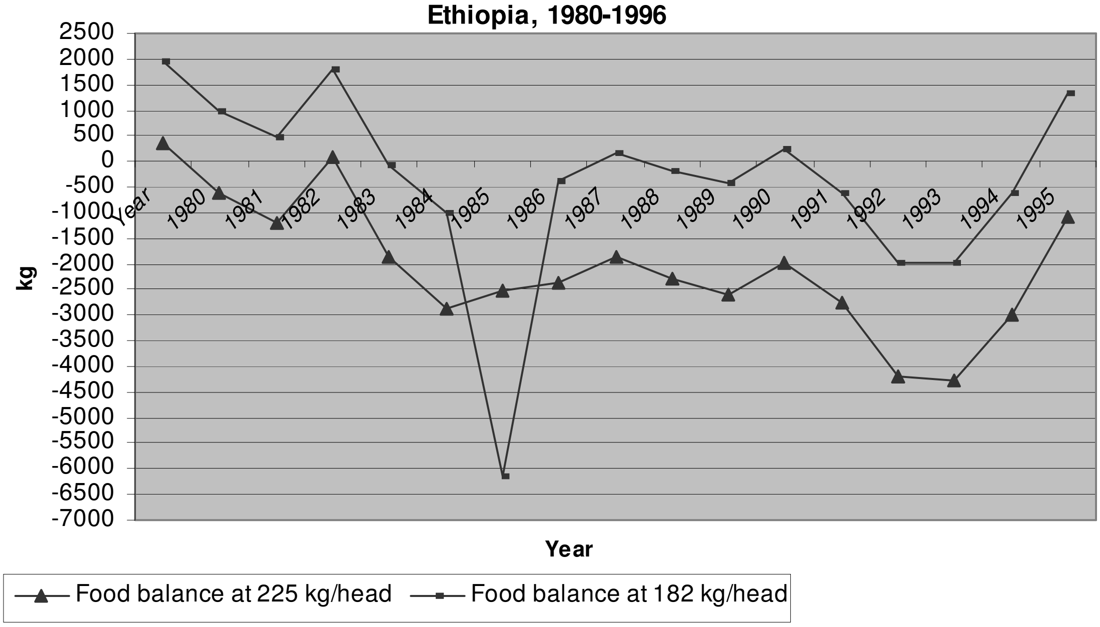
Figure 2.12. Contribution of imports and food aid (percent) to national food availability.



Source:Adapted from Debebe, 1997

One of the reasons for food shortages is unbalanced food production and population growth. For instance, total domestic food production from 1980 to 1996 increased by only 2.2 % per annum while the level of per capita food production dropped by about 12% for the same period due to rapid population growth (2.8% per annum). As a result there have always been food deficits during that period except in 1980 and 1983, even with food aid and imports (Figure 2.13). Moreover, domestic food production could not meet the requirements of the population even with the lowest calorie intake of 1700 kcal per person per day in most of the years during 1980 to 1996 (Figure 2.13).

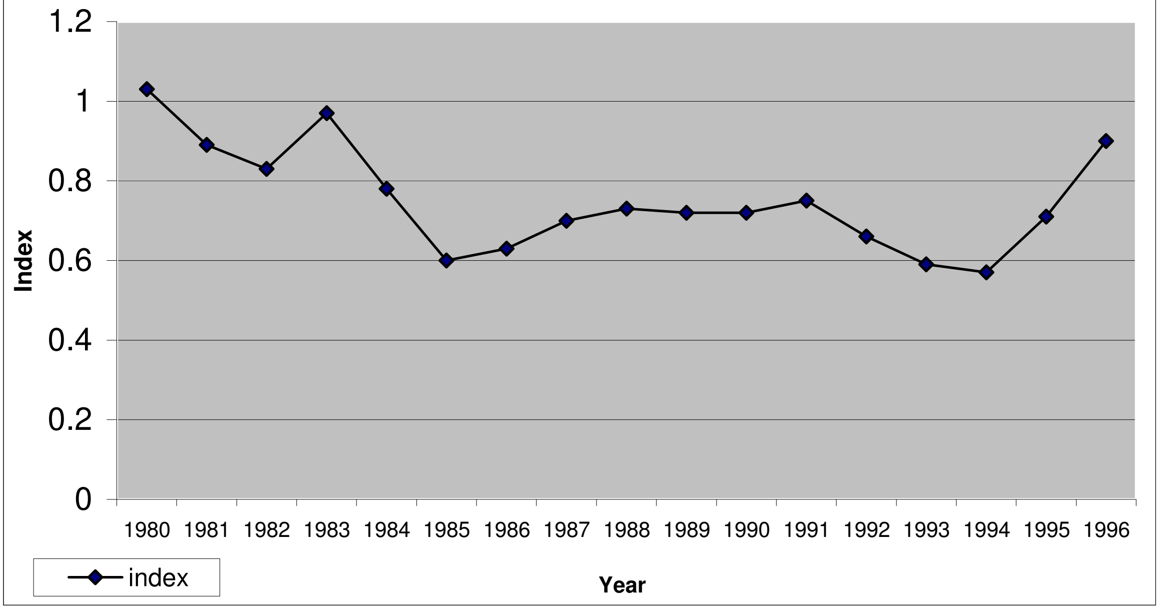
Figure 2.13. Food balance (kg), including imports and food aids, in Ethiopia, 1980-1996



Source: Adapted from Debebe, 1997

On the other hand, the food self–sufficiency index measured as the ratio of domestic food supply to domestic demand was less than one for all periods indicating food deficit except in 1980 (Figure 2.14).

Figure 2.14. Food self-sufficiency (index) in Ethiopia, 1980-1996.



Source: Adapted from Debebe, 1997

The above analyses call for a systematic effort to alleviate the food insecurity in Ethiopia. This can be achieved by promoting the use of improved inputs in all major production areas. Improvement in crop production can be achieved by efficient (not rationing) allocation of improved inputs to productive regions and efficient distribution of outputs from surplus areas.

CHAPTER 3

LITERATURE REVIEW: AGRICULTURAL TECHNOLOGY ADOPTION

3.1 Introduction

In this chapter, a review of relevant literature on adoption and diffusion is provided. The chapter will review and compare the various approaches to study adoption and diffusion found in the literature discussing merits and drawbacks of each. The theoretical framework within which the compared approaches are placed is presented in section 3.2. Section 3.3 will compare analytical models used to analyze adoption and diffusion of technologies and section 3.4 reviews empirical studies of relevance to this research. The final section presents analyses of technology adoption and diffusion in Ethiopia.

3.2 Basic concepts and theoretical foundations of adoption analyses

Technologies play an important role in economic development. Adoption and diffusion of technology are two interrelated concepts describing the decision to use or not use and the spread of a given technology among economic units over a period of time. Adoption of any innovation is not a one step process as it takes time for adoption to complete. First time adopters may continue or cease to use the new technology. The duration of adoption of a technology vary among economic units, regions and attributes of the technology itself. Therefore, adequate understanding of the process of technology adoption and its diffusion is necessary for designing effective agricultural research and extension programmes. The following sections define basic concepts of technology adoption and diffusion and provide a theoretical background to adoption and diffusion processes including hypotheses used to explain the S-shaped curve of diffusion. Stages, approaches and sequence of agricultural technology adoption, and benefits from adoption of innovations are also discussed in this section.

Adoption and diffusion are distinct but interrelated concepts. Adoption commonly refers to the decision to use a new technology or practice by economic units on a regular basis. Diffusion often refers to spatial and temporal spread of the new technology among different economic units. Many researchers belonging to different disciplines have defined the two concepts in relation to their own fields. Among others, the definition given by Rogers (1983) is widely used in several adoption and diffusion studies. Rogers (1983) made a distinction between adoption and diffusion. He defined diffusion (aggregate adoption) as the process by which a technology is communicated through certain channels over time among the members of a social system[1]. This definition recognize the following four elements: (1) the technology that represents the new idea, practice, or object being diffused, (2) communication channels which represent the way information about the new technology flows from change agents (extension, technology suppliers) to final users or adopters (e.g., farmers), (3) the time period over which a social system adopts a technology, and (4) the social system. Rogers (1983) then defined adoption as use or non-use of a new technology by a farmer at a given period of time. This definition can be extended to all economic units in the social system.

Feder et al. (1985) distinguished individual adoption (farm level) from aggregate adoption. Individual (farm level) adoption was defined as the degree of use of a new technology (innovation)[2] in a long-run equilibrium when the farmer has full information about the new technology and its potential. Aggregate adoption (diffusion) was defined as the process of spread of a technology within a region. This definition implies that aggregate adoption is measured by the aggregate level of use of a given technology within a given geographical area. Similarly, Thirtle and Ruttan (1987) defined aggregate adoption as the spread of a new technique within a population. The distinction between adoption and diffusion is

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[1] The Social system refers to a set of interrelated units that share common problems and are engaged in joint problem solving to accomplish a common goal (Rogers, 1983). A social system encompasses individuals, organizations, or agencies and their adopting strategies (Knudson, 1991).

[2] A technology is any idea, object or practice that is perceived as new by the members of a social system (Mahajan and Peterson, 1985). Innovations are classified into process and product innovation. A process innovation is an input to a production process, while product innovation is an end product for consumption. The agricultural technologies considered in this study fall in the first category. In this study the terms innovation and technology are interchangeably used.

important for theoretical and empirical analyses of the levels of the two economic phenomena.

The adoption decision also involves the choice of how much resource (i.e. land) to be allocated to the new and the old technologies if the technology is not divisible (e.g. mechanization, irrigation). However, if the technology is divisible (e.g., improved seed, fertilizer and herbicide), the decision process involves area allocations as well as level of use or rate of application (Feder et al., 1985). Thus, the process of adoption decision includes the simultaneous choice of whether to adopt a technology or not and the intensity of its use. Besides, before adoption choices are made a farmer makes a set of several interdependent decisions (Hassan, 1996).

A distinction has to be made between technologies that are divisible and that are not divisible with regard to the measurement of intensity of adoption. The intensity of adoption of divisible technologies can be measured at the individual level in a given period of time by the share of farm area under the new technology or quantity of input used per hectare in relation to the research recommendations (Feder et al., 1985). This measure can also be applied to the aggregate level of adoption in a region. On the other hand, the extent of adoption of non-divisible agricultural technologies such as tractors and combine harvesters at the farm level at a given period of time is dichotomous (use or no use), and the aggregate measure becomes continuous. In the latter case, aggregate adoption of a lumpy technology can be measured by calculating the percentage of farmers using the new technology within a given area.

3.2.1 Adoption, diffusion and abandonment of new technology

The introduction of a new technology consists of two phases. In the first phase, the new technology is introduced to farmers through for instance, demonstrations plots or other means and the new technology will be adopted when found beneficial. The second phase is characterized by declining use of the new technology over time until abandonment (Dinar and Yaron, 1992). Abandonment (discontinue use) of a new technology is a reflection of either a loss of profitability due to increasing costs of inputs, falling yields or the results of a switch to another more profitable technology. In the case of new improved seeds, abandonment is stopping the use of new variety any more. On the other hand, replacement of the existing improved variety with recently released new one is considered a continuation of use of the improved seed, because the new varieties are substitutes for each other. With this background, technology diffusion is presented next.

The concept of early and late adopters provided the basic hypothesis for explaining the S-shape nature of the adoption path. Studies by Mosher (1979), Rogers (1983), Mahajan and Peterson (1985), and Bera and Kelley (1990) provided explanations related to the process of acquiring information and the time lags that creates in terms of the speed of adoption among various members of the community in question to become adopters. In other words, the S-shaped curve results from the fact that only a few members of the social systems (farmers) adopt a new technology in the early stage of the diffusion process. At the early stages of introduction of a new technology, only few farmers obtain full information about the potential economic benefits of the technology and hence the adoption speed is slow. Moreover, even if they get full information about the potential economic benefits of the technology at the early stage, most farmers fear the possible risks associated with the new technology and hence do not opt to adopt. However, in subsequent time periods potential adopters acquire more information about the benefits of the technology and the degree of riskiness associated with it. Then adoption accelerates until it reaches an inflection point after which it increases gradually at a decreasing rate and begins to level off, ultimately reaching an upper ceiling. Studies by Griliches (1957) and Mansfield (1961) attributed the S-shaped diffusion curve to the spread of information as well as economic factors. Their studies showed that the rate of adoption of a technology is a function of the extent of economic merits (profitability) of the technology, the amount of investment required to adopt the technology and the degree of uncertainty associated with it and availability of the technology. Another study by Gutkind and Zilberman (1985) also revealed that the S-shaped diffusion curve can be explained by the profit maximization behavior, learning by doing and subjective evaluations of decision makers. The Gutkind and Zilberman’s (1985) study also indicated that the tendency of large firms to be early adopters of new technologies explains the S-shape curve, based on the assumption that large farmers have advantages over smaller farmers in most of the determining factors listed above, e.g., better access to information, education, capital and credit.

Theoretical and empirical adoption studies also investigated factors determining the long-run ceilings of the S-shaped diffusion curve. The long-run upper limit or ceiling of the S-shaped curve is determined by the economic characteristics of the new technology in the aggregate adoption. A study by Griliches (1980) showed that aggregate adoption ceiling is a function of economic variables (e.g. profitability) that determine the rate of acceptance of a technology. Differences in profitability of a technology in different regions result in different adoption ceilings.

3.2.2 Speed of technology adoption

Many adoption studies indicated that there is a great variation in the speed of technology diffusion. It has been argued that potential adopters' perceptions of the attributes of the new technology affect the speed with which that technology is adopted. A study by Rogers (1983) identified five characteristics of innovations that have an impact on the speed of adoption. Those characteristics of innovations included: relative advantage, compatibility, complexity, divisibility, and observability. Another study by Supe (1983) added two more attributes that affect the rate of adoption: variations in the cost of adoption and group action requirements of the technology. For example, technologies such as drainage and watershed management require group actions for adoption compared to technologies that are taken up on an entirely individual basis such as improved seed and fertilizer. The later group of technologies are adopted faster than those technologies that require group actions, as all farmers may not be equally interested in these technologies.

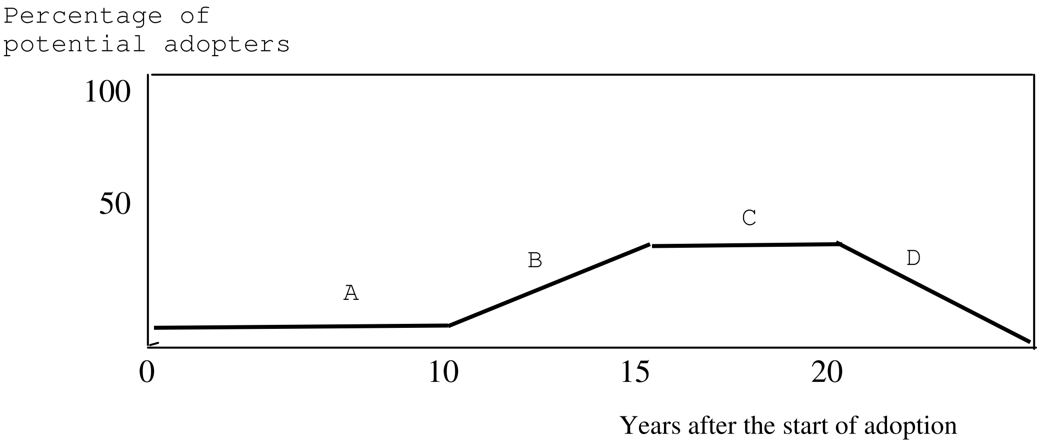
Of the technological characteristics mentioned above, relative advantage is regarded as the one with the strongest effect on the rate of adoption. The relative advantage can be subdivided into economic and non-economic categories. The economic categories are related to the profitability of the technology while the non-economic features are a function of variables including saving of time (leisure) and increase in comfort (Ratz, 1995). The higher the relative advantages the higher the rates of adoption. The compatibility of a technology indicates the degree to which that technology is consistent with the existing social values, cultural norms, experiences and needs of the potential adopters. This attribute also plays a key role in influencing the speed of adoption.

A study by Byerlee and Hesse de Polanco (1986) examined the relationship between rates (speed) of adoption of technologies and various economic factors. Their study showed that the adoption pattern of a particular technology is a function of five characteristics (profitability, riskiness, divisibility or initial capital requirement, complexity, and availability). Their study further indicated that profitability and riskiness of a given technology are a function of agro-climatic and socio-economic environments, such as rainfall and prices. In other words, rainfall and prices indirectly influence the rate of adoption. Interactions between technological components will also affects the rate of adoption. The benefits of using improved seed (hybrid) for instance, are enhanced by fertilizer application especially under favourable environmental conditions, e.g. in high potential areas (Feder, 1982; Byerlee and Hesse de Polanco, 1986; Hassan et al., 1998).

The rate and speed of improved technology adoption depends on the availability of improved technologies, which involve the generation and dissemination of these technologies to users (e.g., farmers). Generation of improved technologies is a time-intensive process and the technologies also depreciate (Alston et al., 1998). More time is also required for adoption to take place i.e. the time that passed from the introduction of the improved technology until the decision is made to use it. Figure 3.1 depicts the time taken to generate and disseminate improved technology and the adoption process. A generic adoption profile includes the technology development lag ending with a release of new technology (A) and the initially increasing adoption rate, which reflects the growing number of farmers in the target area who are using the technology (B). An adoption plateau occurs when most target farmers have been exposed to the technology and have decided whether or not to adopt it (C). Adoption then declines as the technology becomes obsolete (D). Together, these components determine the speed with which adoption of yield increasing technologies have impacts on farmers' production (Mills et al., 1998).

The other important reason for the length of time needed for technology generation, dissemination and adoption is how fast results are achieved as an indicator of the greater potential economic returns. Benefits received today worth more than those received tomorrow because they can be reinvested sooner to earn additional returns (Alston et al., 1998).

Figure 3.1. Technology generation and adoption profile



Source: Adapted from Mills et al (1998)

3.2.3 Categories of adopters and stages of adoption

Adoption studies also identified and described five categories of adopters in a social system. The categories included innovators, early adopters, early majority, late majority, and laggards (Mosher, 1979; Rogers, 1983). Describing the characteristics of these groups a study by Rogers (1983) indicated that the majority of early adopters are expected to be younger, more educated, venturesome, and willing to take risk. In contrary to this group, the late adopters are expected to be older, less educated, conservative, and not willing to take risks. However, a study by Runquist (1984) noted that the practical aspect of the classification of adopters into five categories is relevant to deliberate or planned introduction of innovation. The usefulness of this categorization is restricted as there is evidence indicating a movement from one category to the other, depending on the technology introduced.

Considerable efforts were made to identify the various stages of the adoption decision process. Studies by Rogers and Shoemaker (1971) and Rogers (1983) described the innovation adoption decision process, as the mental process from the first knowledge of an innovation to the decision to adopt or reject. The study further indicated that the innovation adoption decision process is different from the diffusion process. The former takes place within the mind of an individual while the latter occurs among the units in a social system or within a region. Based on this theoretical background the study identified five stages in the adoption process. These are (1) awareness or the initial knowledge of the innovation (2) interest and persuasion toward the innovation, (3) evaluation or the decision whether or not adopt the innovation (4) trial and confirmation sought about the decision made, and (5) adoption. These stages in the diffusion process imply a time lag between awareness and adoption. It is usually measured from first knowledge until the decision is made whether to adopt or not. Hence, adoption is not a random behaviour, but is the result of sequence of events passing through these adoption stages (Rogers, 1983).

3.2.4 Mode and sequence of agricultural technology adoption

Attentions have also been given to explaining the mode (approach) and sequence of agricultural technology adoption. Two approaches are common in the agricultural technology adoption literature. The first approach emphasises the adoption of the whole package while the second one stresses step-wise or sequential adoption of components of a package. Technical scientists often recommend the former approach while field practitioners specifically farming system and participatory research groups advance the latter. There is a great tendency in agricultural extension programmes of developing countries to promote technologies as a package and farmers are expected to adopt the whole package.

Opponents of the whole package approach strongly argue that farmers do not adopt technologies as a package, but rather adopt a single component or a few suitable technologies (Mann, 1978; Byerlee and Hesse de Polanco, 1986). Several adoption studies reviewed by Nagy and Sanders (1990) and Leather and Smale (1991) concluded that farmers choose to adopt inputs sequentially. Initially, adopting only one component of the package and subsequently adding components over time, one at a time. The major reasons often given for sequential adoption of a package of technologies are profitability, riskiness, uncertainty, lumpiness of investment and institutional constraints (Byerlee and Hesse de Polanco, 1986; Leather and Smale, 1991). A farmer first selects the technology that best exhibits these attributes. Another study by Ryan and Subrahmanyam (1975) revealed that farmers might look upon each part of the technological package as a less risky activity than the complete package in terms of what the farmer could lose if crop failure occurs in that season. Their study concluded that sequential adoption of components of technological package is a rational choice for farmers with limited cash. As cash is accumulated from previous adoption of a component of a package, farmers will add another component based on the relative advantage and its compatibility under their condition. This process will continue until the whole package is fully adopted.

A study by Rauniyar and Goode (1996) defined patterns of technology adoption based on the relationship between the technological components adopted. First, the study termed the adoption pattern independent, if the technologies (practices) are independent of one another. Under such conditions the adoption pattern of a farmer will be largely random (Rauniyar and Goode, 1996). This assertion is not in agreement with a study by Rogers (1983), which showed that farmers' adoption decision is not random. Farmers make rational decisions taking into account the environment under which they operate. The probability of adopting a given technology is not conditioned by the adoption of the other technology. Secondly, if farmers adopt technologies in a specific order, the adoption pattern is sequential. This implies that the probability of adopting a technology is conditional on adopting technologies that precede it in the sequence. Thirdly, the adoption pattern becomes simultaneous if more than one technology is adopted as a package and no specific adoption of a technology precedes or follows the adoption of another technology.

3.2.5 Risk and adoption of a new technology

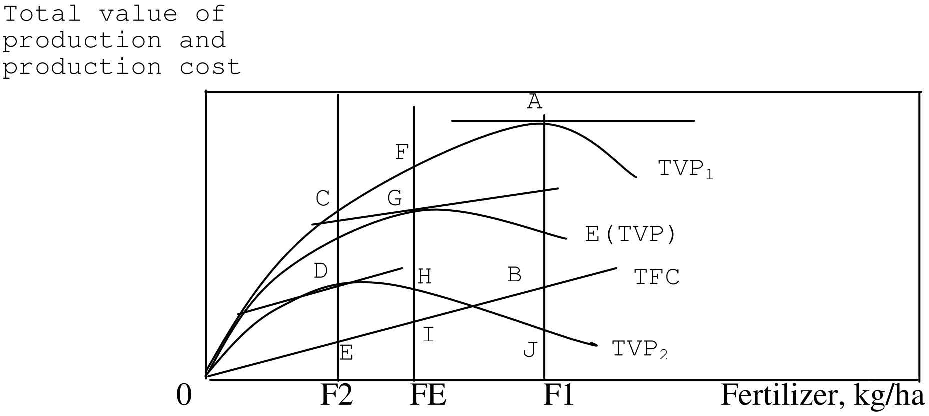
As indicated above adoption decisions depend on farmers' attitude toward risk (risk aversion or risk neutrality) and riskiness of the new technology. The impact of the new technology is not known and farmers have to make subjective judgments about the possible risks they will face. Farmer's risk attitude is analyzed by direct utility elicitation (DUE), observed economic behaviour and experimental methods (Binswagner, 1980). The Von-Neuman Morgenstern (VNM), the modified NVM and the Ramsey methods are among the DUE methods. However, the Ramsey method is less severely affected by preferences to probabilities and gambling (Anderson, Dillon and Hardaker, 1977).

For instance, the impact of risk on the optimal level of fertilizer use is illustrated in Figure 3.2. The type of risk analyzed here is the uncertainty about possible weather outcomes: "good weather" or "bad weather". If "good weather" occurs the best crop yield will be obtained and if "bad weather" occurs crop yield will be poor. The total value product (TVP) received in response to applying fertilizer for the "good and bad weather" and farmers' expected total value product (ETVP), based on the subjective probability of the weather, are represented by TVP1, TVP2 and E(TVP), respectively. A total factor cost (TFC) line shows total production cost associated with an increase in fertilizer use.

The demand for fertilizer depends on its contribution to the value of output. Two elements determine returns to fertilizer use. The first is its technical relationship between the different levels of fertilizer and the quantity of output produced holding all other factors constant. Second, based on profit maximization assumptions of the theory of the firm, an optimum level of fertilizer is achieved at the point where the value of additional output (TVP) from an extra unit of fertilizer is equal to its cost (price of fertilizer).

For instance, three alternatives fertilizer levels: (F1), (F2) and (FE) were chosen, the rationality of which depend on the risk preferences of farmers. A risk averse farmer is assumed to operate at D on (TVP2), while a risk loving farmer operates at A on (TVP1) and a risk neutral farmer operates at G on E(TVP). An application rate of (F1) represents an efficient allocation if a "good weather" occurs (TVP1), and provides the largest profit of AB. On the other hand, if (F1) is chosen and a "bad weather" occurs (TVP2), a farmer incurs a loss of (BJ). If a "bad weather" occurs, application of (F2) level of fertilizer is efficient on (TVP2). At application level (F2), if it turns out to be a "good weather" a profit of (CE) is obtained. But if it turns out to be a "bad weather" the farmer still makes a profit of (DE) albeit it will be small. Finally, a fertilizer application rate of (FE) represents an optimal level of a balanced assessment of the average outcome of a "good and bad weather". A profit of (GI) is obtained if (FE) is chosen, which is less than the largest possible profit (FI) on (TVP1) if it turns out to be a "good weather". On the other hand, if a "bad weather" occurs there will be a loss of (GH) which is less than the largest possible loss (FH) on (TVP2).

Figure 3.2. Decisions under Production risk.



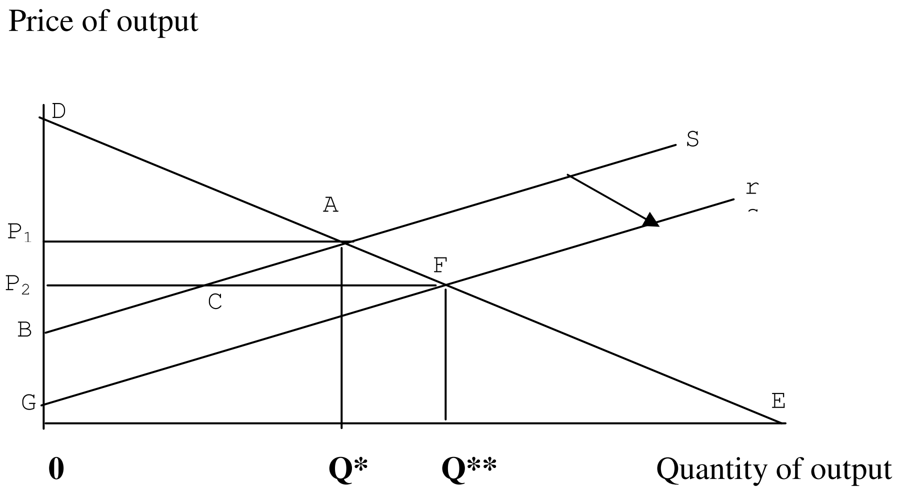
Source: Ellis, 1993.

3.2.6 Distribution of benefits obtained from adoption of innovations

Adoption of a new production technology increases production and shifts the supply curve to the right from earlier position (Figure 3.3). This shift shows the effect of adoption on a number of other variables in addition to the quantity produced (example, the price paid by consumers and the price received by producers). For instance, using economic surplus measures (consumer and producer surplus) the shift can be used to measure the distribution of benefits between producers and consumers as well as to identify the effects on industry revenue and to measure total increases in economic efficiency and total social benefits (Alston et al., 1998).

As Figure 3.3 depicts the adoption of new technology results in shifting of the supply curve from s to r, which increases both the consumers and producers surpluses. Consumers receive area (DAP$_1$) whereas producers receive area (P$_1$AB) in surplus before adoption of the new technology. After adoptions of the new technology consumers receive area of (DA FP$_2$) where as producers receive area of (P$_2$FG). The supply shift then results in output price decrease from P_1 to P_2, which affects both consumer and producer surpluses. The total gain from the adoption of the new technology is represented by area (ABGF).

Figure 3.3. Economic benefits from adoption of new production technology



The impacts of the technology adoption induced supply shift on consumers and producers are complex. As it is clearly depicted, both producers and consumers benefit from the supply shift, but who benefits more depends on the relative elasticity of both demand and supply (Gujarati, 1992). When demand is inelastic than supply, a positive (negative) shift in supply increases (reduces) consumer surplus more than reduction (increase) in producer surplus. With more elastic demand curve, a positive (negative) shift in supply result in smaller increases (reduce) in consumer surpluses than producer surpluses. Similar results are obtained with price inelastic and elastic supply curves, and holding supply price inelastic (elastic).

3.3. Approaches to analysing technology adoption and diffusion

Several analytical frameworks have been developed to analyse adoption and diffusion of agricultural innovations. Some were more suited and applied to adoption decisions while others did model diffusion better. This section provides a review of the various analytical models developed for studying adoption and diffusion of agricultural technologies.

3.3.1. Models explaining technology diffusion

As explained earlier in this chapter, the diffusion process has been commonly modelled to follow an S-shaped curve describing how technology as a new innovation spreads within adopting communities over space and time. Several models (static and dynamic) have been used to analyse this process.

3.3.1.1 Static diffusion model

The logistic function and its variants were commonly used to capture the nature of an S-shaped diffusion curve as discussed below.

3.3.1.1.1 The basic logistic model

A logistic function was specified to model the diffusion process as follows:

$$\partial N_t / \partial t = g_t (N^M - N_t) \qquad (1)$$

where $\partial N_t / \partial t$ is the rate of changes in adoption over time t and g_t is the coefficient of diffusion, which measures how fast adoption occurs. N_t is the cumulative frequency of adopters at time t and N^M is the maximum number of adopters in a social system over time. The number of potential adopters not joining at time t is N^M - N_t.

Griliches (1957) used the above model to estimate the diffusion of hybrid corn in the United States (U.S.). The percentage area planted to hybrid seed was estimated using the ceiling, the time variable and the rate of growth coefficients. This study also used the logistic function to estimate the relationship between the rate of adoption and profitability variables. Differences in profitability of technology in different regions or districts resulted in different adoption rates. The study showed that the diffusion rate of hybrid seeds in different farming areas was positively related to the increased profit achieved by the farmers introducing the new seed. However, the study did not reveal why producers did not adopt the new technology immediately, even if it was profitable.

Past studies on the path of technology adoption measured diffusion in terms of the distribution of adopters (frequency) over time (Rundquist, 1984; Thirtle and Ruttan, 1987). When the cumulative frequency of adoption is plotted against time, the result approximated an S-shaped (sigmoid) diffusion curve. Although the diffusion pattern of most innovations can be derived in terms of a general S-shaped curve, the exact form of each curve including the slope may vary depending on the analytical models used to describe the adoption-diffusion process (Sahal, 1981). For instance, the logistic function, the Gompertz function, the modified exponential function, the cumulative normal distribution function, and the cumulative log normal distribution function all provide S-shaped curves. The logistic distribution function, which is the simplest to estimate and interpret, is more widely used in most adoption and diffusion studies.

Studies by Gore and Lavaraj (1987), Doessel and Strong (1991) and Knudson (1991) questioned some of the assumptions of the basic logistic model. The studies attempted to improve the relevance of the logistic function by relaxing some of its stringent assumptions. For example, Doessel and Strong (1991) relaxed the assumption of constant population and incorporated population variability (unknown population) in investigating the diffusion of new pharmaceutical drugs. It was assumed that the intercept and diffusion rate are not affected by the size of the population. The modified logistic model produced valid estimates if the members of any size of a population have the same behavioural characteristics.

In the study of semi-dwarf wheat varieties in the U.S. by Knudson (1991), the assumption of a fixed adoption ceiling of the logistic model was relaxed to allow for the possibility of non-adoption and changes in complementary technology. The study by Knudson (1991) applied the modified logistic model on semi-dwarf wheat varieties and showed that the modified logistic model better fitted the data compared to the standard logistic model that is commonly based on the assumption of constant ceilings. Another study by Gore and Lavaraj (1987) also relaxed the assumption of homogeneous population and estimated the standard and modified logistic models to describe diffusion of crossbred goats in a spatially heterogeneous population (within town and outside town) in a village in Pune of west India. The study revealed that diffusion in a village within the town follows the logistic model while diffusion in a village outside town was a function of information received from adopters within a village. The modified logistic model resulted in a marginal improvement over the standard logistic model.

3.3.1.1.2 The distinction between innovators and imitators in models of diffusion analyses

The basic logistic model was based on imitation theory, which assumes that the adopting population consists of homogeneous imitators (Feder et al., 1985; Knudson, 1991; Weir and Knight, 2000). While this approach clearly describes how innovation diffuses, communication channels are not explicitly modelled. Their effect is implicitly captured in the diffusion coefficient, g_t (equation 1).

The diffusion model that disaggregates adopters into innovators and imitators measures the value of the constant relating the number of new adopters to potential adopters as a function of the specific technology, the social system, the channel and change agents used to diffuse the technology and economic factors (Mahajan and Peterson, 1978; Akinola, 1986). The said constant can also be expressed as a function of previous adopters if higher order terms are dropped. Modifying the basic logistic diffusion model to provide for these concepts yield (Mahajan and Peterson, 1978):

(1) The coefficient of innovation or the rate of adoption of the proportion of the population whose adoption decision is influenced by exogenous information, and

(2) The coefficient of imitation or the rate of adoption of the population whose adoption is based on internal interactions.

The coefficient of imitation takes into account the interaction between adopters and non-adopters. This modified model is similar to the new-product growth model (Bass, 1969)[3], which was further developed by Mahajan and Peterson (1978).

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[3] Bass (1969) model assumes that the adoption coefficients of imitators and innovators are constant. This assumption is unreasonable as a general case, since socio-economic, institutional, and the supply conditions of the innovation influence these variables.

The theory of imitation on which the standard logistic models were based has been questioned in many diffusion studies. In the standard logistic model the population or social system is assumed to be homogeneous and imitators. Hence, new users imitate adopters. However, adopters do not only influence potential users in the social system as they are also influenced by external information sources such as extension agents and mass media. To estimate such effect, models that account for influences from the internal and external sources of information have been developed. Such models classify the population into two categories, the innovators and imitators. It is assumed that the innovators adopt the new technology independent of others in the social system (Feder and Umali, 1993). Their adoption decision is influenced by external information sources such as extension agents, technology suppliers and mass media. However, the adoption decisions of imitators depend on the number of adopters in the social system. The roles of agricultural extension services and inputs suppliers represent the external information sources while interaction among farmers themselves represents internal information sources (Rogers, 1983).

One problem with the logistic model is that it imposes a symmetric diffusion trend with a maximum diffusion rate occurring when 50% of the potential cumulative adopters have adopted (Thirtle and Rutan, 1987). It is based on the premise that diffusion occurs through interpersonal contacts among a group of homogenous adopters (Mansfield, 1961). But not all diffusion models require symmetry around 50% inflection point. For instance, the Gomptez model (equation 2) imposes an asymmetric trend with the maximum diffusion rate occurring when 37% of the potential cumulative adopters have adopted.

$$\partial N_t / \partial t = g_t \log N^M - N_t \qquad (2)$$

The assumption here is that although adopters are homogeneous, early adopters are relatively more cohesive than middle and late adopters and hence they adopt at a faster pace.

Concerning the symmetric nature of the logistic curve, the symmetry of the logistic curve does not always fit observed data. Alternative non-symmetric diffusion models were developed to fill this gap. The inflection point and degree of symmetry of these flexible logistic models are determined by the observed data sets and not imposed a *priori* (Bewley and Fiebig, 1988).

The above static diffusion models work best when the adoption process modelled satisfies certain assumptions. According to Mahjan and Peterson (1985), six basic assumptions underlie static diffusion models:

1) The adoption decision is binary (an individual adopts or does not adopt);
2) A fixed, finite ceiling exists;
3) The coefficient of diffusion is fixed over time;
4) The innovation is not modified once introduced, and its diffusion is independent from the diffusion of other innovations;
5) One adoption is permitted per adopting unit and this decision cannot be annulled; and
6) Geographical boundaries of a social system stay constant over a diffusion process.

However, for many applications the static diffusion model is open to two objections. First, there will be no rationale *ex ante* for assuming that diffusion follows a particular trend in many cases. Second, in most economic contexts the assumption of a fixed ceiling on the adopting population is unrealistic. For instance, the potential number adopters of a biological innovation will vary depending upon the availability of innovations, which itself is a result of the profit-maximizing efforts of firms. This calls for models that allow more flexibility with regard to inflection and symmetry points (Mahajan and Peterson, 1985 Knudson, 1991).

3.3.1.2 Dynamic diffusion models

Dynamic diffusion models allow the determinants of diffusion to change every time period and, hence, measure the rate of adoption more accurately than the static model. For instance, as the real price of an innovation decreases and stabilizes, an innovation becomes more attractive and is adopted more rapidly. A dynamic model could capture this change whereas a static model could not. Moreover, a dynamic model can include more variables that affect diffusion as a result of its flexible form and hence measure more directly the impact of these factors (Mahajan and Peterson, 1978, 1985, Knudson, 1991).

Studies by Mahajan and Peterson (1978) and Metcalfe and Gibbons (1983) used the dynamic model relaxing some of the assumptions (adoption ceiling, changes in the technology, disadoption) of the static model. Unfortunately, their model, although theoretically appealing, it is difficult to estimate because data required for the profit equations are virtually impossible to obtain.

A model overcoming these data limitations was developed by Knudson (1991) to estimate the diffusion of semi-dwarf wheat varieties across the U.S. In this model, the maximum numbers of adopters were considered to be a function of a wheat supply, wheat prices farmers' received and paid, and the price paid for fertilizers at a given time. All mentioned prices were lagged one year. Two factors accounted for this: First, the model used price variables lagged only for one year because producers' expectations were based on relatively recent experiences used. Second, a common deflator does not deflate the price variables; rather the price variable that would have been the deflector is used as explanatory variable to measure its impact (Tomek and Robinson, 1981). Comparison of results of static and dynamic diffusion models show that the dynamic model provides a better fit to the data as well as offering additional insights into the economic determinants of wheat adoption (Knudson, 1991). In particular, the pattern of adoption of improved varieties was affected by changes in fertilizer prices (Knudson, 1991).

3.3.2 Models analysing adoption of innovations

Generally, it is assumed that farmers' decisions in a given period of time and space are derived from maximization of expected utility or expected profit subject to resources constraints. Therefore, adoption depends on farmers' discrete choice of a new technology from a mix including the traditional technology and a set of components of the new technology (Feder et al., 1985). To answer the question of what determines whether a particular technology is adopted or not and intensity of adoption, most of the adoption of agricultural innovations studies used static rather than dynamic models.

3.3.2.1 Static adoption models

A static model refers to farmers' decisions to adopt an improved technology at a specific place and a specific period of time. This model attempts to answer the question of what determines whether a particular technology is adopted or not and what determines the pattern of adoption at a particular point in time. The results of these studies are often contradictory regarding the importance and influence of certain variables (Ghadim and Pannell, 1999). One limitation of the static model is that it does not account for time in the adoption process nor for the farmers' ability to learn to improve their technical efficiency in growing and marketing the crop. These weaknesses are addressed in dynamic adoption models.

The majority of adoption studies continue to be in the static binary setting of logit or probit models (Jansen, 1992; Shields et al., 1993; Polsen and Spencer, 1991). In these models the adoption decision is merely dichotomous (whether or not to adopt) where a functional relationship between the probability of adoption and a set of explanatory variables is estimated econometrically using logistic distribution for the Logit procedures and the normal distribution for the Probit procedures. The Logit/Probit methods investigate the effects of regressors on the choice to use or not use, but it does not measure the degree or intensity of adoption (Feder et al., 1985). For instance, if a Probit model is used to analyse data on fertilizer adoption, a farmer who adopts the recommended level of fertilizer is treated the same as a farmer who applies one tenth of the recommendation (Ghosh, 1991). But the alternative static econometric procedures such as the Tobit (Tobin, 1958) are used to analyze quantitative adoption decisions when information on the intensity of adoption is available (e.g., data on percentage of area planted to improved varieties, amount of fertilizer/herbicide applied, etc.). However, in working with continuously measured dependent variables such as quantity or area, some of the data points will have a zero value (i.e., for non-users). In this case the dependent variable is censored where information is missing for some range of the sample. If information on the dependent variable is available only if the independent variable is observable, the dependent variable is described as truncated (Kennedy, 1992). The Tobit model provides coefficients that can be further disaggregated to determine the effect of a change in the i^{th} variable on changes in the probability of adopting the new technology and the expected intensity of use of the technology. However, a study by Dong and Saha (1998) indicated that a Tobit model imposes restrictions that the variables and coefficients determining whether and how much to adopt decisions are identical.

The alternatives to analyse farmers' adoption decisions include the use of double hurdle models, which take into account zero observations (Cragg, 1971; Heckman, 1976). The choice of a model is important because it influences the empirical results obtained (Jones and Yen, 1994). Inappropriate handling of non-users also can result in biased and inconsistent estimates (Amemiya, 1984). For instance, the Tobit model assumes that decisions regarding adoption and intensity of use are related. However, studies by Cragg (1971) on the demand for durable goods and Coady (1995) on fertilizer use indicated that such decisions might not be intimately related. The Heckman (1976) model is the most restrictive of the double hurdle models available because it assumes that none of the zeros for the non-adopters are generated by the adoption decision (i.e., first hurdle dominance) so that standard Tobit censoring is irrelevant (Jones, 1989).

Another study by Saha et al (1994) also modelled adoption as a mixed dichotomous-continuous framework with non-random sample selection, where producers' adoption intensity was conditional on their knowledge about the new technology. They argued that producers' choices are significantly affected by their exposure to information about the new technology. The model is comprised of three equations with correlated errors. The first two are the sample selection and the adoption versus non-adoption equations, both of which have dichotomous dependent variables. The third equation explains adoption intensity, a continuous variable. With this model their study showed that including sample selection and adoption intensity in the model specification yields substantially different results and inferences compared to the traditional dichotomous specification.

A study by Dong and Saha (1998) proposed the more general framework of a double-limit hurdle model that incorporates Tobit and probit models as testable special cases. The study departs from the existing adoption studies in that actual adoption occurs when the innovation is perceived as more profitable, on average, than the traditional technology

(Feder et al, 1985). The study by Dong and Saha (1998) argues that adoption may not occur even when the new technology is expected to be more profitable, because the value of the alternative course of action, waiting and adopting only if one is certain about the return from the new technology, may be higher.

Hassan et al (1998) also used a two-stage decision process to study farmer's adoption of modern maize varieties in Kenya. Both decisions of whether or not to adopt improved maize seed, and whether to plant hybrids or open pollinated varieties (OPVs) were modelled as binary choices. This procedure was selected because only a negligible number of farmers mix maize types and there is no need to investigate area allocated to each. In this model farmers choose between local cultivars and two types of improved seed (hybrid and improved OPVs). Thus, the decision problem is separated into two stages, with each stage represented by a separate equation. One equation models farmers' choice between local and improved maize varieties. The second equation analyses adoption decision about which type of improved variety to use: hybrid or improved OPVs (non-adopters are excluded from the second equation).

Other study by Hassan (1996) showed that a fairly comprehensive range of plating choices made by maize farmers in Kenya, including discrete endogenous variables creating self-selectivity, is modelled and estimated as one system of interrelated decisions. Two-stage and three-stage probit procedures are used to handle the simultaneity and self-selectivity problems. It is common that although some elements of farmers' planting decisions are observed as qualitative endogenous choices (whether or not to double crop) they are usually treated as exogenous variables. Few examples of simultaneous estimation of qualitative adoption decisions are found in the agricultural technology adoption (Smale et al., 1995; Saha et al., 1994).

A study by Workeneh and Parikh (1999) used Probit and ordered Probit to examine both the significance of the impact of farmers' perceptions in adoption decisions of new technology and how perceptions are influenced by the decision to adopt new technology. The Probit approach was used to analyse the adoption decision, while farmers' perception variables were modelled using the ordered Probit methodology since there is an ordering to the categories associated with the dependent variable. The ordered Probit model assumes that there are cut-off points which define the relationship between the observed and unobserved dependent variables (Pindyck and Rubinfeld, 1981). A simultaneous equations model combining the Probit and ordered Probit approaches provided a useful approach to modelling the two-way relationship between perception and adoption.

For jointly determined dependent variables simultaneous equations systems of discrete and continuous endogenous variables such as Heckman (1978) and Nelson and Olson (1978) were proposed. However, systems estimation by conventional two or three stage least square Generalized Probit model estimates would not eliminate simultaneous equation bias. Therefore, Heckman (1978) used a reduced form of parameter estimates as instruments to overcome the problem of estimating systems of equations with discrete and continuous endogenous variables. These instruments result in consistent parameter estimates and are asymptotically more efficient than the Generalized Probit estimates. Hence, each structural equation can be estimated with the instruments included as one of the explanatory variables with the appropriate discrete or continuous variable estimation procedures.

3.3.2.2 Dynamic adoption models

Dynamic adoption models allow for changes in farmers' adoption decisions as farmers gain skills in growing or marketing the improved seed from year to year. In a dynamic model, at the beginning of each period the type of technology the farmer uses in that period, his allocation of land to different crops, and use of other variables are determined. At the end of each period, the actual yields, revenues and profits/losses realized, information and the experiences accumulated during the period by the farmer, and information from other farmers are used to update decision making in the next period (Ghadim and Pannell, 1999).

A few studies used dynamic models to explain adoption decisions. O'Mara (1971) was among the first to employ a Bayesian approach in explaining the evolution of a decision-makers' perception about a new technology. Linder et al (1979), Stoneman (1980), Linder and Fischer (1981) followed O'Mara's work where a common theme of these studies is that the producer collects information about actual profits derived by other producers from the innovation and updates *prior* perceptions about the expected return from the new technology.

Studies by Beseley and Case (1993b), and Foster and Rosenzweig (1995) established the importance of learning in the dynamic adoption process. The study by Beseley and Case (1993b) modelled farmers as being uncertain about the profitability of the new seed relative to the old ones. The said study simulated the sub-game perfect number of plots to be planted to the new seed, given that farmers learn about the profitability of the new seeds through experience and compared this with the pattern found in their data. In contrast, Foster and Rosenzweig (1995) modelled the optimum input use as being unknown and stochastic. Farmers learn about the optimal combination through their experience and from the experience of their neighbours.

A study by Carletto et al (1996) modelled adoption and abandonment as combination of two processes which are unfolding over time, but with different origins. The first is the historical time where market and institutional conditions were highly favourable to adoption. The other is the human time, which is composed of two opposite forces (positive and negative). A positive force for adoption and retention is the accumulation of knowledge associated with the passage of time before adoption (learning from others) and years of production after adoption of new technology (learning by doing). A negative force is associated with the passage of time after adoption caused by yield loss. The various time structural factors are unlikely to affect all farmers in equal manner, creating biases capable of offsetting the initial competitiveness of small farmers in growing new technologies over time. This study modeled adoption not as one time behavioral choice within specified time intervals, but as processes of choices of when to adopt and when to abandon using Weibull duration model based on the semi-log functional form.

A study by Cameron (1999) examined the dynamic adoption process of learning using panel data in the adoption of new high-yielding variety. This study used average profit differential between the new and the old seed that has been experienced by the farmer as the dynamic learning term.

3.4 Empirical studies of technology adoption and diffusion

Adoption is a behavioral choice at a particular time and space while diffusion is the adoption pattern over time. Agricultural technology adoption has long been of interest to social scientist because of its importance in increasing productivity and efficiency. The agricultural sector in developing countries has its own special characteristics (seasonality of production and heavy dependence of production on natural phenomena). Because of these special characteristics of agriculture the following reviews were made only for developing counties.

3.4.1 Adoption studies in developing countries

In developing countries, adoption studies started about four decades ago following the Green Revolution in Asian countries. Since then, several studies have been undertaken in Asia and Latin America to assess the rate, intensity and determinants of adoption. Most of these studies focused on the Asian countries where the Green Revolution took place and was successful.

A review by Ruttan (1977) on several empirical studies on the adoption of Green Revolution technologies revealed the following generalizations:

1. The new High Yielding Varieties (HYVs) of wheat and rice were adopted at a rapid rate in those areas where they were technically and economically superior to local varieties.
2. Farm size and farm tenure have not been serious constraints on the adoption of new HYVs, and were not important sources of differential growth in productivity. This was mainly because productivity of HYVs was approximately the same on small and large farmers' fields.
3. The introduction of the new high yielding wheat and rice technology has resulted in an increase demand for labour.
4. Landowners have gained relatively more than tenants and labourers from the

adoption of high yielding varieties of wheat and rice.

However, the review indicated that there are many exceptions to the generalizations made. These exceptions occurred due to the fact that the technologies have been introduced to environments with different economic, social, institutional, political and agro-climatic settings. A study by Perrin and Winkelman (1976) also summarized adoption studies done by the Centro International de Mejoramieto de Maiz Y Trigo (CIMMYT) on maize and wheat in six countries (Kenya, Tunisia, Colombia, El-Salvador, Mexico, and Turkey). The study concluded that the differences in adoption rates among those countries were explained by differences in information acquired, agro-climatic and physical environments, availability of inputs, differences in market opportunities for the crops, and differences in farm size and farmers' risk aversion characteristics. A comprehensive survey of agricultural technology adoption studies in developing countries by Feder et al. (1985) and Feder and Umali (1993) also found that farm size, risk, human capital, labour availability, access to credit and land tenure systems were the most important factors in influencing farmers' decision of technology adoption.

A study by Jarvis (1981) indicated that the diffusion of fertilized grass-legume pastures in Uruguay followed the logistic path during the first years following its introduction. The study considered the number of ranchers borrowing money from the bank for pasture development each year as a proxy for new adopters of improved pastures. Credit recipients also received good technical assistance form livestock development coordination project. The information on borrowers provides a good estimate of total adopters and the rate of new adopters over time. The adoption of improved pastures by Uruguayan ranchers was estimated by varying the ceiling from 10% to 100% of the total potential adopters. The logistic function with the highest coefficient of determination (R^2) was considered as the best estimates of the ceiling and the rate of diffusion. In this study, the rate of diffusion (hectares planted) was expressed as a function of beef and fertilizer prices. Both the rate and limit of diffusion were found positively related to changes in the profitability of the technology when beef and fertilizer prices were included.

Using panel data, studies by Beseley and Case (1993b), and Foster and Rosenzweig (1995) revealed that learning from own experience and learning from neighbours' experience are both important determinants of adoption. These findings are in contrast to earlier investigation by McGuirk and Mundlak (1991) that showed that adoption was constrained by insufficient fertilizer and irrigation, not by insufficient information. An other study by Cameron (1999), using panel data confirmed that learning is an important variable in the adoption process, cross-sectional estimates of a dynamic process are biased but the extent of this bias may be small, and illustrated methods to estimate the unobserved household heterogeneity in a dynamic model.

3.4.2 Adoption and diffusion research in Africa

In Africa, new agricultural technologies have been introduced in the mid 1970. The success story achieved in Asia was not duplicated in African countries except for hybrid maize in Kenya (Gerhart, 1975; Blackie, 1989; Roy, 1990; Byerlee, 1994a) and Zimbabwe (Rukuni, 1994), thus the literature on technology adoption in Africa is relatively limited.

Akinola (1986a) applied Bass's (1969) innovator-imitator model in the diffusion of cocoa spraying chemicals among Nigerian cocoa farmers. The model employed includes the internal and external information sources that exist in agricultural technology diffusion process. The result indicated that the Bass (1969) model is only slightly better than the standard logistic model. Another study by Akinola (1986b) relaxed the assumption of constant adoption coefficient of innovators; the coefficient of imitators and the equilibrium number of potential adopters remain constant with time. The said study tested the diffusion patterns of cocoa spraying chemicals in Nigeria and indicated that the data on the diffusion of cocoa spraying chemicals among Nigerian farmers fitted the model fairly well.

Rauniyar and Goode (1996) estimated the interrelationships among technologies already adopted by maize farmers in Swaziland. By applying factor analysis the study showed that farmers adopted the technologies investigated in three independent packages: (1) improved maize variety, basal fertilizer, and tractor ploughing, (2) topdressing fertilizer, and chemicals, and (3) planting date, and plant population (density). However, the empirical findings did not support sequential adoption. The study explained that farmers in Swaziland tend to adopt packages rather than individual technology component or practice.

In contrary to these findings there are a number of empirical studies supporting sequential adoption pattern (Ryan and Sabrahamanym, 1975; Byerlee and Hesse de Polanco, 1986; and Leather and Smale, 1991).

3.5 Analyses of technology adoption and diffusion in Ethiopia: Current status and research gaps

This section reviews adoption studies in Ethiopia and presents methodological approaches used, important variables identified by the previous studies, and their limitations.

Since the end of 1960, a number of institutions have been attempting to generate and disseminate improved agricultural technologies to smallholders in Ethiopia. Adoption studies started in the mid 1970. Some of these studies were carried out in areas where integrated rural development projects had been undertaken following the introduction of integrated rural development pilot projects and minimum package programmes in some parts of the country (Tesfai, 1975; Cohen, 1975; Bisrat 1980; Aragay, 1980). These studies focused on evaluating the performance of the pilot projects and on examining the rate of adoption of technologies promoted by these projects. A study by Cohen (1975) did go beyond determining the rate of adoption and assessed the economic and social impacts of the new technologies in the Chilalo Agricultural Development Unit (CADU) area.

Research conducted in the 1980s and onwards in Ethiopia assessed the status of agricultural technology adoption using descriptive statistics and found out that the rate of adoption of improved varieties, fertilizer, herbicide, and other agronomic practices were low (Mulugetta et al., 1992). The amounts of fertilizer and herbicide applied by most farmers in Ethiopia were below the recommended levels (Hailu et al., 1992; Legesse et al., 1992; Legesse, 1992). Some of the research conducted during this period also focused on the impact of centrally planned economic policies (i.e., state farm formation, collectivization, resettlement, villagization, price control and inter regional trade regulations) on the technology adoption process.

Formal adoption studies using econometric models were carried out after the mid 1980.

These studies provided information on the use of improved inputs including seed, fertilizer, herbicides, extent of adoption and factors that limit adoption decisions of smallholders in Ethiopia. Although these studies provided useful information on the rate of adoption and factors influencing adoption, the intensity of adoption was not adequately addressed. In general, the adoption studies had some limitations in their analyses and, thus, did not adequately explain farmers' adoption decisions.

Most of the adoption studies conducted in Ethiopia used conventional static adoption models (e.g., Logit and Probit) for dichotomous dependent variables. In a few cases, the Tobit molel was used to study farmers' extent and intensity of adoption of improved technologies. Moreover, some of these studies had methodological limitations (Aragay, 1980; Yohannes et al, 1990), while others have data limitation (Bisrat, 1980). The study by Aragay (1980) had two methodological limitations. First, the study had used a linear regression model to analyze the adoption behaviour of farmers. This model determines the probability that an individual with a given set of attributes makes one choice rather than the alternative (Pindyck and Rubinfeld, 1981). Thus, the study did not include non-adopters in the analysis and therefore creates sample selection bias. Second, to identify factors affecting adoption the study drew conclusions from a correlation analysis, which does not control for the effect of other variables simultaneously.

Most empirical adoption studies in Ethiopia actually examined the relationship between observed explanatory variables and actual decisions made by individual decision makers in acceptance of a technology. However, the study by Yohannes et al (1990) used intended (planned) adoption for some of sample farmers as the dependent variable. The said study considered those farmers who have expressed their intention to adopt the technology in the following years as adopters. Although it is often valuable to obtain farmers' opinions about the feasibility of using a technology and identify its merits and drawbacks, this information cannot be used to assess adoption decisions. Statements about what a farmer would like to do or hopes to do are not substitutes for data on actual technology adoption (CIMMYT, 1993). Those farmers who have a plan to adopt a technology may or may not adopt it.

Using a two-step regression model, a study by Bisrat (1980) investigated patterns and determinants of fertilizer adoption in the Bako and Jima areas. In the first step, the study estimated the rate of adoption using a Logit model, then regressed rate of acceptance on a number of explanatory variables. The limitation of this study was that the number of observations for each study area was small (only four per area). As a result, the two parameters, (the intercept and slope or rate of adoption) were estimated with only two degrees of freedom.

Some of the studies were conducted more than two decades ago (Cohen, 1975; Tesfai, 1975; Bisrat, 1980; Aragay, 1980) and since then, a number of changes have taken place in the structure of the rural economy of the country. For instance, the landlord-tenant relationship was abolished and extension strategy and policies related to rural development and rural organizational structures have been changed. As a result, the findings of these studies may not reflect critical factors currently underlying adoption patterns. There were also a few adoption studies after the economic reforms in the post-socialist system. Most of these reviewed studies used a component approach neglecting the fact that farmers often choose to adopt components of a technology package sequentially. All of the reviewed adoption studies except Bisrat (1980) and Chilot et al. (1986) did not examine profit, whereas only Yohannes Kebede (1990) and Abinet and Dillon (1992) addressed risk in adoption decisions. Moreover, only Asfaw et al. (1997) and Negatu and Parikh (1999) considered farmers' perception of improved varieties. Surprisingly, none of the adoption studies in Ethiopia considered the value of straw in farmers' adoption decisions.

With regard to analytical models, all reviewed adoption studies except Legesse (1998) used the conventional static models in farmers' adoption decisions. As indicated earlier static models do not capture changes in adoption decisions over time. Studies on the extent and intensity of adoption, which are important for increasing food production and achieving food security, were limited (e.g., Legesse, 1992; Mulugetta et al., 1995; Chilot et al., 1996; Asfaw et al., 1997; AD Alene et al., 2000). In the latter years, there were also improvements in using better models such as discriminate analysis (Getachew et al., 2000, Tesfaye et al., 2001), duration models (Legesse, 1998), and Probit and ordered Probit models (Negatu and Parikh, 1999), double hurdle two-stage models (Berhanau and Swinton, 2003) to explain farmers' adoption decisions. However, none used panel data in a dynamic adoption process such as learning

The above summary indicates that there are still research gaps that should be addressed in order to explain farmers' adoption decisions adequately. For instance, adoption is a dynamic process, which results from learning about the new technology overtime. To better understand farmers' adoption decisions, one needs to particularly study farmers who have used the new technology over time. Although the dynamic process of adoption is recognized in the theoretical literature (O'Mara, 1971; Linder et al., 1979), almost all the reviewed studies used cross-sectional data due to the scarcity of micro-level data over time. Thus, the studies have been unable to explore the dynamic nature of the process of adoption. However, studies by Besley and Case (1993b), Foster and Rosenzweig (1995) and Cameron (1999) used panel data and established the importance of learning in the adoption process. Information on the importance of learning, extent of adoption, impact of profit and risk, which are key factors in influencing farmers' adoption decisions over time are not available in Ethiopia and not adequate elsewhere. Moreover, all of these reviewed adoption studies except Traxler and Byerlee (1993) had not examined the impact of profit and risk by including the straw yield. Excluding the straw yield of an improved variety underestimates the profit from the adoption of improved seed. This study, therefore, attempted to fill these gaps by providing further evidence on the importance of learning in the dynamic adoption of improved technologies. A component or a package approach was employed to a sub-sample of *tef* and wheat producers who have been using these technologies overtime after exposure. The Xtprobit and Xttobit panel data models were used to examine the dynamic adoption process. The study included the value of *tef* and wheat straw in the estimation of profit and risk from the improved varieties. The information obtained will be useful to researchers and policy makers in the generation and dissemination of new technologies in order to raise agricultural productivity and food security.

CHAPTER 4

APPROACH AND METHODS OF THE STUDY

4.1 Introduction

As indicated in the previous chapter, this study used two approaches to analyse smallholders' decisions to adopt improved crop production technologies in Ethiopia. First, a model was developed to determine the importance of learning and other factors in the adoption process. Second, a framework for analysing intensity of adoption was developed to use panel data to capture the inter-temporal aspects of farmers' adoption decision over time through a learning process in terms of gains in profits. The technology adoption analysis undertaken in this study also examined the role of risk in adoption decisions.

The next section presents the technology adoption analytical framework. The empirical specification and estimation procedures for implementing the approach are presented in section 4.3. Data sources and methods of collection are discussed in section 4.4.

4.2 Analytical approaches to technology adoption

The importance of information gathering and learning-by-doing in the adoption of new technology has been emphasized by a number of analysts (Carletto et al, 1996; Dong and Saha, 1998). The said studies argue that producers' choices are significantly influenced by their exposure to information about new technologies. Consequently, these studies modelled adoption as a dynamic process in which the adopters update information about the new technology through a learning process. Thus, the decisions whether or not to use and intensity of adoption in conjunction with the adoption choice were modelled separately.

In the adoption process of a new technology, a learning period precedes any adoption decision. In this phase of the adoption process the level of farmers' acquired information (learning) determines whether or not to use a new technology. The level and quality of awareness and knowledge acquired are functions of information costs as well as individual characteristics of the farmer such as age and education. At the end of the learning process, the farmer decides whether or not to use, which is subject to the farmers' assessment of the benefits obtained and risks faced from using the new technology. Adoption is chosen only if the benefits from the improved technology outweigh costs. Then, the farmer decides what proportion of resources (i.e. land) to allocate to the new technology (e.g. intensity of use) based on actual benefits obtained and risk faced in the previous years.

4.2.1 Modelling learning and adoption decisions

Farmers face the choice of switching from using their old production methods, which they have worked with and known for some time to using newly introduced methods claimed to be better. Guided by their objectives of profit maximization they need to evaluate the claimed advantages of the new technology. But farmers are uncertain about the benefits of the new technology given their limited knowledge about its performance and require some learning about how best to use it to maximize its profits. The learning process phase of adoption involves forming expectations by farmers about gains (in terms of profit) from using the new technology.

The variable, Y_{ijt}, is defined to reflect farmer's adoption decision at time t, which equals 1 if the new technology is used and zero otherwise. One can write

$$\begin{aligned} Y_{ijt} &= 1 \qquad \text{if } E(\pi_{ijt} - \pi_{ilt}) > 0 \\ &= 0 \qquad \text{if } E(\pi_{ijt} - \pi_{ilt}) < 0 \end{aligned} \qquad (1)$$

Where Y_{ijt} represents the decision of farmer i to adopt technology j at time t; $E(\pi_{ijt} - \pi_{ilt})$ is the expected gains in profit from using the new technology in place of the old method by farmer i at period t; and π_{ijt} and π_{ilt} are, respectively, profits from the new and the old technology by farmer i at time t;

As explained earlier a learning period precedes any adoption decision and in the adoption process the level of farmers' acquired information (learning) determines whether or not to use a new technology. Following Cameron (1999), the expectation of the profitability of the new technology relative to the old technology can thus be represented as:

$$E(\pi_{ijt} - \pi_{ilt}) = f(x_{it}, K_{ijt}) \tag{2}$$

Where x_{it} is a vector of explanatory variables of farmer i at time t and K_{ijt} is the state of knowledge of farmer i about the new technology at time t. It is assumed that the stock of knowledge does not decrease over time (Cameron, 1999).

In this study, it is assumed that a farmer can better learn about the new technology by using it (learning by doing) and improves his information. When the farmer uses the new technology there is learning. If the new technology is not used then no learning has occurred in that year and the farmers' stock of knowledge remains the same.

Farmers accumulate experiences (knowledge) as they continue to learn from using the new technology. Thus, knowledge gained from previous experience in using the new technology may increase over time (Cameron, 1999). Hence, the average of all profits differentials that the farmer has experienced in previous years (i.e., the difference between the profitability of the newly introduced technology and the old technology averaged over all previous periods) in which the new technology was used indicate whether the farmer has gained knowledge or not and can be specified as:

$$K'_{ijt} = \sum_{n=1}^{t-1} L_{ijt-n}(\pi_{ijt-1} - \pi_{ilt-1}) / N_{it} \tag{3}$$

Where K'_{ijt} is the knowledge gained about the new technology from previous experiences of farmer i at time t (i.e., the weighted sum of average gain in profit from the new technology in previous years). L_{ijt-n} is control for whether there is learning or not about the new technology in previous years by farmer i at t. If the farmer used the new technology in previous years, L_{ijt-n} equals 1 and 0 otherwise. π_{ijt-1} and π_{ilt-1}, are profits from the new and the old technology by farmer i in previous years and N_{it} is the number of years farmer i had used the new technology previously. The above formulation suggests that the farmer is updating his knowledge based on new observations but still gives some weight to his observations in previous periods.

One can therefore postulates that a vector of explanatory variables including farm and household characteristics, farmer's stock of knowledge about the new technology and riskines of the new technology determine farmers' decision to adopt a new technology at any time, which can be modelled as:

$$Y_{ijt} = f(x_{it}, K_{ijt}, R_{ijt}) \tag{4}$$

Where R_{ijt} measures riskiness of technology j to farmer i at time t and other variables as defined earlier.

The above adoption model is useful for a binary outcome variable and the appropriate models are either probit or logit. When adoption decisions are monitored over time, the appropriate model needs to account for the whole period (T) since introduction of the new technology such that the variable, Y_{ijt}, reflects farmer's decision to adopt at any period and equals 1 if the new technology was used during time horizon T (whether later abandoned or not) and zero otherwise. To capture the change in adoption decision over time this study used panel data to support the Xtprobit regression modes specified as:

$$Y_{ijt} = f(x_{it}, K_{ijt}, R_{ijt} + Cr_{ijt}) \tag{5}$$

where Y_{ijt} is adoption decision of farmer i about technology j at time t, K_{ijt} and R_{ijt} are knowledge gained and risk faced by farmer i at time t; and Cr_{ijt} is availability of credit for farmer i to purchase technology j at time t.

4.2.2 Modelling intensity of adoption

A farmer who continues using the new technology this year may discontinue next year due to unavailability of complementary inputs (e.g. fertilizer in case of improved seed) but could continue again a year or two later after solving the problem. Such farmers could be wrongly defined as non-adopters if cross-sectional data were used. Thus, there is a need for monitoring the adoption process over time. In such case, the appropriate model needs to account for the whole period (T) since introduction of the new technology such that the variable, Y_{ijt}, reflects farmer's decision to adopt at any period and equals 1 if the new technology was used during time horizon T (whether later abandoned or not) and zero otherwise.

When decisions to adopt and intensity of use are made sequentially, stepwise decisions models are used. The experiences gained in previous years from using the new technology influence the intensity of use of the new technology in the following year (Ghadim and Pannell, 1999; Dong and Saha, 1998; Leathers and Smale, 1991). The intensity of use can change depending on farmers' gained experiences in the previous years. To capture the change in intensity of use of the new technology over time this study employed panel data to support the Xttobit regression model, which defines intensity of use as:

$$A_{ijt} = a(X_{it}, K'_{ijt}, R_{ijt-1}, Cr_{ijt}) \qquad (6)$$

Where A_{ijt} measures intensity of use of new technology j (amount of fertilizer or herbicide, proportion of area under the technology, etc.) at time t by farmer i; Cr_{ijt} is availability of credit for farmer i to purchase technology j at time t; and other variables as explained earlier. A farmer also learns about the rates applied in the past from his previous experience in using the new technology. The knowledge gained from previous farmer's experience in using the new technology combined with household and farm characteristics and riskiness of the new technology in previous years determine intensity of use of improved technologies over time.

4.3 Specification of the empirical models

Following the analytical representations described earlier, the empirical models employed in this study split the explanation of the observed decision to adopt and intensity of use into two components. First, experience is gained only when farmer uses the new technology over time. Second, this gained experience guided the farmer in his decisions to intensify adoption (how much land and other inputs to allocate to the new technology) in the future. This implies that the factors influencing adoption and intensity of use over time may be different and application of Xtprobit and Xttobit models, respectively, are more appropriate than the Probit and Tobit models in analysing panel data (Stata, 2001).

Although improved seed is the major component of the new technology package promoted in the study area, models of adoption of the improved variety as well as fertilizer and herbicide on the two main crops grown (*tef* and wheat) were estimated based on separate Xtprobit models, specified as:

$$Y_{ijt} = \partial_0 + \partial_1 X_{i1t} + \partial_2 X_{i2t} + \ldots + \partial_9 X_{i9t} + \partial_{10} R_{ijt-1} + \partial_{11} K'_{ijt-1}, + \mu_{ijt} \text{ ;(t=1...5)} \qquad (7)$$

Where Y_{ijt} is farmers' decision to adopt improved *tef* or wheat technologies at time t (equals 1 if the farmer adopted the improved *tef* or wheat technologies at least once during 1997-2001 and 0 otherwise). The j refers to the three technologies improved seed, fertilizer and herbicide. All explanatory variables as explained earlier and defined in Table 4.1.The vector of model parameters to be estimated is specified as ∂ (∂_0 to ∂_{11}) and μ_{ijt} is the error term.

For the intensity of adoption of improved *tef* and wheat technologies, separate Xttobit models were specified for each technology:

$$A_{ijt} = \beta_0 + \beta_2 X_{i1t} + \beta_2 X_{i2t} + \ldots \beta_9 X_9 + \beta_{10} K'_{ijt} + \beta_{11} R_{ijt-1} + \mu_{ijt} \qquad (8)$$

Where A_{ijt} measures intensity of adoption of technology j (share of land area planted to improved *tef* or wheat variety, amount of fertilizer and herbicide inputs used per hectare by farmer i at time t. β is the vector of model parameters to be estimated and ε_{ijt} is the error terms. All other explanatory variables as defined earlier and listed in Table 4.1.

4.3.1 Variables included in the empirical models

In order to analyze farmers' adoption decisions over time in Ethiopia, farmers' learning from own experience about the new technology was included with farm and household characteristics into the regression models.

Tef and wheat are grown in different farming systems by different farmers and hence farmers' choices for the two crops are assumed independent. Thus, separate empirical models were estimated for each crop in their major production areas. Besides, *tef* is an indigenous crop to Ethiopia while wheat is relatively new. In the major growing areas the most important questions are to grow improved or local variety, and how much resources (land, labour and purchased inputs such as improved seed, fertilizer and herbicide) to allocate to *tef* or wheat.

The knowledge gained (K'_{ijt}) was included to capture the dynamics of farmers' learning about the promoted technologies. The improved *tef* and wheat technologies were introduced as packages during the 1995-1996 in limited areas where farmers were able to have some information about these packages. These technologies were widely demonstrated to farmers in 1997 and 1998 crop seasons. Thus, sample farmers learned more about improved *tef* and wheat technologies from their own experience from 1997 onwards. Unfortunately data were not available on the stock of knowledge of farmers before 1997. However, it is possible to compute learning from own experience in using the improved *tef* or wheat packages after 1997 as specified in equation (3). This study used the lagged profit differential between the new and the old technology specified in equation (3) to measure knowledge gained (K'_{ijt}) from learning as a function of actual gains in profit from using the improved *tef* or wheat technologies for the period the farmer used these technologies in previous years. Equation (3) is repeated below to define the learning horizon (T):

$$K'_{ijt} = L_{ijt-1}(\pi_{ijt-1} - \pi_{ilt-1}) / N_{it} \qquad (3')$$

Where j refers to technologies: 1 for improved seed (V), 2 for fertilizer (F), and 3 for herbicide (H). The learning time horizon was defined over a period of 5 years (t = 1-5) denoting the beginning of promoting the new technologies in 1997 to survey time in 2001. L controls for whether there was learning (L=1 if farmer used technology) or not (L= 0 otherwise), which means that if there is no learning in previous years from the improved *tef* or wheat technologies, farmers experience will be zero for that period.

Farmers' profit for any technology j at a given time can be derived as:

$$\pi_{ijt} = P_{Q_{ijt}} Q_{ijt} - P_{I_{ijt}} I_{ijt} \qquad (9)$$

Where π_{ijt} is profit of farmer i from technology j at time t; P_{Qijt} and P_{Iijt} are prices of output (Q_{ijt}) and input (I_{ijt}), respectively, for farmer i at time t. Total profit is derived from two joint products (i.e., grain and straw). Omitting the value of straw in evaluating the new crop technology underestimates the total profit obtained from the adoption of the new crop technology (Traxler and Byerlee, 1993). Furthermore, learning from own experience (K'_{ijt}) also improves by considering the value of straw in farmers' adoption decisions. Thus, the knowledge gained in previous years in equation (3) was specified to vary with the measure of the total profit derived from the two products (grain and straw).

This is the best available proxy for learning although it has a number of limitations most important of which is the fact that it fails to take into account learning from others such as neighbours. The study collected panel data over the five years of learning (1997-2001) based on farmers' recall of the use of the improved *tef* or wheat technologies in their respective production areas.

This study measured riskines of the new and the old technologies (R_{ijt}) as the variance of farmers' yield. As it is expected that yield variations will be different in medium and high potential areas and among PAs within the same potential area and therefore, yield variances were estimated for farmers in each peasant association.

$$\mathrm{R}_{\mathrm{ijt}-1} = \sum (\mathrm{Q}_{\mathrm{ijgt}-1} - \overline{\mathrm{Q}}_{\mathrm{ijgt}-1})^2 / \mathrm{n}_{\mathrm{gt}-1} \qquad (10)$$

Where: R_{ijt-1} is the measure of riskiness of technology j for farmer i in previous year. Q_{ijgt-1} is yield of farmer i for technology j in peasant association (PA) g in previous years; $\overline{Q}_{ijgt-1}$ is mean yield for technology j in PA g in previous years; and n_{gt-1} is number of sample farmers in each PA in previous years. It is assumed that the new technology is more risky than the old technology since the farmer has no experience in using the new technology (Carleto et al., 1996).

Family members helping the farmer are male and female members above the age of 15 who help the farmer in different farm operations (land preparation, weeding, harvesting, threshing, etc.) in the production of the two crops.

Variables X_1 to X_9 measure selected farmer characteristics such as age, education, etc. and key farming attributes (farm size, credit, distance to market, roads, etc.) as described in Table 4.1.

Table 4.1 Description of variables used in the empirical adoption models

Variable	Name of variable	Unit/type	Variable description
Y_{ijt}	Adoption decision	Dummy	D = 1 if adopted; 0 otherwise
A_{ijt}	Intensity of input use	Percent kg/l	Proportion of land under improved seed, or amount of fertilizer (kg) and herbicide (l) per hectare
X_1	Farm size	ha	Farm size owned
X_2	Age	Years	Age of household head
X_3	Family labour	Number	Family members above 15 years old helping farmer
X_4	Education	Dummy	Level of education of household head:
X_5	Livestock owned	TLU[a]	Number owned by farmer
X_6	Frequency of DA[b] visit	Hours	Access to information (inputs)
X_7	Distance to Addis Ababa	Hours	From *Woreda* capital to Addis Ababa
X_8	Road condition	Dummy	1 if asphalt from *Woreda* to Addis; 0 otherwise
X_9	Credit	Kg	Amount of fertilizer obtained on credit
K'_{ijt}	Knowledge gained	Birr1/ha	Gains in knowledge about improved over traditional technology
R_{ijt-1}	Risk	index	Yield variance in PA[c]

a. TLU is tropical livestock unit
b. DA is development agent
c. PA is peasant association

4.4 Survey design and data collection

Given that the main objective of this study is to analyse the adoption of *tef* and wheat technologies by smallholders in their respective major growing areas, it was necessary to collect information on several aspects of relevance in the two production systems. Particularly it was necessary to measure the variables included in the empirical models listed and described in the preceding sections.

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1 1 US $ = 8.5 Ethiopian Birr at the time of the study

The availability of farm records by smallholders could have been an ideal source of information from which the required input and output data could be obtained. Unfortunately, neither farm records nor adequate disaggregated time series data on input and output use in the systems under study exist in Ethiopia particularly those relating to smallholders. Several alternatives for obtaining information are available. The most common among those is the method of undertaking field surveys. Surveys are useful means particularly if the object to be studied includes variables that are measurable and can be aggregated (Assefa, 1995). Directly measured and quantified variables include resource use, production, costs and returns. Hence, basic information on these and other factors can be obtained through field surveys.

There are several ways of organizing field surveys depending on frequency of visits to the respondents whereby sets of questions are usually administered by an interviewer using a detailed structured questionnaire. Survey methods range from single visit to multi-visits. A single visit survey is where information is colleted in a single meeting between the enumerator and the respondent (farmer) whereas in multi-visits survey the interviewer makes more than one visit (e.g., weekly or fortnightly) to respondents. The periodic visit survey is in between the single visit and multi-visits surveys where an enumerator meets the respondents on well defined and timed rounds organized around the completion of crucial phases. The decision on which survey method to choose depends on tradeoffs between quality of data required and the cost of the information obtained. Due to limitations on the time and financial resources available for this, the single visit field survey method has been employed to generate the necessary information for the intended analyses.

Primary data collected from the farm surveys included area, both grain and straw yield of *tef* and wheat varieties, input use, prices of inputs and outputs, farmers' perception of improved technology, and distance to markets and input distribution centers. Times of initiation (year) of adoption of improved *tef* and wheat technologies, source of seed and credit, criteria for selecting the improved varieties were also recorded. The collected data also included farm and household characteristics such as farm size, family size, age, education, and experience in growing improved varieties measured in years.

In addition, secondary data were gathered to supplement the primary sources. The secondary data were collected from institutions involved in technology generation, multiplication, and transfer and promoting formal rural credit. Using short guidelines to collect secondary data, information on fertilizer procurement, supply, and marketing was collected from the Agriculture and Input Supply Enterprise (AISE), the Ministry of Agriculture (MOA), and the Ethiopian Fertilizer Agency. Information on the status of improved variety generation, production and distribution was obtained from the Ethiopian Agricultural Research Organization (EARO), the Ethiopian Seed Enterprise (ESE) and the Ethiopian Seed Industry Agency (ESIA). Data on crop area, production, yield and prices were extracted from different bulletins of the Central Statistical Authority (CSA). Information regarding prices and quantities of inputs (improved seed, fertilizer, herbicide) used and credit supplied were obtained from the Northern and Western *Shewa* Zones of the *Oromiya* Regional State of Ethiopia.

Based on the scope of the study defined above, the following sub-sections describe the study area, sampling procedures and sample size determination methods employed for collection of the required data, and types of collected data needed for the study.

4.4.1 Study area

The study was conducted in the Northern and Western *Shewa* Zones of the Oromiya Regional State of Ethiopia during the 2001 crop season. Northern and Western Shewa Zones are among the major *tef* and wheat producing areas in the country where improved t*ef* and wheat technologies have been demonstrated to farmers. The Northern *Shewa* Zone represents the medium potential producing areas while Western *Shewa* Zone represents the high potential areas based on area, production, and yield of t*ef* and wheat crops (CSA, 2001). The major crops in Northern and Western Shewa Zones include cereals, pulses and oil seeds. Cereals account for 78% and 87% of total crop production in Northern and Western Shewa Zones, respectively. *Tef* accounts for about 35% and 40% of crop area in Northern and Western Shewa Zones, respectively. Wheat, the second most important crop covers about 18% and 17% of the area in Northern and Western Shewa zones, respectively. In terms of production, *tef* contributes more than 20% and 30% where as wheat accounts for 23% and 20%, respectively, in Northern and Western Shewa Zones. Furthermore, t*ef* and wheat account for about 25% and 16% of crop area, and about 15% and 18% of crop production in Oromiya. *Tef* yields are low in the study areas. It is at most about 1000 kg/ha. However, yields in Western Shewa Zzone are higher than Northern Shewa Zone. On the other hand, wheat yields are better than *tef* yields in the study areas, and Western Shewa Zone is better than Northern Shewa zone in production. Generally, yields are low but better in Western Shewa Zone than in Northern Shewa Zone due to better utilization of inputs such as improved seed, fertilizer and herbicide (CSA, 2001). Farmers who grow both crops are not included in this study.

Fichae, the capital of Northern *Shewa* Zone is located along the *Addis Ababa- Debre Markos* road 115 km north of *Addis Ababa*. The capital of Western *Shewa* Zone, *Ambo* is situated 125 km west of *Addis Ababa* along the *Addis Ababa-Lekemit* road. There are 12 and 23 *woredas* (districts) in Northern and Western *Shewa* Zones, respectively**.**

4.4.2 Sampling procedure and sample size determination

Due to scarcity of resources (human and physical) and time required a sample was needed following the laws of the statistical theory of sampling in order to draw valid inferences from the sample and to ascertain the degree of accuracy of the results. A sample is desirable over census not only for less costs incurred but also for allowing frequent empirical investigation, possibility to minimize systematic errors through training, improved measurement and supervision, and allowing for wider scope and more specific studies. The appropriateness of a sampling method depends on how it will successfully meet the objectives of the study and follows the statistical theory of sampling. This study used multi-stage stratified sampling design in selecting farmers to be surveyed.

The first stage involved a purposeful selection of Northern and Western Shewa zones from central Ethiopian highlands based on availability of strong research and extension programs for smallholders' food grain production and presence of distinct zones (medium and high potential). The two zones are representative of most smallholders' farming conditions in central Ethiopia. The second stage involved selection of *weredas* in the two zones based on their adequate representation of distinct potential *tef* or wheat production areas across agro-climatic zones and on active operation of the National Extension

Program (NEP) in these *weredas.* The third stage involved selection of peasant associations (PAs) from each selected *weredas* while in the final stage farm households from selected PAs were chosen for the survey.

In the study area, farmers are organized into peasants associations (PAs)[2]. In this study, in order to capture the impact of *tef* or wheat technologies on food grain production in different agro-climatic conditions relatively homogenous PAs were needed to minimize heterogeneity (in terms of agroclimate). Therefore, five relatively homogenous PAs were selected from each district and 10 farm household heads in each PA were selected for each crop. Whereas selection of PAs aimed at more homogeneity within strata, the sample was designed to also represent wide heterogeneity of climates and farming conditions between PAs.

The head of the farm household who actually makes the day-to-day decisions on farm activities, technology adoption and inputs' use was used as the basic sampling unit for this study. A sampling frame was available at the PAs in each district listing members of the PA, which were used for selection of the target sample units to be surveyed for this study. The PAs include all family heads who live within the boundary of the PA and make their living from farming.

In any research work, sample size determination is necessary but it is usually a difficult exercise. Theoretically, the sample size is determined by the pre-assigned level of accuracy of the estimates of the mean of the parameters. However, this requires knowledge about the variability of a large number of parameters because all have different degrees of variability. Unfortunately, this knowledge seldom exists prior to the study. Therefore, in practice sample size is mostly determined by considering financial constraints, and availability and adequacy of other resources such as trained manpower and time (Assefa, 1995). Nevertheless, it is possible to improve this situation by stratifying the population into as many sub-population as possible based on one or more classification variables.

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[3] Following the 1975 Rural Land Reform (Nationalization), PAs were organized in the rural areas with the aim of implementing the land reform. The PAs are responsible for the management of the distribution of land. They were established on an average of 800 ha of land with 80 to 350 family heads residing in villages adjacent to one another. The PAs also serve as the lowest administrative unit of local government (Stork et al, 1991).

Taking these issues into considerations, a total of 300 farm household heads were selected from the two zones.

Either reducing the spread measure (standard deviation) or increasing sample size can increase sampling precision (Hassan, 2000). Thus, there is a trade-off between spread measure or precision level (F) measuring the gain in efficiency and the cost of increasing the sample size. An optimal sample size is determined at the point where no significant efficiency gains will be attained by using extra resources to include additional sampling units. For this study a 5% precision level was decided desirable. Using the number of oxen owned in 2000, the mean ($\ddot{X}$) and standard deviation (S) were estimated and used to determine the total sample size[3]. The numbers of *weredas* in Western *Shewa* zone are twice the numbers in Northern *Shewa* zone. Accordingly, variable sampling fractions have been applied such that the number of selected PAs and sample farmers are distributed proportionally to *woredas* between the two zones for each crop.

The multistage random sampling procedures were used to draw a sample of farmers for the study. First, *tef* or wheat producing *woredas* (districts) in each zone were identified and divided into relatively homogenous agro-ecological zones (high and medium potential) based on total area and average production. Because of limited time and resources, not all the *weredas* in each zone were covered by the survey. Instead potential *weredas* to be sampled were selected based on percent of farmers using t*ef* or wheat technologies, and accessibility (reachable by four-wheel drive vehicle). Particularly, *weredas* where t*ef* or wheat was produced as a major crop and where technologies of these crops have been demonstrated were identified in consultation with zonal extension specialists. *Weredas* that were inaccessible and where t*ef* or wheat are not grown as major crops were excluded from the lists. Using proportional sampling procedure, 6 *woredas* (2 from North and 4 from West *Shewa* Zones), each for t*ef* and wheat were selected randomly. The selected *woredas* were *Degem* and *Wore Jarso* for wheat, *Girar Jarso* and *Wore Jarso* for *tef* in Northern Shewa zone. In Western *Shewa* zone *Ada Berga, Dendi, Lemon a*nd *Wolis*o were selected as major t*ef* producing districts where as *Ambo* was substituted for *Dendi* as major wheat producer.

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[3] $n = \frac{(100 * S)^2}{F * \ddot{X}}$ Where $\ddot{X}$ is sample mean and S is standard deviation (Hassan, 2000)

In the second stage, relatively accessible and representative PAs from the selected *weredas* were identified using available records from *wereda* agricultural offices and in consultation with *wereda* extension team leaders and supervisors who have good knowledge of the PAs. After the complete lists of accessible PAs were assembled, five PAs were randomly selected from each *wereda.* In total 30 PAs were selected each for *tef* and wheat technology adoption.

In the third stage, farm household heads who participated in the *tef* or wheat technology packages demonstrations in each of the selected PAs were identified from the lists of farmers held at the extension center and *wereda* bureau of agricultural offices. Since we are interested in farmers' learning from their own experience only farmers who participated in 1995 and 1996 demonstration programs were included in the sampling frame. Therefore, farm households who participated in the improved *tef* or wheat technology demonstrations in the selected PAs were selected proportional to the number of woredas. Thus, 165 and 234 farmers were sampled for wheat and *tef*, respectively from Northern and West *Shewa* Zones.

Table 4.2. Structure of the selected sample of farmers

	Area under Crop (ha)[b]	Number of Selected *woredas*	Number of Selected *PAs*	No. of selected farms
North Shewa	**257.48**	**4**	**12**	**102**
Wheat system	69.35	2	7	45
Proportion (%)[a]	9	17	23	11
Tef system	93.27	2	5	57
Proportion (%)[a]	12	17	17	14
West Shewa	**487.52**	**8**	**18**	**297**
Wheat system	102.2	4	8	120
Proportion (%)[a]	14	33	27	30
Tef system	237.47	4	10	177
Proportion (%)[a]	32	33	33	44
TOTAL	**745**	**12**	**30**	**399**

a. Percent of total **b**. CSA, 2001

4.4.3 Survey instruments and procedures of data collected

An important step in data collection was development of a structured and detailed questionnaire. The questionnaire was designed for a single visit survey. A structured questionnaire was used to collect primary data. The researcher using his experience and the experiences of similar interviews in Ethiopia and other developing countries prepared the questionnaire. The questionnaire focused on the use of improved agricultural technology on *tef* and wheat separately. The structured questionnaire was pre-tested for appropriateness (clarity, adequacy and sequence of questions), revised according to the feedback from pre-testing and finalized. Selection of appropriate enumerators who had experiences in field surveys and provision of intensive training on the objectives, contents and method of the study preceded the actual data collection. Data collection took place during the 2001 crop season through a single visit to the selected sample of farm households.

As elsewhere in Ethiopia, in the study areas, farmers are used to local units to measure area, weight and volume and rarely use standard metric units. It is, therefore, expected that the measurement methods and conversion factors used may introduce some measurement errors in the data. In spite of this problem, data for this study were collected using local measurement units. This alternative was chosen because most farmers were more comfortable giving responses in the local units than standard metric units. In addition, information regarding units of measurement and their conversion factors were gathered from extension agents and rural input and grain traders. Rural grain traders (grain assemblers) use local units when they purchase grain from farmers and metric units when they are selling to consumers or wholesalers, so they are knowledgeable about the local measurement units and their conversion factors. In the case of land area, the common conversion factor (4 *timad*/kirt = 1 ha) used by the agricultural department in reporting cultivated area was used. Moreover, in this study neither areas of land under improved varieties, fertilizer and herbicide nor yield were measured (i.e. study did not use crop-cut methods). The data were obtained from farmers' memory recall method. As farmers typically report very low yield due to fear of high income tax and other contributions. Thus, reported yields were adjusted upward by 50% for *tef* and 45% for wheat based on yield difference from crop-cut and what farmers had reported for the two crops in the selected PAs (personal observation during pre-testing). Yield adjustment is necessary when farmers' reported yields are found not representing the real situation (CIMMYT, 1988).

Another limitation of the study was on estimation of the straw yield. Farmers could not be blamed on this because they have never attempted to measure it. Besides, the local unit they are used to is so confusing and also vary not from one area to another area but from farmer to farmer within the same area. Therefore, it was very difficult to standardize the local unit for each location with the time available for the survey. The best alternative was to use available research data, grain and straw yield multiplying factor (Alemu et al, 1991; Amsal et al, 1994). Thus, straw yield was estimated by multiplying *tef* and wheat grain yield with their respective multipliers (0.8 for wheat and 1.0 for *tef*).

CHAPTER 5

SELECTED ATTRIBUTES, PATTERN AND SEQUENCE OF ADOPTION OF IMPROVED *TEF* AND WHEAT TECHNOLOGIES

5.1 Introduction

This chapter describes selected attributes, pattern and sequence of adoption of *tef* and wheat technologies in the study area. The t*ef* and wheat research programmes have developed a number of t*ef* and wheat technologies that have the potential to increase productivity. However, the pattern and sequence of adoption of these technologies were not known.

In this study, adoption decisions refer to use of new technologies. A farmer is defined as an adopter if he uses at least one of the *tef* or wheat improved varieties with or without fertilizer and herbicide, otherwise a non-adopter. Based on their use of improved varieties farmers were classified as adopters and non-adopters. Adopters were classified again into partial adopters (farmers using improved variety with fertilizer or herbicide) and full adopters (farmers using improved variety with fertilizer and herbicide). Sequence of adoption refers to stepwise use of components of a package of a new technology.

One of the ways farmers learn about the new technologies is by participating in the demonstrations of improved technologies. The year farmers have participated in the demonstration program is considered as information gathering and the period the farmer has used the new technology in successive years after participation in the demonstration is the time for learning from own experience (knowledge). Finally, the decision to continue or abandon is made each year after the farmer had used the improved varieties, i.e., the farmer has gained experience in growing the improved technology. Experience gained in using the new technology (knowledge) is computed as the difference in net benefits between the new and traditional technology for the successive years the farmer has used the new technology (Cameron, 1999).

Risk in growing improved varieties is also defined as the variability in yield for the period the farmer has used the new technology and it is measured as the variance of yield among the same group of farmers in the same selected peasant association for the same period (Just and Pope 1979). Yields vary from location to location and from year to year. To capture yield variability over space and time, the averaged yield variance was computed from the variance of yield of each peasant association (PA) for each growing season over the years of growing period.

The next section presents descriptive analysis of selected economic attributes improved *tef* and wheat technologies. The pattern and sequence of adoption of improved *tef* and wheat technologies are presented in 5.3 and 5.4, respectively.

5.2 Comparison of *tef* and wheat farmers

To compare the three farmer groups (non-adopters, partial and full adopters) an average of two or more years data for the same factor were considered for the periods farmers have used improved technologies from 1997 to 2001. This method was used as all sample farmers did not grow the improved varieties for five years as they did not start at the same time since the improved varieties were rationed due to limited supply. Farmers' data on yield, input use, total cost that vary total and net benefits were used in partial budgeting. Sample farmers used the same rate for local and improved seeds. Since local and improved seeds had the same price in the local market, their costs were not included in the partial budgeting analysis. From the partial budgeting, the marginal rate of return was estimated to show the gain in net benefits from non-adoption to partial or full adoption. The marginal rate of return is the change in net benefit divided by the change in cost that varies from non-adoption to adoption (partial or full) expressed as percentage. The minimum returns analysis was used to measure the variability in benefits of the new technologies in comparison with the traditional technology. The minimum returns analysis compares the averages of the lowest net benefits (usually 25%) for the three groups of farmers. It is expected that partial and full adoption of improved technologies give better average lowest net benefits than non-adoption even in the worst cases (Byerlee and Hesse de Polanco, 1986; CIMMYT, 1988).

5.2.1 Comparing *tef* farmers

Comparison was made between the three groups of farmers in terms of resources owned, input use, yield obtained, benefits obtained, costs incurred, and risk faced. Comparison of the three groups of farmers indicated that there were big differences between non-adopters, partial and full adopters in most cases. For instance, non-adopters were significantly different from full adopters in terms of *tef* area, livestock and oxen ownership, family size, and fertilizer obtained on credit (Table 5.1).

Table 5.1. Selected attributes of *tef* production practices in Northern and Western Shewa zones, (1997-2001)[a]

Item	Traditional technology	Improved	technology
	Non -adopters	**Partial adopters**	**Full adopters**
Farm size (ha)	2. 8a	2.6a	2. 8.a
Tef area (ha)	1.5a	1.7ab	2.1b
Prop. of improved. Area (%)		0.54a	0.39b
Family size (no)	6.8a	7.0ab	7. 8b
Active labour (no)	2.3a	2.9b	2.8b
TLU	5.7a	6.3ab	7.5b
Oxen, (no)	2.3a	2.6ab	2.9b
Wealth index	2.1a	2.1a	2.4a
Age (year)	49.0ab	53.5bc	46.0a
Fertilizer on credit (kg)	191a	181a	269b
Distance to Addis (km)	86a	134c	77b
Distance to market (hr)	1.7a	2.1b	1.7a
Time to DA office (hr)	1.2a	1.5a	1.4a
Frequency of DA visit (no)	2.1a	1.5a	2.3a

a. Figures in the same row followed by different letters are significantly different from each other at least at 5% level.

Full adopters were younger than partial adopters and the difference was significant. Although non-adopters were significantly closer to Addis and local market, and more frequently visit the development agent (DA) office than partial adopters, they had not adopted the improved *tef* package (improved varieties) because of their colour, which they thought would not fetch good prices. On the other hand, partial and full adopters had significantly higher active family labour force than non-adopters to help them in the adoption of improved *tef* technology, which is more labour intensive than the traditional *tef* technology.

Comparison of partial and full adopters also showed that full adopters were significantly closer to Addis and local market and more frequently visit the DA office than partial adopters. On the other hand partial and full adopters were not significantly different in their *tef* area at 5% significance level. However, partial adopters allocated significantly more area to improved varieties than full adopters because of the fear of risk incurred in the adoption of full package that would be explained later.

5.2.1.1 Profitability of the *tef* technology

Table 5.2 presents selected indicators of the profitability of the traditional and improved *tef* technologies. The traditional technology produced significantly lower yields than the improved *tef* technology. Full adopters also obtained significantly higher yield than partial adopters due to the use of herbicide. Fertilizers and herbicide uses were common in both traditional and improved technologies with differences in the rate of application. As it is depicted in Table 5.2 partial and full adopters used significantly higher rates of inputs (fertilizer and/or herbicide) than non-adopters. However, partial and full adopters were not significantly different in their fertilizer application although full adopters used slightly higher rate. Besides, both partial and full adopters applied the recommended rate of fertilizer on average. Application of herbicide was lower than the recommended rate for non-adopters and full adopters. Besides, none of the partial adopters used herbicide with the improved variety (Table 5.2). In the study area the use of improved variety with herbicide is not a common practice and not included in the analysis.

In terms of labour utilization[1], non-adopters, partial and full adopters differ significantly in the amount of family labour used in the production of *tef*. In terms of draft power

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[1] The labour data for weeding, harvesting and threshing and oxen data for threshing were obtained from farmers' recall, which is based on estimation not actual data.

requirement, as expected full adopters of the package of improved *tef* technology used significantly higher draft power than the traditional technology and partial adopters (Tables 5.2).

Table 5.2. Selected indicators and profitability of *tef* technologies in Northern and Western Shewa zones (1997-2001)[a]

Item	**Traditional technology**	**Improved technology**	
	Non -adopters	**Partial adopters**	**Full adopters**
Yield, kg/ha	6.2a	10.1b	12.3c
Fertilizer, kg/ha	136a	158b	166b
Herbicide, l/ha	381a	none	525b
Labour use (man-days/ha)	31.1a	50.4b	61.8c
Draft (oxen-day/ha)	6.9a	11.2b	13.5c
Total benefits, Birr[2]/ha	1871.40a	2954.65b	3724.45c
Total cost that vary, Birr/ha	480.00a	631.80b	738.85c
Net benefits, Birr/ha	1391.40a	2322.85b	2986.1c
MRR[1] (%), non to partial adoption		614	616
MRR (%), partial to full			620
Risk (yield variance)	7.7a	18.7b	21.14c
Knowledge, Birr/ha		1268.25a	1212.70a

a. Figures in the same row followed by different letters are significantly different from each other at least at 5% level.

[1] Marginal rate of return (MRR) on investment in the adoption of improved *tef* technology i.e., marginal net benefit (the change in net benefit) divided by the marginal cost (the change in costs) and expressed as percentage

In this study total benefit from the production of *tef* or wheat (grain and straw) was considered for any year that the farmer had planted *tef* or wheat in Northern and Western Shewa zones. Prices of output, and cost of inputs in each zone for each year the farmer had planted the two crops were also considered in the estimation of total benefits and costs that vary, respectively. Cost of transportation of inputs and outputs were also considered in the estimations. In this study average benefit of farmers who were using the old technology was considered for farmers who have used only the new technology (Cameroon, 1999).

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[2] 1 US $ = 8.5 Ethiopian Birr at the time of the study

In terms of benefit, partial and full adopters obtained significantly higher total benefits than non-adopters. Besides, the costs that vary were significantly different for the three groups of farmers. On the other hand partial and full adopters had significantly higher net benefits than non-adopters, and full adopters had significantly higher net benefits than partial adopters due to significant yield differences (Table 5.2).

The marginal rate of return (MRR) was used to show the benefit obtained in changing from non-adoption to partial or full adoption, and from partial to full adoption. The results indicated that adoption of the improved *tef* technology provided acceptable return on investment in the improved *tef* technology over the five years (Table 5.2). Based on experience and empirical evidence, in most cases, the minimum acceptable rate of return to farmers is from 50% to 100% (CIMMYT, 1988). Thus, both the change from traditional to partial adoption or full adoption; and from partial to full adoption fulfills this criterion. This implies that farmers should have continued adoption of the improved *tef* technology in 2001 crop season. In 2001 crop season, however, 58% of sample farmers reported that they have discontinued adoption of the improved *tef* varieties due to their colour because they were afraid of lack of market. The new varieties provided significantly higher net benefits and the MRR indicates that investment in the new varieties still provided acceptable rate of return as shown in Table 5.2.

To assess the riskiness of the improved *tef* technology, two approaches (comparison of yield variance and comparison of 25% of lowest net benefits) were used. To determine minimum return analysis, the average of the bottom 25% net benefits of traditional technology (non-adoption) was compared to the averages of lowest 25% net benefits of improved technology (partial and full adoption). The one with the higher lowest net benefit is considered less risky even in worst cases. Thus, comparison of the 25% lowest net benefits for the three groups of *tef* farmers showed that full adoption of the improved *tef* technology gave higher lowest net benefits (1852.35 Birr/ha) followed by partial adoption (1339.7 Birr/ha) than non-adoption (695.3 Birr/ha). This implies that partial and full adoptions are less risky than non-adoption and full adoption is less riskier than partial adoption. On the other hand, the variance of yield analysis indicated that full adoption was significantly the most risky (highest variance) option followed by partial adoption (Table 5.2). This result contradicts the minimum returns analysis which does not consider variability and dispersion.

Finally, comparison was made between partial and full adopters in terms of experience they had gained, average profit differential of the five years period (1997 – 2001). Surprisingly partial adopters and full adopters were not significantly different in their experience of growing the improved *tef* varieties (Table 5.2) In fact full adopters were significantly younger than partial adopters, which means they were better to learn from their own experience in growing improved varieties. As Table 5.2 showed, comparisons among the three groups of farmers resulted in superiority of partial and full adoption over non-adoption and full adoption over partial adoption but with higher yield variances (more risky) for partial and full adoption than non-adoption. These results did not support most farmers' choice of non-adoption due to fear of improved varieties do not fetch good prices. Both partial and full adoption of improved varieties were more productive, beneficial and even gave better lowest net benefits than non-adoption even under worse conditions although yield variances were high for partial and full adoption. This could be improved as partial and full adopters gain more experience in growing improved varieties in the future.

5.2.2. Comparing wheat farmers

Similarly wheat growers were compared in the same manner. Non-adopters of improved wheat varieties were not significantly different than partial and full adopters in many cases such as farm size, family size, livestock and oxen ownership, wealth, age, fertilizer obtained on credit and frequency of development agent (DA) visit. Moreover, non-adopters had significantly more labor force but slightly less than full adopters, and were closer to Addis than partial adopters (Table 5.3). Although full adopters were younger than non-adopters and partial adopters, the difference was not significant.

On the other hand, partial adopters were significantly closer to local market and travel less distance to DA office than non-adopters and full adopters. However, this did not make significant difference in their frequency of visit to DA office between the three groups of farmers in 2001 crop season.

In terms of wheat area, full adopters had significantly larger areas than partial and non-adopters. However, partial adopters allocated significantly larger area to improved varieties than full adopters although they had significantly lower active labour force than full adopters (Table 5.3). This could be due to significantly shorter distances partial adopters travel to DA office than full adopters to get updated information about improved varieties.

Table 5.3. Selected attributes of wheat production practices in Northern and Western Shewa zones, (1997-2001)[a]

Item	Traditional technology	Improved	technology
	Non -adopters	**Partial adopters**	**Full adopters**
Farm size (ha)	2. 8a	3.0a	2.6a
Wheat area (ha)	0.83a	0.75a	0.98b
Prop. of improved area (%)		98a	88b
Family size (no)	7.5a	7.4a	7.8a
Active labour (no)	3.6a	2.2b	4.2a
TLU	5.4a	5.6a	6.4a
Oxen (no)	2.1a	2.2a	2.4a
Wealth index	2.1a	2.2a	2.1a
Age (year)	46.4a	47.0a	44.7a
Fertilizer on credit (kg)	145a	73.5b	166a
Distance to Addis (km)	88a	122b	101a
Distance to market (hr)	2.1a	0.8b	1.6c
Time to DA office (hr)	1.8a	0.6b	1.6a
Frequency of DA visit (no)	1.2a	1.6a	1.2a

a. Figures in the same row followed by different letters are significantly different from each other at least at 5% level.

5.2.2.1 Profitability of the wheat technology

As expected full adoption of the improved wheat technology gave the highest yield followed by partial adoption of the wheat technology. However, the difference in yield between non-adopters and partial adopters was not significant (Table 5.4). In terms of input use (fertilizer and herbicide), full adopters used significantly higher rates of fertilizers than partial and non-adopters whereas fertilizer rates were not significantly different for non-adopters and partial adopters. Besides, non-adopters used the lowest rate of herbicide and the difference between non-adopters and full adopters was significant. Only four farmers used herbicide with improved wheat varieties as a package. The rates of herbicide used were lower than the recommended rate while only full adopters on the average used the recommended rate of fertilizers (Table 5.4)

In terms of labour and oxen utilization, as expected, partial and full adopters used significantly more labour in the production of wheat than non-adopters whereas partial adopters also used significantly more labour than full adopters in the production of wheat. This could be attributed to the fact that partial adopters used labour for weeding while full adopters used herbicide for weed control. Full adopters also used significantly more draft power for threshing than non-adopters and partial adopters whereas non-adopters and partial adopters were not significantly different in their draft power requirement for threshing wheat due to yield obtained (Table 5.4).

In terms of benefit, non-adopters had the lowest total and net benefit among wheat growers. Non-adopters got significantly lower total benefit than full adopters. The difference in total benefit between non-adopters and partial adopters, and partial and full adopters was significant at 10% level. Full adopters had significantly higher costs that vary than non-adopters and partial adopters (Table 5.4) due to significantly higher rates of fertilizers, herbicide and draft power utilization in threshing. The difference in cost that vary between non-adopters and partial adopters was also significant at 10% level due to significantly higher utilization of family labour by partial adopters for different operations. In terms of net benefit, non-adopters had significantly lower net benefit than full adopters whereas the difference between partial and non-adopters was not significant.

The marginal rate of return (MRR) was estimated for changing from traditional to partial and full adoption, and from partial to full adoption. The MRR for changing from non-adoption to partial and full adoption, and from partial to full package adoption provided acceptable return on investment in the adoption of the wheat technology (Table 5.4). Based on experience and empirical evidence, both the change from traditional to partial and full adoption, and from partial to full adoption provided the minimum acceptable rate of return to farmers on improved wheat production.

Table 5.4. Selected indicators and profitability of wheat technologies in Northern and Western Shewa zones (1997-2001)[a]

Item	Traditional technology	Improved	technology
	Non -adopters	Partial adopters	Full adopters
Yield, kg/ha	8.0a	8. 8a	11.5b
Fertilizer, kg/ha	106a	111a	156b
Herbicide, l/ha	330a	650b[b]	507b
Labour use (man-days/ha)	25.4a	42.8b	35.0c
Draft (oxen-day/ha)	8.7a	9.9a	12.9b
Total benefit, Birr/ha3	1219.10a	1440.90ab	1701.20b
Total cost that vary, Birr/ha	428.50a	490.40a	597.55b
Net benefit, Birr/ha	790.60a	950.50ab	1103.65b
MRR[1] (%)		258	292
MRR (%), partial to full			143
Risk (yield variance)	12.2a	28.9b	35.9c
knowledge, Birr/ha		939.2a	347.35b

a. Figures in the same row followed by different letters are significantly different from each other at least at 5% level

b. Only four farmers used herbicide with improved varieties as a package.

[1] Marginal rate of return (MRR) on investment in the adoption of improved wheat technology., i.e., marginal net benefit (the change in net benefit) divided by the marginal cost (the change in costs) and expressed as percentage

Comparisons of yield variance of the three groups of farmers to assess the riskiness of the wheat technologies indicated that full adoption was significantly the most risky package followed by partial adoption of the package (Table 5.4). On the other hand comparison of the lowest 25% net benefits confirmed that full adoption was the most risky option. Non-adoption, partial and full adoption of improved wheat gave on average the lowest net benefit of 317.7, 500.30 and 365.70 Birr/ha, respectively. This implies that partial adoption is less risky than full adoption because it gave better lowest net benefit than full adoption. Thus, partial adoption was selected than full adoption because the net benefits

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[3] 1 US $ = 8.5 Ethiopian Birr at the time of the study

were not significantly different and partial adoption gave acceptable MRR of 258% over non-adoption (Table 5.4). This could be due to higher cost of full adoption as the result of significantly higher utilization of fertilizers, herbicides, family labour and oxen power than partial adoption.

Comparison of partial and full adopters in terms of experience (average profit differential) they had gained over the five years period (1997 – 2001) indicated that surprisingly partial adopters were found more experienced than full adopters and the difference was significant at 1% level (Table 5.4). This was due to high variability of yield obtained by full adopters than partial adopters over the years and the net benefits obtained were not significantly different.

5.3 Pattern of adoption of *tef* and wheat technologies

In the pattern of adoption, percentages of farmers adopting the *tef* and wheat technologies were estimated for each year the farmers had adopted the improved technologies from 1997 to 2001. The majority of t*ef* farmers (65%) discontinued adoption of improved t*ef* varieties and planted local varieties in 2001 crop season. The major reasons for discontinuation were unwanted grain colour (32%), shortage of fertilizers (30%), seed expensive (15%), and shortage of land as reported by about 6% of farmers who discontinued growing improved t*ef* varieties. In the case of wheat, unlike *tef*, about 84% of farmers continued adopting the improved wheat varieties in 2001 crop season, which indicated that farmers have liked the varieties. The reasons given for discontinuing improved wheat varieties were seed becoming more expensive (36%), compared to grain price, low yield in the past (10%), shortage of land (10%), and shortage of fertilizers as reported by 9% of wheat farmers.

5.3.1 Pattern of adoption of wheat technology

Figures 5.1 present pattern of wheat technology adoption in the study area from 1997-2001. Adopters were further classified as partial adopters at the recommended (padopr) and not at the recommended rates (padop), and full adopters at the recommended (fadopr) and not at the recommended rates (fadop). This classification helped to show not only who was adopting the improved wheat technologies but also who was adopting at the recommended rate or not. In the subsequent sections, the following categories of adoption patterns are used:

adopters - farmers using improved varieties

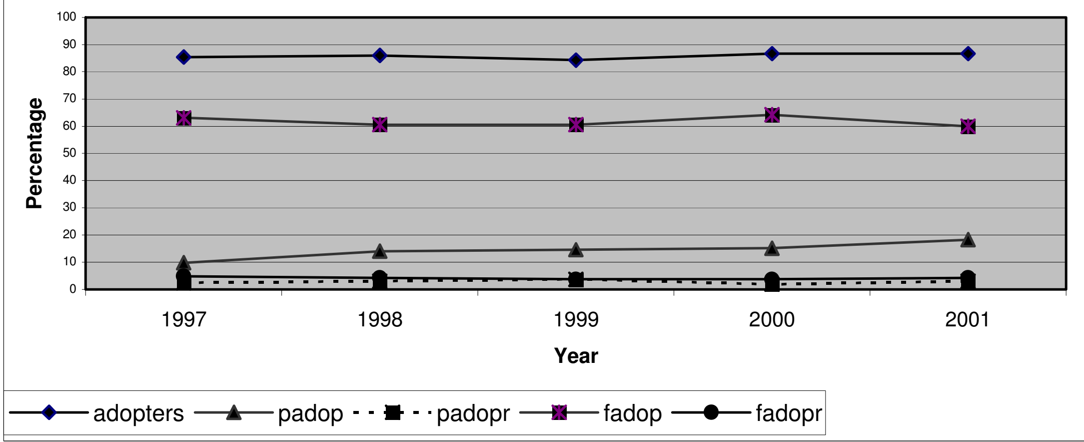
padop - use part of the package (V+F) not at the recommended rates,

padopr - use part of the package (V+F) at the recommended rates

fadop - use full package (V+F+H) not at the recommended rates

fadopr - use full package (V+F+H) at the recommended rates

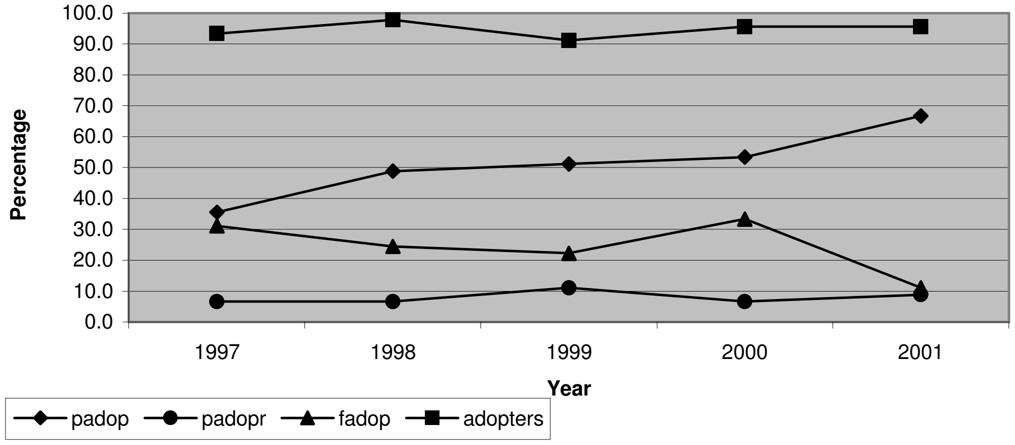
Figure 5.1. Percent of farmers adopting wheat technology in the study areas , 1997-2001



Most of sample farmers (more than 80%) have adopted the improved varieties from 1997 to 2001 (adopters). However, 60% of sample farmers adopted the full package (improved varieties with fertilizer and herbicide) at less than recommended rates (fadop) while only less than 5% adopted full package (improved varieties with fertilizer and herbicide) at recommended rates (fadopr). Farmers adopting part of the package (improved varieties with fertilizer) at less than the recommended rates (padop) ranged from 10% in 1997 to 18% in 2001 whereas farmers adopting part of the package (V+F) at the recommended rates (padopr) were less than 4%. Farmers adopting the full package were significantly more educated than farmers adopting the partial package. Generally, farmers adopting the full package (V+F+H) at less than the recommended rates remained the same (60%) where as farmers adopting part of the package (V+F) at less than the recommended rates increased from about 10% to 18% over the years.

On the other hand patterns of adoption of improved wheat technology in medium (North Shewa) and high potential (West Shewa) growing areas are presented in Figures 5.2 and 5.3, respectively. More than 90% and 80% of farmers adopted the improved varieties (adopters) in medium and high potential growing areas, respectively from 1997-2001. In medium potential growing areas, more than 35% of sample farmers adopted part of the package (improved varieties with fertilizer) at less than the recommended rates (padop) while less than 35% adopted the full package (improved varieties with fertilizer and herbicides) at less than the recommended rates (fadop). The sharp decline in the number of farmers adopting full package followed by concurrent increase of farmers adopting part of the package at less than the recommended rates from 2000 to 2001 indicates farmers' rationale of not using herbicide in medium potential areas to minimize risk and to use the available family labour force. Besides, less than 10% of farmers adopted the partial package (padopr) while less than 1% adopted the full package at the recommended rates.

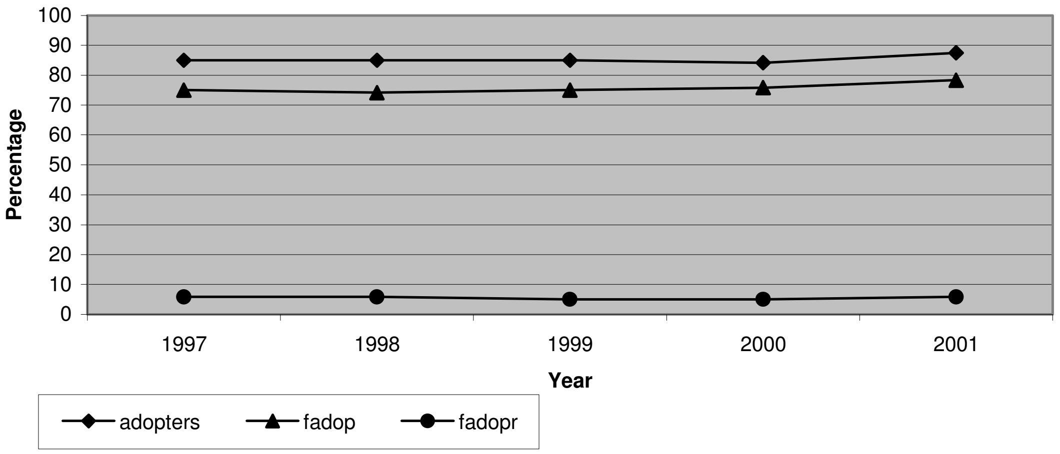
Figure 5.2. Percentage of farmers adopting wheat technology in North Shewa zone, 1997-2001



The trend in medium potential growing areas indicated an increasing shift from full adoption to partial adoption at less than the recommended rates while partial adoption at the recommended rate more or less remained the same.

In high potential growing areas (West Shewa), more than 70% of farmers adopted the full package at less than the recommended rates (fadop) while 5% adopted at the recommended rates (fadopr) from 1997 to 2001. Besides, farmers adopting the partial package were less than 1%. Figures 5.2 and 5.3 revealed that in high potential growing areas most farmers adopt full package at less than the recommended rates while in medium potential growing areas most farmers adopt partial package at less than the recommended rates.

Figure 5.3. Percent of farmers adopting wheat technology in West Shewa Zone, 1997-2001

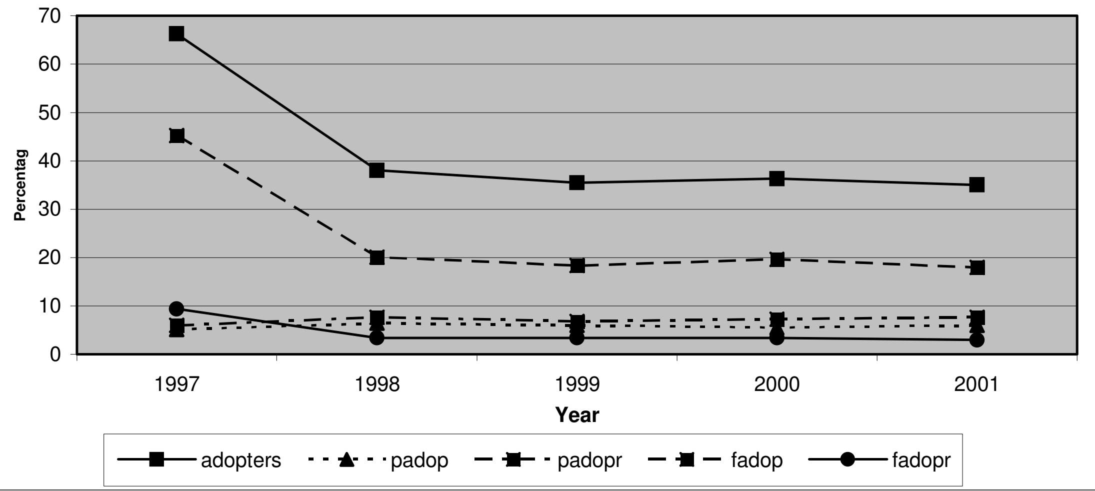


The trend in high potential growing areas remained the same for full adoption both at less than the recommended rates and recommended rates from 1997 to 2001.

5.3.2 Pattern of *tef* technology adoption

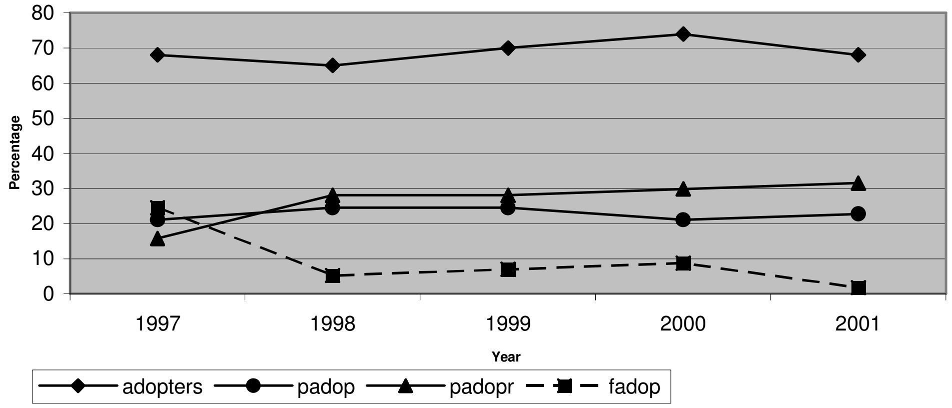
The percent of farmers who adopted improved *tef* seeds (adopters) declined from 66% in 1997 to 35% in 2001 (Figure 5.4). This indicates that only 35% gained knowledge and continued adoption while 31% of farmers discontinued because of the unwanted colour. Similarly farmers who used full package (fadop) dropped from 45% in 1997 to 18% in 2001. Very few farmers (less than 5%) adopted the full package (fadopr) except in 1997 where 9% adopted immediately after demonstration and dropped to 3% starting 1998 and remained the same until 2001. On the other hand, farmers adopting partial package (padop and padopr) were less than 10% (Figure 5.4).

Figure 5.4. Percentage of farmers adopting *tef* technology in the study areas, 1997-2001



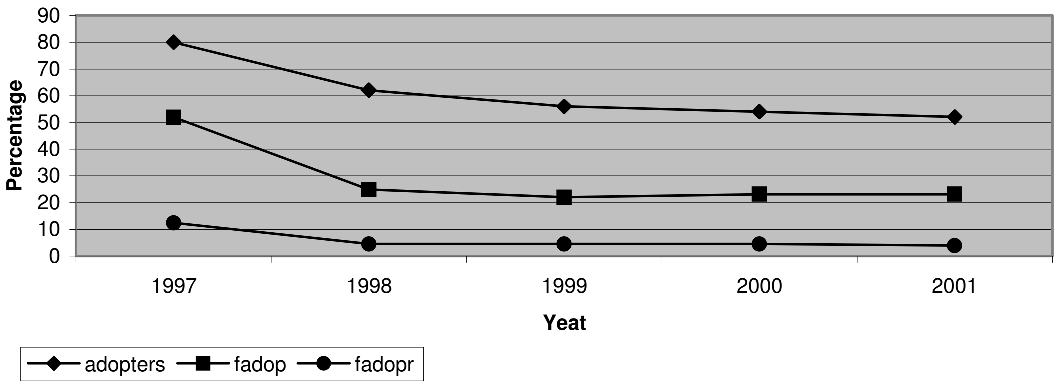
In medium potential growing areas, more than 65% of farmers adopted the improved *tef* varieties (adopters) from 1997-2001 (Figure 5.5). However, more farmers adopted the partial package (padop and padopr) rather than the full package (fadop) because of the risk involved in adopting the full package. Unlike wheat, out of the partial adopters more farmers adopted at the recommended rates except in 1997 due to the gained experience. Besides, adoption of full package (fadop) dropped from 25% in 1997 to 2% in 2001 while partial package adoption (padopr) increased from 16% in 1997 to 32% in 2001 (Figure 5.5).

Figue 5.5. Percentage of farmers adopting *tef* technology in North Shewa Zone, 1997-2001



In the high potential growing zone, improved *tef* variety adoption (adopters) decreased from 80% in 1997 to 52% in 2001 (Figure 5.6) because farmers did not like the varieties. In these areas only less than 1% adopted the partial package whereas more than 20 % adopted the full package (faop) at less than the recommended rates. However, the number of farmers adopted the full package at less than the recommended rates (fadop) decreased from 52% in 1997 to 23% in 2001. Similarly farmers who adopted the full package at the recommended rate (fadopr) also dropped from 12% to 4% for the same period (Figure 5.6).

Figure 5.6. Percentage of farmers adopting *tef* technology in West Shewa zone, 1997-2001



5.4 Sequential adoption of improved technologies

In the sequence of adoption, farmers adopting partially and fully, and non-adopting were first identified. Then for each group, farmers adding or dropping components, and maintaining the same components they used to do were identified for the successive years after 1997.

Mostly development agents persuaded farmers to adopt the whole package of improved technologies (improved seed, fertilizer and herbicide) to take full advantage of the highest gains in profit due to the complementarity of components of the improved technologies. However, farmers often choose not to use the whole package but only some of its components in sequential manner i.e., improved variety with fertilizer first, then adopt herbicide later, etc. (Byerlee and de Polanco, 1986; Leaters and Smale, 1991). Farmers' sequential adoptions of components of the improved technology are influenced by the gains realized from using various components.

For sequential adoption, farmers were grouped into non-adopters (no use of improved varieties), partial adopters (farmers adopting improved seed with fertilizers) and full adopters (farmers adopting improved seed with fertilizers and herbicide). Then data on these three groups of farmers were examined separately from 1997 up to 2001 on their use of components of the improved *tef* and wheat technologies. Farmers using only improved seed without fertilizers and herbicide, and farmers using improved seed with herbicides were dropped from this analyses since their number was less than five.

In 1997, 14% of wheat growers were non-adopters while 18% and 68% were partial and full adopters, respectively. Wheat growers' were significantly different in their education levels (Table 5.5).

Table 5.5. Education level of wheat growers in Northern and Western Shewa Zones in 1997.

Type of wheat Growers	**Number**	**Percentage**	**Education level, percentage**		
			Illiterate	**Literate**	**Formal**
Non-adopters	24	14	30	33	37
Partial adopters	29	18	65	4	31
Full adopters	112	68	30	25	45

Source: Own survey

Table 5.6 presents the sequence of adoption of components of wheat technology by non-adopters (24) from 1997 to 2001. Out of the non-adopters in 1997, 54% remained as non-adopters while 4% and 42% became partial adopters and full adopters, respectively, in 2001. Out of the non-adopters more farmers (37%) became full adopters rather than partial adopters from 1998 to 2001 due to their better education.

Table 5.6 Sequential adoptions of components of wheat technology by non-adopters in Northern and Western Shewa Zones, 1997-2001.

Item	**Percent of farmers adopting as of 1997**			
	1998	**1999**	**2000**	**2001**
Non-adopters	71	67	50	54
Partial adopters	4	0	0	4
Full adopters	25	33	50	42

Source: own survey

In the case of partial adopters (29), 3% became non-adopters while 90% remained as partial adopters and 7% added the herbicide component and became full adopters in 2001 (Table 5.7). Most farmers (more than 79%) remained as partial adopters while less than 5% became non-adopters and less than 17% became full adopters form 1998 to 2001.

Table 5.7 Sequential adoptions of components of wheat technology by partial adopters in Northern and Western Shewa Zones, 1997-2001.

Item	Percent of farmers adopting, as of 1997			
	1998	**1999**	**2000**	**2001**
Non-adopters	3	4	4	3
Partial adopters	79	86	79	90
Full adopters	7	10	17	7

Source: own survey

On the other hand, out of those farmers (112) who were full adopters in 1997, 7% became non-adopters, while 9% dropped the herbicide component and became partial adopters whereas 84% remained as full adopters in 2001. Most farmers (more than 80%) remained as full adopters while less than 10% and 12% became non-adopters and partial adopters, respectively, from 1998 to 2001 (Table 5.8). Full adopters were significantly better educated than non-adopters and partial adopters.

Table 5.8 Sequential adoptions of components of wheat technology by full adopters in Northern and Western Shewa Zones, 1997-2001.

Item	Percent of Farmers adopting, as of 1997			
	1998	**1999**	**2000**	**2001**
Non-adopters	4	8	8	7
Partial adopters	9	12	8	9
Full adopters	87	80	84	84

Source: own survey

Similarly, the sequences of adoption of components of t*ef* technology were observed from 1997 to 2001. In 1997, 34% of t*ef* growers were non-adopters while 13% and 53% were partial and full adopters, respectively. Table 5.9 presents the sequences of adoption of components of t*ef* technology by non-adopters from 1997 to 2001. Out of non-adopters (80) in 1997, 89% remained as non-adopters whereas 1% and 10% became partial and full adopters, respectively in 2001 (Table 5.9). More than 89% of farmers also remained as non-adopters from 1998 to 2001.

Table 5.9 Sequential adoptions of components of *tef* technology by non-adopters in Northern and Western Shewa Zones, 1997-2001.

	Percent of farmers adopting, as of 1997			
Item	**1998**	**1999**	**2000**	**2001**
Non-adopters	90	94	91	89
Partial adopters	0	0	0	1
Full adopters	10	6	6	10

Source: own survey

In the case of farmers who were partial adopters (30) in 1997, 40% dropped the improved t*ef* varieties and became non-adopters while 60% remained as partial adopters and none became full adopters in 2001 (Table 5.10). From 1998 to 2001, more than 53% remained as partial adopters while more than 33% became non-adopters because they did not like the colour of the varieties and they were older.

Table 5.10 Sequential adoptions of components of *tef* technology by partial adopters in Northern and Western Shewa Zones, 1997-2001.

	Percent of farmers adopting, as of 1997			
Item	**1998**	**1999**	**2000**	**2001**
Non-adopters	33	37	37	40
Partial adopters	57	60	53	60
Full adopters	10	3	10	0

Source: own survey

On the other hand, out of full adopters in 1997(124), 55% dropped the t*ef* varieties and became non-adopters while 12% dropped only the herbicide component and became partial adopters whereas 33% remained as full adopters in 2001 (Table 5.11). The majority of farmers (more than 50%) became non-adopters since they did not like the colour of the varieties while 13% became partial adopters and more than 33% remained as full adopters from 1998 to 2001.

Table 5.11 Sequential adoptions of components of *tef* technology by full adopters in Northern and Western Shewa Zones, 1997-2001.

	Percent of farmers adopting, as of 1997			
Item	**1998**	**1999**	**2000**	**2001**
Non-adopters	51	53	53	55
Partial adopters	13	13	13	12
Full adopters	36	34	34	33

Source: own survey

5.5 Summary and Conclusion

Comparison of the three groups of farmers (non-adopters, partial and full adopters) both for *tef* and wheat production indicated that non-adopters, partial and full adopters were significantly different in many respects such as crop area, active labour force, fertilizer obtained on credit, distance to Addis Abeba and distance to market. Their major differences were in input use, yield and returns. For instance, the majority of *tef* farmers did not like the new varieties because of their colour thinking that they will not fetch good prices and discontinued production. However, the partial budgeting showed that the improved varieties were profitable and provided acceptable returns on investment. The marginal rate of return (MRR) for changing from non-adoption to partial and full package adoption was more than 600%, i.e., for every *Birr* the farmer spends in *tef* technology he/she gets back six additional *Birr*. Unfortunately, about 62% of farmers discontinued growing the improved *tef* varieties after demonstration due to their undesirable color while the remaining (38%) realized the yield advantage and continued growing although the improved varieties were more risky (high yield variance) than the local ones in the past growing seasons. Partial and full adopters had on the average yield variances of 18.7 and 21.4, respectively, which are 143% and 174% higher than average variance of yield of non-adopters, respectively. Thus, partial adoption was found more acceptable than full adoption in terms of its less riskiness and providing acceptable return on investment in the technology.

In the case of wheat, the majority of farmers had continued adopting the improved wheat varieties realizing the benefits obtained in the past. The MRR for changing from non-adoption to partial and full package adoption resulted in more than 200% additional income. However, for wheat partial adoption was found as profitable and provided acceptable rate of return on investment (258%) as full adoption, and less risky than full adoption. Partial adopters of improved wheat varieties also gained more experience than full adopters because of high variability of yield in full adoption. That could be the main reason why small farmers adhere to partial adoption rather than full adoption because of fear of debt as a result of inputs taken on credit and high variability in yield.

Sample farmers were asked their use of improved varieties of *tef* and wheat with fertilizers and herbicides after participating in the demonstration programmes form 1997 to 2001. Pattern of adoption was determined by percentage of farmers using the components of improved technologies (seed, fertilizers and herbicide). The pattern of adoption of improved varieties with fertilizer and herbicide from 1997-2001 indicated that most of the sample farmers adopted the full package (three components) at less than the recommended rates simultaneously both for *tef* and wheat. The patterns of adoption of *tef* and wheat technologies in high and medium potential growing areas vary because of risk. In medium potential growing areas both *tef* and wheat growers adopted the partial package and partial adoption was increasing from 1997-2001. On the other hand, in high potential growing areas full adoption dominated for both *tef* and wheat production. Moreover, percentage of wheat farmers adopting the full package remained the same from 1997 to 2000 and slightly increased in 2001. For *tef*, percentage of farmers adopting the full package decreased from 50% to 20% from 1997 to 2001 indicating that farmers did not like the *tef* varieties that were demonstrated to them although they were profitable and provided acceptable rate of return (MRR) as indicated in Table 5.2.

In the sequence of adoption of components of *tef* and wheat technologies, most of the group members remained where they belonged in 1997. In the case of wheat growers, out of the non-adopters (24) in 1997, 54% remained as non-adopters where as 4% and 42% became partial and full adopters, respectively, in 2001. Most of the non-adopters were better educated and that is why 42% became partial adopters after five years. Out of the partial adopters (29), 3% and 7% became non-adopters and full adopters, respectively, while 90% remained as partial adopters in 2001. Partial adopters were the least educated among wheat growers. Out of full adopters (112) in 1997, 7% and 9% became non-adopters and partial adopters, respectively, while 84% remained as full adopters in 2001. Full adopters were significantly the most educated among wheat growers and the youngest although the difference was not significant. That is why a few dropped the improved varieties.

In the case of *tef* growers, out of non-adopters (80) in 1997, 89% remained as non-adopters whereas 1% and 10% became partial and full adopters, respectively, in 2001. Non-adopters were not significant in their education level and age. However, they were the youngest of all. Out of the partial adopters (30), 40% became non-adopters while 60% remained as partial adopters in 2001. Partial adopters were the oldest of all and were significantly different from non-adopters in terms of age and wealth. On the other hand out of full adopters (124) in 1997, 55% and 12%became non-adopters and partial adopters, respectively, whereas 33% remained as full adopters in 2001. Most of full adopters dropped the improved *tef* varieties because of the high risk.

Generally, the sequence of adoption of wheat technologies indicated that out of non-adopters in 1997, 42% became full adopters in 2001 while 3% and 7% of partial and full adopters, respectively, became non-adopters during the same period. In the case of *tef* growers, out of the non-adopters in 1997, 89% remained as non-adopters and 10% became full adopters in 2001 while 40% and 55% of partial and full adopter, respectively, dropped the improved varieties since they did not like the varieties. This implies farmers adopt components of a technology sequentially when they found them useful and drop when they found them unacceptable.

CHAPTER 6

EMPIRICAL ANALYSES OF THE ADOPTION OF *TEF* AND WHEAT TECHNOLOGIES

6.1 Introduction

Improved technologies such as improved seeds, fertilizers and herbicides have played a great role in enabling farmers to increase their production and hence improve their standard of living. Therefore, the process of adoption of these improved technologies have been the interests of many economists. Essentially adoption is a dynamic process that involves learning about the improved technologies over time. Although the dynamic aspects of adoption have been recognized well in the literature, with the exception of a few, almost all previous studies used cross-sectional data to study adoption which do not allow proper modeling of the dynamics of the adoption process. Thus, these studies have not been able to explore the dynamic nature of the process of adoption. The present study attempts to model the dynamics of adoption by incorporating the importance of learning in the process of adopting *tef* and wheat technologies in Ethiopia using panel data. For the investigation of dynamic adoption of *tef* and wheat technologies, separate adoption models were estimated using panel data.

Tef and wheat are among the most important cereal grains in Ethiopia in terms of area coverage and production (CSA, 2001). Yields of these crops are low due to low adoption of improved technologies mainly improved seed and fertilizers. Northern and Western *Shewa* zones are medium and high potential growing areas, respectively, for the two crops. National Extension Programs (NEP) have been launched to enhance the food production in the two zones. *Tef* and wheat are among the major crops where NEP has been implemented. The new *tef* and wheat technologies require a new set of knowledge which farmers gain through learning (using the technologies). This study used profit differential between the improved and traditional technologies that have been grown by the farmer as a dynamic learning term. In this study panel data for 165 wheat farmers and

234 *tef* farmers were used to study the dynamic process of learning in the adoption of improved *tef* and wheat technologies.

6.2 Hypotheses

From the conceptual model discussed in Chapter 4, the following hypotheses were advanced to be tested:

a) With age, a farmer can become more or less risk averse to an improved technology. The older the farmer the lower is the probability to adopt and allocate area to improved *tef* and wheat technologies.

b) Exposure to education will increase a farmer's ability to obtain, process and use information relevant to the adoption of improved technologies. The less educated the farmer is the lower the probability he will adopt and allocate area to improved *tef* and wheat technologies.

c) The more family labour available in the household the more likely the family will adopt and allocate area to improved *tef* and wheat technologies.

d) Population pressure in the study area is causing a land shortage, and hence the scope for increasing land productivity depends on higher cropping intensity. This in turn will require farmers to allocate their limited land to improved technologies. Besides, farm size is an indicator of wealth and perhaps a proxy for social status and influence within a community and hence it is expected to be positively associated with the decision to adopt improved *tef* and wheat technologies.

e) Access to information through visit to development agent is hypothesized to positively influence farmers' decision to adopt and intensify use of improved *tef* and wheat technologies.

f) Closer distance to input and output markets and better road condition positively influences farmers' decision to adopt and allocate area to improved *tef* and wheat technologies.

g) Knowledge gained through own experience positively influences farmers' decision to continue adoption and area allocation to improved *tef* and wheat technologies.

h) Riskiness of improved technology discourages adoption and area allocation to improved *tef* and wheat technologies.
i) Ownership of livestock is hypothesized to be positively related to the adoption and intensity of improved *tef* and wheat technologies.
j) Farmers who have access to credit (in cash or in kind) are more relaxed in terms of financial constraints. Hence, access to credit will increase the probability that a farmer will adopt and allocate area to improved *tef* and wheat technologies.

6.3 Specification of the empirical adoption models

In this study panel data were used to study farmers' adoption decisions and intensity of use. Panel data, unlike cross-sectional data, can produce consistent estimates of parameters. The advantages of panel data over cross-section or time-series data are that panel data take into account heterogeneity by considering individual-specific variables; give more informative data, more variability, less collinearity among variables, more degrees of freedom and more efficiency; better suited to study dynamics of change; and better detect and measure effects that simply cannot be observed in pure cross-section or pure time-series data (Gujarati, 2003). Despite their substantial advantages, panel data pose several estimation and inference problems such as heteroscedasticity for cross-sectional data and autocorrelation for time-series data. There are also some additional problems, such as cross-correlation in individual units at the same point in time (Gujarati, 2003).

There are several estimation techniques to address the above problems. The two most important are the fixed effects model (FEM) and the random effects model (REM) or error components model (ECM). In FEM the intercept in the regression model is allowed to differ among individuals in recognition of the fact that each individual may have some special characteristics of its own. FEM is also appropriate in situations where the individual specific intercept may be correlated with one or more independent variables. An alternative to FEM is ECM. In ECM it is assumed that the intercept of an individual unit is random, drawn from a much larger population with a constant mean value. The individual intercept is then expressed as a deviation from this constant mean value. One advantage of ECM over FEM is that it is economical in degrees of freedom, as we do not have to estimate N cross-sectional intercepts. We need only to estimate the mean value of the intercept and its variance. ECM is appropriate in situations where the random intercept of each cross-sectional unit is uncorrelated with the independent variables (Gujarati, 2003). Therefore, this study used ECM in the analysis of adoption of improved *tef* and wheat technologies over time.

6.4 Estimation procedures of empirical adoption models

There are three categories of farmers: farmers who have used only the new technology, farmers who have used only the old technology and farmers who have used the new and old technology simultaneously after the demonstration programs. Thus, only farmers who have used the new technology gain experience. For farmers who have used both the new and the old technologies simultaneously one can easily estimate the gains in profit. In this study, however, there are some farmers who have used only the new technology (improved seed with fertilizer, and improved seed with fertilizer and herbicide) after the demonstration programs. To estimate the gain in profit for farmers who have used only the new technology, average profits of farmers who have used the old technology were deducted from the profits of farmers who have used the new technology in their respective peasant association (PA). This follows the practice in another study by Cameron (1999), where average profit of farmers who have used the old technology in the village was subtracted from the profit of farmers who had used only the new technology.

In this study total profit from the production of *tef* or wheat (grain and straw) using the same input (improved seed, fertilizer, herbicide, improved seed with fertilizer, improved seed with fertilizer and herbicide) were considered for any year that the farmer had planted *tef* or wheat in Northern and Western Shewa zones. Equation (9) in Chapter 4 was used to estimate gains in profit from the *tef* or wheat technologies.

In this study, panel data regression models (Xtprobit and Xttobit) were employed to study farmers' decisions to adopt a new technology and resource allocation to the new technology. First, farmers' must make the initial choice of whether or not to use *tef* or wheat technologies for the first time in any one period. Second, conditional on choosing to adopt, farmers then must decide how much land to use. Third, the farmer has also to decide whether or not to try component(s) or the whole package conditional on choosing to use the new technology. Finally, following the adoption decision, each year the farmer has to decide whether or not to continue, which is influenced by gains in profit in previous years and risk faced in using the improved *tef* or wheat technologies. Farmers' knowledge (learning from own experience) improves as the farmers continue to use the new *tef* or wheat technologies.

Obviously, the above decisions are related and can be jointly determined or not. When decisions are not jointly determined farmers can adopt improved seed or fertilizer or herbicide. Thus, a panel data probit model (Xtprobit) was used to identify farmers who have used and not used the new technology over time (Equation 7 in Chapter 4). The dependent variable takes a value of one if the farmer has used the *tef* or wheat technologies, and zero otherwise for the specified period (1997-2001). Similarly, the independent variables will be year-specific to observation at the values taken in the year of adoption. On the other hand to capture the change in intensity of use of new technologies over time a panel data Tobit model (Xttobit) was used (Equation 8 in Chapter 4).

Accordingly explanatory variables were checked for problems of multicollinearity, endogenity and heteroscedasticiy. To detect the problem of multicollinearity among continuous explanatory variables, the variance inflation factor (VIF) was estimated. Values of VIF greater than 10 are often taken as signals that the data have collinearity problems. Likewise, contingency coefficients were used to check the degree of association among discrete variables. For endogeneity, an attempt was made not to include the dependent variables as explanatory variables to each and heteroscedasticiy is not a serious problem in panel and time series data.

6.5 Empirical results

This section presents comparison of the main features of wheat and *tef* growers, and models' estimation results using the computer Software Stata 7.0, which is appropriate to analyze panel data (Stata Corp., 2001). First, the main features of wheat and *tef* growers are compared. This is followed by results of farmer's adoption decisions over time, which involves two choices i.e., to use or not, and intensity of use of improved *tef* and wheat technologies over time using Xtprobit and Xttobit models, respectively. The results of *tef* and wheat technology adoption decisions are presented separately since the two crops have different farming systems and different samples were considered for the two crops in their respective production areas.

6.5.1 Comparison of the main features of wheat and *tef* farming systems

Farmers in the study area grow more than one crop to satisfy their needs. The major crops grown in the study areas include t*ef,* wheat, grass pea and chickpeas. Minor crops consist of barley, maize, lentils and faba-beans. Based on the major crop grown, the study area is divided into two farming systems: *tef*-based (*tef*, grass pea, lentil, chickpea, maize) and wheat-based (wheat, barley, faba bean, maize) farming systems where more than 95% of farmers grow *tef* or wheat in their respective areas.

Survey results suggest that, on average, wheat farmers are slightly younger (42 years) than *tef* farmers (45 years). On the other hand, education among wheat farmers is much higher (46%) than among *tef* farmers (29%). The age of a farmer is correlated with education. Younger farmers are more likely to have received some education than older farmers due to recent (late 1970s) expansion of formal education in the rural areas of Ethiopia (Wagayehu and Lars, 2003). Thus, wheat farmers are expected to have better capacity to understand improved technologies and learn faster than *tef* farmers. The average family size was slightly higher among wheat farmers than *tef* farmers (7.6 persons versus 7.0 persons). But wheat farmers had significantly higher family labour than *tef* farmers (3.6 persons versus 2.3 persons), which means wheat farmers can provide the additional labour required for adopting labour intensive improved technologies.

While average farm sizes were similar for wheat and *tef* growers (2.78 ha and 2.79 ha, respectively), *tef* farmers cultivated larger shares of their farmland to *tef* (60%) compared to the share of wheat (30%). This suggests that *tef* farmers are more specialized in *tef* production with some pulses (chickpea and lentil) in the rotation on 21% of the land. On the other hand, wheat farmers use more mixed cropping and diversify with barley and pulses on 22% and 19% of area, respectively. This may be attributed to the high risk associated with wheat production as improved wheat varieties grown in the area are introductions from outside (Hailu, 1992) mainly from the International Maize and Wheat Improvement Center (CIMMYT) and found to be susceptible to pests and diseases while *tef* varieties are local selections and hence better adapted (Seyfu, 1993).

Wheat farmers allocated most of the wheat area (90%) to improved varieties while *tef* farmers allocated only 20% of *tef* area to improved varieties from 1997 to 2001. More improved wheat varieties[1] (6 including the old ones) are distributed to farmers compared to only three improved *tef* varieties[2] supplied and grown at the time of the study. Most important is the fact that the zonal extension offices supplied much higher quantities of improved wheat seed (120.8 tons) than *tef* (10.8 tons) during 1999 and 2000 crop seasons. Improved seeds are supplied by the Ethiopian Seed Enterprise (ESE) depending on availability during the cropping season. This clearly is expected to lead to higher adoption of improved varieties by wheat farmers (86% of farmers) than *tef* farmers (42%) during the study period.

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[1] Wheat varieties included Dashen, Enkoy, ET-13, Kubsa, Wabe and Galema. Dashen and Enkoy are phased out of production by The National Variety Release Committee due to their susceptibility to disease and the seeds are no longer produced and supplied by ESE. However, farmers continued to grow these varieties and they are considered as local varieties in this study. Dashen and Enkoy are planted on 10% of total wheat area during the study period. ESE produced and supplied the seeds of the other varieties.

[2] Improved *tef* varieties supplied to farmers are DZ-354, DZ-196 and CR-7.

Wheat farmers showed a slightly higher demand for information about improved technologies than *tef* farmers as indicated by the number of visits they made to development agent (DA) office in 2001 (2.0 versus 1.3, respectively). This was in spite of the fact that both need same time to reach the DA office (1.4 hrs and 1.3 hrs for wheat and *tef* farmers, respectively). On the other hand, wheat farmers were closer to local markets (1.5 hrs versus 1.8 hrs) while *tef* farmers were much closer to major markets such as Addis Ababa (91 km versus 103 km from district capital to Addis Ababa). Moreover, 60% of wheat growers were located in districts where the capitals are connected to Addis Ababa by tarmac roads compared to *tef* farmers (36%). This suggests that proximity and access to information, input supply sources and markets are among the factors that contribute to higher adoption of improved technologies among wheat farmers.

Wheat was grown by 95% of farmers mainly for own consumption among those using local varieties (35% selling only) compared to those adopting improved varieties where 49% of the produce was sold. That means users of local wheat varieties appear to produce mainly for own consumption (65%). The opposite is true for *tef* where 69% of grain produced from improved *tef* was sold compared to only 40% of grain produced from local varieties. On aggregate, however, equal amounts of wheat and *tef* (48% and 46% of produce, respectively) were sold in the local market. This seems to suggest that although wheat farming appear to be more market oriented in terms of input use, both *tef* and wheat farmers sell half of their produce in the market (i.e., equally market oriented)

Similar levels of fertilizer and herbicide were used on wheat and *tef*. In terms of livestock ownership wheat and *tef* farmers were not different (6.0 TLU versus 6.1 TLU).

Five years after participating in the National Extension Package program, most wheat farmers (85%) continued adopting the new improved wheat varieties as compared to only 35% of *tef* farmers. Better education and longer experience together with better access to and availability of seed helped continued replacement of varieties among wheat farmers.

6.5.2 Results of wheat technology adoption analyses

This section presents parameter estimates of adoption and intensity of use of wheat technologies. Most adoption studies (Akinola and Young, 1985; Akinola, 1987; Jha et al., 1990; Hassan et al., 1998) used farmer's age at the time of the study. However, farmers may have made the decision to adopt earlier than the time of the study (Legesse, 1998). The present study considered the age of the farmer at the time of adoption[3] while other variables were measured at the time when the study is conducted.

Wheat farmers were classified into adopters and non-adopters. Non-adopters are farmers who use none of the new improved varieties or fertilizer or herbicide while adopters are farmers who used at least one of the new improved varieties or fertilizer or herbicide during the study period.

The parameter estimates of the Xtprobit model employed to identify factors influencing farmer's adoption of wheat technologies are presented in Table 6.1. Table 6.2 presents estimation results of the Xttobit model employed to examine factors influencing intensity of use of wheat technologies. In all analyses the likelihood ratio test statistics suggest the statistical significance of the fitted regressions. Results of the analyses also revealed that the adoption and intensity of use of wheat technologies are influenced by different factors and at different levels of significance for different factors.

Age of the farmer: The age of the farmer had different influences on adoption and intensity of use of improved wheat seed (Tables 6.1 and 6.2). The age of the farmer had negative influence on the adoption and intensity of improved seed and amount of herbicide applied on wheat. The influence was significant only for adoption of improved seed as older farmers are more conservative and avers to risk associated with new technologies. Studies by Legesse (1998) and Hassan *et al.* (1998) also obtained a negative relationship between technology adoption and the age of the decision maker. On the other hand, the age of the farmer had positive influence on the adoption and intensity of

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[3] Also experience, livestock ownership and credit were measured at the time of adoption.

fertilizer and adoption of herbicide on wheat due to previous knowledge gained, as fertilizer and herbicides are earlier technologies introduced to the area.

Farmer's education level: Educated farmers are more interested in trying new technologies than non-educated. As expected, education had positive impact on adoption and intensity of use of wheat technologies, except for amount of fertilizer applied on wheat (Tables 6.1 and 6.2). This may be attributed to the fact that while educated farmers are more willing to adopt new innovation they have less access to cash and assets such as ownership of livestock. This limits their ability to purchase fertilizer and hence apply lower rates than the less wiling to adopt but wealthier farmers. The influence is significant only for likelihood and intensity of herbicide use on wheat. This is consistent with results of studies by Mafuru *et al.* (1999) and Shiyani *et al.* (2002).

Family labour: Larger households will be able to provide the labour that might be required by the improved technology. New wheat technologies promoted in the region appear to be labour intensive since partial and full adopters used significantly more labour than non-adopters in the production of wheat as indicated in Chapter 5 (Table 5.4). Adoption and intensity of use of improved seed and herbicide, and amount of fertilizer applied on wheat were positively and significantly influenced by family labour (Tables 6.1 and 6.2) suggesting farmers who have more family labour adopt improved seed and allocate more area, apply more fertilizer and herbicide since they can supply the required labour for different operations. This result is consistent with the findings of Getachew *et al.* (1995), who found positive and significant effect of family labour on adoption of coffee berry disease (CBD) resistant varieties. These results suggest that larger families will more likely adopt improved wheat technologies. The negative impact of family labour on the likelihood of adoption of fertilizer on wheat is hard to explain.

Farm size: As expected, farm size positively influenced the likelihood and intensity of adoption of improved wheat seed and fertilizer where only the likelihood of improved seed adoption was significant (Tables 6.1 and 6.2). On the other hand, farm size had negative and significant influence on the adoption and intensity of herbicide use on wheat. These negative impacts suggest that small farmers may be trying to utilize their limited resources (purchased inputs like fertilizer and herbicide) more efficiently to increase production while large farmers want to increase production by applying lower rates on larger areas. Small farmers used 0.505 l/ha herbicide and 136 kg/ha fertilizer on wheat while large farmers used 0.44 l/ha and 130 kg/ha of herbicide and fertilizer, respectively. Large farmers, however, applied those to larger land areas. Livestock ownership helps larger farmers use improved varieties with lesser rates of fertilizer and herbicide on larger areas. A study by Shiyani *et al. (*2002) provided a negative relationship between farm size and adoption of improved varieties and fertilizer. On the other hand, our results suggest that large farmers could increase their production by using improved seed with fertilizer but without herbicide.

Frequency of visit to Development Agent (DA) office: Agricultural extension services are the major sources of information for improved technologies. One can get access to information about new technologies through attending formal training, participate in package testing programs, visit demonstration fields, attending field days and visiting the development agent (DA) at his office. Of these, visit of farmers to the development agents' office was considered for this study. Farmers who frequently visit the DA's office are updated on the availability and arrival of improved technologies.

Frequency of visit to DA's office positively influenced the likelihood and intensity of adoption of improved seed where the impact was significant to area allocated to improved wheat seed (Tables 6.1 and 6.2). Studies by Kaliba *et al.* (1998) and Mafuru *et al.* (1999) indicated that extension was a significant factor affecting land allocated to improved maize varieties in Tanzania.

Farmer's knowledge in using improved technologies: Farmers learning from their own experience in growing the improved technologies is an important factor in the promotion of improved technologies. In this study farmer's knowledge was defined as the profit differential between improved and traditional technologies assuming that farmers care more about profitability. Thus, farmers who participated in the demonstrations of improved wheat technologies have gained some knowledge and are therefore expected to use their knowledge in their future adoption decisions. As expected, farmers' knowledge had positive and non-significant impacts on adoption of wheat technologies. The non-significant effect of farmers' knowledge on improved seed adoption can be explained by the fact that non-adopting farmers are using some old improved varieties (Dashen and Enkoy) that were still productive on farmer's fields although the National Variety Release Committee banned these varieties due to their susceptibility to disease. The profit differential between the new and old varieties might be small to justify the cost of new seed purchases. A study by Chilot *et al.* (1996) also revealed that farmer's experience had no significant effect on the adoption of wheat varieties in Wolmera and Addis Alem *weredas* (districts).

Distance to Addis Ababa: Addis Ababa is considered as an external market for farmers' surplus output. Besides, farmers can buy inputs like herbicide from small shops in Addis Ababa and transport inputs like fertilizer at their own expense when there is delay in transporting fertilizers by the Ministry of Agriculture (MOA) to the district capital. Thus, closer distance of district capital to Addis Ababa enables traders to travel easily to purchase surplus produce from local assemblers and facilitate input delivery to farmers. The coefficients of distance to Addis Ababa had the expected negative signs and had significant effect on the adoption and intensity of fertilizer and herbicide use on wheat (Tables 6.1 and 6.2). The negative sign indicates the importance of proximity to regular sources of improved inputs and external markets leading to better access, lower transport cost, and timely delivery of inputs and disposal of outputs, and better output price for farmers.

Road condition: It is not only the proximity to local and external markets that influence adoption of improved technologies, but the road condition (tarmac) also matters. As expected, better road conditions from the district capital to Addis Ababa positively and significantly influenced the likelihood and intensity of adoption of improved seed and fertilizer on wheat (Tables 6.1 and 6.2) suggesting better roads are essential for timely input delivery and output disposal and less transport cost of inputs and outputs and hence investment in improved road infrastructure is crucial for promoting adoption and hence productivity gains.

Livestock: Generally livestock is considered as an asset that could be used either in the production process or be exchanged for cash (particularly small ruminants) for the purchase of inputs (fertilizer, herbicide, ete.) whenever the need arises. Besides, livestock is considered as a sign of wealth and increase availability of cash for adoption. Also livestock, particularly oxen, are used for draft for different farm operations. Ownership of livestock had positive and significant effects on the adoption of fertilizer and intensity of use of herbicide on wheat (Tables 6.1 and 6.2) due to availability of cash to adopt these technologies. Besides, livestock had positive and significant influence on allocating area to improved seed due to availability of oxen for farm operation. A study by Chilot *et al.* (1996) indicated similar positive and significant influences of livestock ownership on the intensity of fertilizer use on wheat.

Credit: The serious cash shortages faced by small farmers partly due to deteriorating output prices and increasing external input prices makes availability of credit to be an important determinant of farmer's adoption decisions. As expected, credit had positive and significant effect on adoption and intensity of fertilizers and herbicide use on wheat and adoption of improved varieties (Tables 6.1 and 6.2). The non-significant effect of credit on area allocated to improved varieties could be explained by farmer’s use of improved seed from their previous harvest and credit was needed for the purchase of improved seed initially at the time of adoption. Other studies revealed a positive and significant association between access to credit and adoption of HYVs and intensity of use of fertilizer (Herath and Jayasuriya, 1996; Hassan *et al.,* 1998; Techane *et al.,* 2006).

Table 6.1. Parameter estimates of the Xtprobit model for adoption of wheat technologies in Northern and Western Shewa Zones, 1997-2001.

Variable name	**Estimated coefficients for** **Seed** **(n =165)**	 **Fertilizer** **(n = 165)**	 **Herbicide** **(n = 165)**
Constant	0.6526	0.6475	-2.4835
	(0.4998)	*(1.1586)*	*(10959)*
Age of farmer	-0.0334**	0.0266	0.0203
	(0.0121)	*(0.0197)*	*(0.0169)*
Farmer's education	0.2357	0.04227	0.8197**
	(0.2098)	*(0.2658*	*(0.2803)*
Family labour	0.2408**	-0.0891	0.7927***
	(0.0938)	*(0.0995)*	*(0.2803)*
Farm size	0.3568**	0.2587	-0.5195***
	(0.1184)	*(0.1973)*	*(0.1343)*
Frequency of DA visit	0.1659	NR	NR
	(0.1042)		
Knowledge gained	0.0002	0.0002	0.0003
	(0.0001)	*(0.0002)*	*(0.0002)*
Distance to Addis	NR	-0.0333**	-0.3868***
		(0.0130)	*(0.0065)*
Road condition	2.4240***	1.5540*	NR
	(0.4177)	*(0.8945)*	
Livestock owned	0.0309	0.2251**	0.0391
	(0.0393)	*(0.0973)*	*(0.0489)*
Credit	0.0038**	0.0225***	0.0098***
	(0.0017)	*(0.0015)*	*(0018)*
Log-likelihood	-190.30	-81.42	-183.61
Likelihood-ratio	218.13***	15.45***	164.76***
Wald	54.56***	30.93	58.51***

Note: NR means not relevant; **, and *** indicates significance at 5% and 1% level, respectively

Figures in parentheses are standard errors

Table 6.2. Parameter estimates of the Xttobit analysis of intensity of wheat technology adoption in Northern and Western Shewa Zones, 1997-2001.

Variable name	**Estimated coefficients for**		
	Seed (n =165)	**Fertilizer (n = 165)**	**Herbicide (n = 165)**
Constant	0.0871	1.3218***	0.3616***
	(0.2193)	*(0.1725)*	*(0.0506)*
Age of farmer	-0.0061	0.0004	-0.0002
	(0.0048)	*(0.00257)*	*(0.0010)*
Farmer's education	0.0239	-0.0353	0.0498***
	(0.1022)	*(0.0130)*	*(0.0114)*
Family labour	0.1633**	0.0395**	0.0368***
	(0.0524)	*(0.0130)*	*(0.0043)*
Farm size	0.0658	-0.0263	-0.0327***
	(0.0448)	*(0.0214)*	*(0.0060)*
Frequency of DA visits	0.5525***	NR	NR
	(0.0754)		
Knowledge gained	0.00005	0.0001	0.00001
	(0.00005)	*(0.00001)*	*(0.00001)*
Distance to Addis	NR	-0.0062**	-0.0007**
		(0.0018)	*(0.0003)*
Road condition	2.1960***	0.5766***	NR
	(0.2812)	*(0.1243)*	
Livestock owned	0.0502**	0.0084	0.0036*
	(0.0156)	*(0.0068)*	*(0.0020)*
Credit	0.0004	0.0012***	0.0002**
	(0.0004)	*(0.0002)*	*(0.0001)*
Log-likelihood	-305.08	-490.63	227.12
Wald	86.56***	144.52***	176.95***

Note: NR means not relevant; *, **, and *** indicates significance at 10%, 5% and 1% level, respectively.

Figures in parentheses are standard errors

6.5.3 Results of *tef* technology adoption analyses

In this section, parameter estimates on determinants of adoption and intensity of *tef* technologies are presented. This study considered the age of the farmer at the time of adoption[4] while other variables were measured at the time when the study was conducted.

Tef farmers were classified into adopters and non-adopters. Non-adopters are farmers who used none of the new improved *tef* varieties or fertilizer or herbicide while adopters are farmers who used at least one of the improved *tef* technologies between 1997 and 2001.

The parameter estimates of the Xtprobit and Xttobit models employed to examine factors influencing adoption and intensity of *tef* technologies are presented in Tables 6.3 and 6.4, respectively. Results of the analyses also revealed that the adoption and intensity of adoption of *tef* technologies are influenced by different factors and at different levels of significance for different factors.

Age of the farmer: The age of the farmer had different influences on adoption and intensity of *tef* technologies (Tables 6.3 and 6.4). The age of the farmer had positive effect on adoption and intensity of fertilizer and herbicide use on *tef*. However, the impact was significant on adoption and intensity of herbicide use on *tef*. It is important to note that these inputs were introduced earlier than improved varieties and hence farmers had more experience in using these inputs. Older farmers apply more fertilizer and herbicide to *tef* than younger farmers due to their better financial status given the wealth differential between the two groups. On the other hand, the age of the farmer had negative and significant influence on the likelihood and intensity of adopting improved *tef* seed. Younger farmers appear to be more eager to test new technologies than older farmers. A study by Techane *et al.* (2006) had similar non-significant relationships between the age of the household head and the adoption and intensity of fertilizer use.

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[4] Also experience, risk, livestock ownership and credit were measured at the time of adoption.

Farmer's education level: As would be expected, education had positive and significant effect on adoption of herbicide on *tef* (Table 6.3) as exposure to education increases farmer's ability to obtain, process and use information about improved technologies. On the other hand, education had negative and significant influence on intensity of herbicide use on *tef* (Table 6.4). This may suggest that factors other than education have stronger power in influencing intensity of herbicide use on *tef* as education among *tef* farmers was similar.

Family labour: As shown in Tables 6.3 and 6.4, family labour had positive influence on adoption and intensity of improved *tef* seed, adoption of fertilizer and herbicide on *tef* indicating the importance of large active family members in the adoption of improved technologies by supplying the required farm labour for different operations. Family labour had significant influence on intensity of improved seed adoption as *tef* is labour intensive crop. Family labour also had negative and significant effect on amount of herbicide applied on *tef*. The negative impact of family labour on intensity of herbicide use on *tef* indicates that herbicide is a substitute for weeding labour.

Farm size: Farm size negatively and significantly influenced amount of fertilizer use on *tef* (Table 6.4) indicating small farmers can increase their production by using more fertilizer. A study by Endrias *et al*. (2006) also found similar negative and significant influence of farm size on adoption of improved sweet potato varieties. On the other hand, farm size had positive and significant effect on intensity of herbicide use on *tef*. This may be due to the fact that large farm areas would require significantly higher labour efforts in weeding and hence herbicide is the cheaper option and also affordable for large farmers due to their better financial ability compared to small farmers.

Frequency of visit to DA office: As expected, frequency of visit to DA's office positively influenced the likelihood and intensity of adoption of improved *tef* seed and fertilizer and adoption of herbicide on *tef* although the results were not significant (Tables 6.3 and 6.4). The positive signs indicate that farmers who visited the DA office continued growing the improved varieties with fertilizer and allocated more area to improved varieties and applied more fertilizer and herbicide to increase their production. The negative sign on herbicide adoption is hard to explain. Studies by Kaliba *et al*. (1998) and Mafuru *et al.* (1999) indicated that extension contact was a significant factor affecting land allocated to improved maize varieties in Tanzania.

Farmer's knowledge in using improved technologies: As expected, farmer's knowledge gained in previous years had positive impact on adoption and intensity of improved *tef* technologies (Tables 6.3 and 6.4). However, knowledge gained had significant influence only on area allocated to improved varieties indicating that farmers who continued using the improved *tef* technologies over time have benefited from higher yield they provide than the local varieties. Most farmers did not like the improved varieties because of their colour and discontinued planting them a year after the demonstration.

Risk: Risk is an important explanatory variable in the adoption of improved technologies since yield loss due to the use of improved technology discourages farmers from adopting improved technologies. In this study risk is defined as yield variance. Risk had negative significant influence on the likelihood and intensity of adoption of improved *tef* seed (Tables 6.3 and 6.4) suggesting the new improved varieties are less riskier than local varieties. That could be one major reason why some farmers had continued using the new improved varieties as risky technologies discourage farmers not to use these technologies.

Livestock: Livestock ownership had positive influence only on the adoption of fertilizer on *tef* (Tables 6.3 and 6.4). On the other hand livestock ownership had unexpected negative effect on the likelihood and intensity of improved seed and herbicide adoption and amount of fertilizer applied on *tef.* As livestock provides the required draft power for different farm operations and cash for the purchase of improved inputs like fertilizer and herbicide, and *tef* needs fine seedbeds and adequate weed control, the result is strange and hard to explain. Livestock also supply manure, which is mostly used for fuel and some for garden crops around homestead.

Credit: As expected, availability of credit had positive and significant influence on adoption and intensity of improved *tef* technologies (Tables 6.3 and 6.4) as serious cash shortages faced by small farmers is a constraint to farmers ability to purchase and use improved inputs and affect optimal applications. A study by Techane *et al.* (2006) reported similar positive and significant influence of credit on the adoption and intensity of fertilizer use on cereals.

Table 6.3. Parameter estimates of the Xtprobit model for adoption of *tef* technologies in Northern and Western Shewa Zones, 1997-2001.

Variable name	**Estimated coefficients for**		
	Seed (n =234)	**Fertilizer (n = 234)**	**Herbicide (n = 234)**
Constant	1.1343**	1.4022	-1.3144*
	(0.4296)	*(0.8954)*	*(0.6767)*
Age of farmer	-0.0096*	0.0056	0.0222**
	(0.0059)	*(0.0133)*	*(0.0084)*
Farmer's education	-0.0882	-0.0749	0.5167**
	(0.1152)	*(0.2548)*	*(0.2122)*
Family labour	0.0173	0.0194	0.0183
	(0.0345)	*(0.0762)*	*(0.0447)*
Farm size	-0.0533	-0.1186	0.8656***
	(0.0570)	*(0.1627)*	*(0.1323)*
Frequency of DA visit	0.0147	0.0413	-0.0184
	(0.0640)	*(0.1067)*	*(0.0536)*
Knowledge gained	0.00015	0.00006	0.00012
	(0.00011)	*(0.0001)*	*(0.00009)*
Risk	-0.0570***	NR	NR
	(0.0098)		
Livestock owned	- 0.01208	0.0486	-0.0153
	(0.0187)	*(0.0491)*	*(0.0254)*
Credit	0.0037***	0.0085**	0.0028***
	(0.0006)	*(0.0031)*	*(0.0008)*
Log-likelihood	-521.87	-139.65	-325.52
Likelihood-ratio	439.12***	31.56***	631.30***
Wald	87.49***	10.89	85.86***

Note: NR means not relevant; *, **, and *** indicates significance at 10%, 5% and 1% level, respectively.

Figures in parentheses are standard errors

Table 6.4. Parameter estimates of the Xttobit analysis for intensity of *tef* technology adoption in Northern and Western Shewa Zones, 1997-2001

Variable name	**Estimated coefficients for**		
	Seed (n =234)	**Fertilizer (n = 234)**	**Herbicide (n = 234)**
Constant	0.2215	1.6944***	0.4256***
	(0.1488)	*(0.1653)*	*(0.0192)*
Age of farmer	-0.0039**	0.0010	0.0007**
	(0.0019)	*(0.0028)*	*(0.0003)*
Farmer's education	-0.0077	-0.0441	-0.0045***
	(0.0471)	*(0.0493)*	*(0.0062)*
Family labour	0.0129**	-0.0023	-0.0022*
	(0.0053)	*(0.0082)*	*(0.0013)*
Farm size	-0.0354	-0.1374***	0.0073
	(0.0263)	*(0.0261)*	*(0.0029)*
Frequency of DA visit	0.0015	0.0006	0.0048
	(0.0149)	*(0.0202)*	*(0.0026)*
Knowledge gained	0.00004**	0.00001	0.000003
	(0.00001)	*(0.00001)*	*(0. 000003)*
Risk	-0.0078***	NR	NR
	(0.0013)		
Livestock owned	-0.0038	-0.0022	-0.0035***
	(0.0063)	*(0.0057)*	*(0.0010)*
Credit	0.0005**	0.0009***	0.00004*
	(0.0001)	*(0.0001)*	*(0.00003)*
Log-likelihood	-6370.04	-812.56	540.96
Wald	57.58***	78.28***	35.14***

Note: NR means not relevant; *, **, and *** indicates significance at 10%, 5% and 1% level, respectively.

Figures in parentheses are standard errors

6.6 Summary of key empirical results

Comparison of the main features of *tef* and wheat farmers revealed that wheat farmers are slightly younger and more educated than *tef* farmers. The average family size was slightly higher among wheat farmers than *tef* farmers. But wheat farmers had significantly higher family labour than *tef* farmers. While average farm size is similar for wheat and *tef* farmers, *tef* farmers cultivated larger shares of their land to *tef* (60%) compared to the share of wheat farmers (30%). This suggests that *tef* farmers are more specialized in *tef* production while wheat farmers use more mixed cropping and diversify with barley and pulses due to higher risk associated with wheat production as improved wheat varieties grown in the area are introduction from outside and found susceptible to pests and diseases while *tef* varieties are local selections and hence better adapted. In terms of livestock ownership wheat and *tef* farmers were not different.

Wheat and *tef* farmers allocated 90% and 20% of wheat and *tef* area, respectively, to improved varieties from 1997 to 2001. More improved wheat varieties (6 including the old ones) are distributed to farmers compared to only three improved *tef* varieties. Besides, the zonal extension office supplied much higher quantities of improved wheat seed than *tef* based on farmer's demand in 1999 and 2000 crop seasons. This clearly is expected to lead to higher adoption of improved varieties by wheat farmers (86% of farmers) than *tef* farmers (42%) during the study. Similar levels of fertilizer and herbicide were used on *tef* and wheat.

Wheat farmers showed slightly higher demand for information about improved technologies than *tef* farmers as indicated by the number of visits they made to DA office in 2001. On the other hand, wheat farmers were closer to local markets while *tef* farmers were much closer to major markets such as Addis Ababa. Moreover, 60% of wheat farmers were located in districts where the capitals are connected to Addis Ababa by tarmac roads compared to *tef* farmers (36%). This suggests that proximity and access to information, input supply sources and markets are among the factors that contribute to higher adoption of improved technologies among wheat farmers.

Wheat was grown by 95% of farmers mainly for own consumption. Among those using local and improved varieties 35% and 49%, respectively, of the produce was sold. The opposite holds true for *tef* where 69% and 40% of grain produced from improved and local varieties, respectively, were sold. That means more local wheat seeds are consumed than local *tef* (96% versus 68% of produce). However, on aggregate equal amounts of wheat and *tef* (48% and 46%) were sold in the market. It means although wheat farming appears to be more market oriented in terms of input use, both *tef* and wheat farmers sell about half of their produce in the markets.

Five years after participating in the National Extension Package program, most wheat farmers (85%) continued adopting the new improved wheat varieties as compared to 35% of *tef* farmers. Better education and longer experience together with better access to and availability of seed helped continued replacement of varieties among wheat farmers.

An examination of the relationship between the adoption of wheat and *tef* technologies and selected explanatory variables over time revealed that adoption and intensity of wheat and *tef* technologies are influenced by different factors and at different level of significance for different factors.

The study showed that awareness, availability and profitability of the new technologies enhanced farmer's learning in the adoption of wheat and *tef* technologies as farmer's knowledge had positive influence on the likelihood and intensity of wheat and *tef* technologies. However, farmer's preference of the colour of *tef* varieties was critical to the adoption of new improved *tef* varieties. On the other hand, wheat and *tef* technologies were found scale neutral as small farmers can increase their production by using purchased inputs efficiently while large farmers can increase their production by using lower rates of fertilizer on larger fields and allocating more areas to improved varieties. Improved wheat and *tef* technologies were labour and draft power intensive, hence, large family labour and livestock ownership were found prerequisites for adoption of these technologies. Surprisingly, livestock ownership had negative insignificant impact on *tef* technologies that is hard to explain. The study further revealed that younger age, larger family labour and farm size, frequency of visit to DA office, better roads, livestock ownership and availability of credit are the key determinants in the likelihood and intensity of improved wheat seed adoption. Large family labour, closer distance to Addis Ababa, livestock ownership and availability of credit in the case of fertilizer and in the case of herbicide better education and small farm size are key factors as was better road on the likelihood and intensity of fertilizer adoption.

For *tef*, the study showed that younger age, large family labour, farmer's knowledg, less riskiness of the improved varieties and availability of credit are key determinants of the likelihood and intensity of improved seed adoption. For herbicide, old age, small family labour and large farm size are key determinants as was availability of credit and small farm size on the likelihood and intensity of fertilizer adoption.

This implies that timely availability of improved wheat and *tef* technologies and provision of credit enhances farmer's learning from their own experience on the adoption of wheat and *tef* technologies and increase food production. Inputs like fertilizer and herbicide are imported from outside and need to be imported and distributed to farmers in time to enhance adoption and increase production and productivity. Development of better roads facilitates the transportation of inputs to the farm and outputs to local and major markets in the promotion of improved wheat and *tef* technologies. Thus, policies and strategies that strengthen the roads would help enhance the use of improved inputs.

The study result indicated that younger farmers adopted improved wheat and *tef* technologies than older farmers suggesting that more attention should be given to younger farmer to enhance adoption of improved technologies and increase productivity. Education of the farmers was not significant in explaining adoption of improved seeds suggesting that policy makers should give more emphasis in expanding primary education and increasing the enrolment rates of their children in rural areas.

Extension did not prove to be important for adoption of wheat and *tef* technologies except for area allocation to improved wheat varieties, as it had no significant influence on the likelihood and intensity of adopting wheat and *tef* technologies. Thus, there is a need to upgrade DAs skills (pre-service and in-service training) to improve their services to accomplish the objectives of NEP, which give emphasis to raise smallholders' production and productivity. Appropriate policies are needed to improve the efficacy of extension for farmers to achieve increased agricultural productivity.

The fact that farm size has an impact on adoption of wheat and *tef* technologies, policy makers should give more emphasis in provision of credit to small farmers who account for most of the cultivated land and production in the country to increase food production. Livestock ownership was critical to the adoption of wheat technologies as crop and livestock productions are complementary. The negative impact of livestock ownership on *tef* technologies is hard to explain and should be investigated further. Policies and strategies to improve the livestock production system (draft power and nutrition) should be designed to achieve increased agricultural productivity.

Wheat and *tef* technologies are labour intensive suggesting that these technologies should not be introduced in areas where there is labour shortages. Thus, policies and strategies should consider availability of active labour force before introducing labour intensive technologies. Similarly wheat and *tef* technologies require more draft power than the traditional technologies, thus, due attention should be given before introduction of these technologies in to an area.

Riskiness of the improved *tef* seed did not stop farmers from using improved *tef* varieties due to significantly higher yield and net benefits obtained compared to the local varieties. This implies that farmers are willing to take some risk in the adoption of new technologies. Therefore, policies and strategies should assist farmers' effort by providing crop failure insurance.

CHAPTER 7

SUMMARY, CONCLUSIONS AND IMPLICATIONS OF THE STUDY

The objective of this study was to assess the role of knowledge gained in the process of adopting improved *tef* and wheat technologies in Ethiopia. As part of the agricultural development-led industrialization program, the Ethiopian government launched the new extension program (NEP) based on the experience of the Sasakawa Global 2000 project. The program took place at a time of major policy changes on marketing of outputs, pricing and subsidies on inputs that affect the agricultural sector. In spite of large number of farmers participating in the NEP and increased utilization of improved technologies, mainly improved varieties and fertilizers, yields of cereals remained low. There has been a growing concern by researchers, extension personnel and policy makers about the effectiveness of adoption of these technologies particularly on the area allocated to and amount of use of these technologies over time and farmers' learning from the NEP to enhance the food shortage problem in the country. Therefore, this study was initiated to identify factors that influence farmer's decision to continue to use new technologies or not after participating in the NEP and determine farmers' knowledge gained from adoption using panel data.

There are several studies on farmers' adoption of improved technologies using static models with cross-section data in developing countries including Ethiopia. Results of static models using cross-section data do not adequately explore the effects of explanatory variables due to failure to account for changes in farmer's perception and attitudes over time, as adoption is essentially a dynamic process. Nevertheless, only very few studies have dealt with learning as a dynamic adoption process and no study in Ethiopia has analysed knowledge gained in the adoption of improved technologies over time.

This study employed a knowledge model and panel data to analyze the effects of knowledge gained from learning as a dynamic process in the adoption of improved *tef* and wheat technologies. Panel data regression models (Xtprobit and Xttobit) were employed to study farmers' decisions to adopt and intensity of use of new technologies. Panel data are better suited to study dynamic changes and the random effect models control for unobserved variables and potential endogeniety. Household characteristics, socio-economic and institutional factors influencing farmers' adoption were analysed for the *tef* and wheat crops.

This study used panel data obtained from a survey of farmers who participated in the NEP from 1995 to 1996 in Northern and Western Shewa zones of Oromiya in Ethiopia. To better understand farmer' adoption decisions, one needs to particularly study farmers who have used the new technologies of *tef* and wheat over time. Northern and Western Shewa zones were selected to represent medium, and high potential production environments, respectively, for growing *tef* and wheat in Ethiopia. Out of the total number of participating farmers in the two zones for the two crops, separate samples of 165 wheat farmers and 234 farmers growing *tef* were selected proportionally and randomly from wheat-based and *tef*-based farming systems, respectively. Selected farmers were interviewed during the 2001 crop season. Data collection was accomplished in a single visit using structured questionnaires to solicit information from the same panel of farmers on their adoption practices to study the dynamics of farmer's knowledge from their own learning over the five years following the introduction of the improved practices in 1997.

Comparisons of the main features of *tef* and wheat farmers revealed that wheat farmers are slightly younger (42 versus 45 years), more educated (46% versus 29%) and have slightly higher family size (7.6 versus 7.0 persons) than *tef* farmers. Besides, wheat farmers had significantly higher family labour (3.6 versus 2.3 persons) than *tef* farmers. Thus, most wheat farmers adopted improved technologies due to their better capacity to understand and ability to provide additional required labour for improved technologies.

While average farm size is similar for wheat (2.78 h) and *tef* farmers (2.79 ha), *tef* farmers cultivated larger shares of their land to *tef* (60%) compared to the share of wheat farmers (30%). This suggests that *tef* farmers are more specialized in *tef* production while wheat farmers use more mixed cropping and diversify with barley and pulses due to higher risk associated with wheat production as improved wheat varieties grown in the area are introduction from outside and found susceptible to pests and diseases while *tef* varieties are local selections and hence better adapted. However, *tef* farmers allocated only 20% of *tef* area to improved varieties due to shortage of desirable varieties whereas wheat farmers allocated 90% of wheat area to improved varieties from 1997 to 2001. For instance, more improved wheat varieties (6) and higher quantities of improved seed (120.8 tons) were distributed to farmers compared to only three improved *tef* varieties and 10.8 tons of seed supplied by Zonal extension offices during 1999 and 2000 crop seasons. This clearly led to higher adoption of improved wheat varieties (86% versus 42%) during the study period.

Wheat and *tef* were mainly grown for own consumption. More local wheat seeds (96%) were consumed than local *tef* (68%). However, on aggregate equal amounts of wheat and *tef* (48% and 46%) were sold in the market. It means both wheat and *tef* farmers are not yet market oriented.

Wheat farmers showed a slightly higher demand for information about improved technologies than *tef* farmers as indicated by the number of visits they made to development agent (DA) office in 2001(2.0 versus 1.3, respectively). This was in spite of the fact that both need same time to reach the DA office (1.4 hrs and 1.3 hrs for wheat and *tef* farmers, respectively). On the other hand, wheat farmers were closer to major markets such as Addis Ababa and were located in districts where the capitals are connected to Addis Ababa by tarmac roads compared to *tef* farmers. This suggests that proximity and access to information, input supply sources and markets are among the factors that contribute to higher adoption of improved technologies among wheat farmers.

The results of this study provided empirical evidence of the positive impact of the effectiveness of NEP and farmer's learning in enhancing the adoption of improved *tef* and wheat technologies to increase production. The result showed that adopters of wheat and *tef* technologies have increased their production by 20% and 39%, respectively, than non-adopters. The results could help design appropriate strategies to enhance the adoption and intensity of improved agricultural technologies to meet the priority needs of smallholder farmers and to alleviate the food shortage problem in the country.

The study found access and availability of credit to be more powerful than other factors in explaining adoption and intensity of wheat and *tef* technologies. Availability of credit had positive and significant influence on the adoption and intensity of wheat and *tef* technologies. However, wheat and *tef* technologies (particularly fertilizer and herbicide) are usually rationed and farmers cannot buy what they want for their crops. For instance, on average farmers obtained 148 kg and 202 kg of fertilizers on credit from 1997 to 2001 in wheat-based and *tef*-based farming systems, respectively, while they need 180 kg and 326 kg of fertilizers based on crop area for wheat and *tef*, respectively. Further, the distribution of fertilizers between the two crops is not based on crop response even though there is less response of *tef* to fertilizers as compared to wheat. Usually fertilizers are delivered late and most of the fertilizers go to *tef* as its planting is delayed by one month compared to wheat. Therefore, in the short run timely availability of credit to purchase available inputs based on responses is required in order to promote the adoption of improved wheat and *tef* technologies and increase food production in the country. In the long run, farmers should be encouraged to purchase their inputs on cash if they can afford and be advised not to pay interest rates unnecessarily.

Family labour was powerful in explaining adoption and intensity of wheat and *tef* technologies suggesting that these technologies required additional labour for different operations and hence may not achieve high adoption in areas where there are labour shortages. Therefore, policies and strategies should consider availability of labour before introducing such labour intensive technologies.

Farmer’s knowledge gained from own learning had positive impact on continuing adoption and increased levels of wheat and *tef* technologies. However, the study revealed that most farmers discontinued growing improved *tef* varieties because of the undesirable colour (not as white as the local cultivars).

Risk was significant only on the likelihood and intensity of improved *tef* seed adoption because farmers who continued adoption were willing to take some risk due to significantly higher yield, lower yield variance and net benefits obtained. This implies farmers are willing to adopt less risky technologies. Therefore, policies and strategies should be designed to enhance farmers' capacity to take some risk in their effort to increase agricultural productivity.

The age of the farmer was significant on adoption of improved wheat seed and on the likelihood and intensity of improved *tef* seed and herbicide on tef. Younger farmers adopted more improved wheat and *tef* technologies than older farmers suggesting that more attention should be given to younger farmers to enhance adoption of improved technologies and increase productivity.

Farmers' education was significant only in the likelihood and intensity of use of herbicide on wheat and *tef* which suggests that use of herbicide need some care due to its hazard and computation in determining the rates. Policies and strategies should therefore place more emphasis on expanding primary education and increasing school enrolment rates of children in rural areas to achieve increased agricultural productivity in the future.

Farm size was critical in the adoption of improved wheat and *tef* technologies. In the case of wheat, farmers can increase their production by spraying lower rates of herbicide on larger wheat fields while *tef* farmers can increase their production by using herbicide and applying higher rates of fertilizer on smaller areas of *tef*. Although small farmers account for most of the cultivated land and production in the country, the fact that farm size has some positive influences on adoption of wheat and *tef* technologies implies that policy makers should give equal attention to large as well as small farmers in designing technological intervention for increased productivity and food production.

Except for area allocation to improved wheat seed, extension did not prove to be important for adoption of improved *tef* and wheat technologies. As extension is the main source of information for small farmers appropriate policies need to be designed to improve its efficacy for farmers to achieve increased agricultural productivity.

Distance to Addis Ababa was critical in the adoption of improved wheat technologies mainly fertilizers and herbicide as proximity to information, sources of input supply and markets save time and reduce transportation costs. Better roads are also essential for the likelihood and intensity of use of improved wheat seed and fertilizers as they improve timeliness of delivery of inputs and marketing of outputs and reduce transportation costs. Given the critical role of proximity to major markets (Addis Ababa) and better roads for promoting adoption and productivity gains, investment in improved road infrastructure is crucial. Thus, policies and strategies to expand the existing road infrastructure and build new ones based on production potential are highly recommendable.

Adoption was found profitable and provided acceptable rate of return on investment than non-adoption. This implies that as improved wheat and *tef* technologies are more profitable than traditional technologies farmers allocate more area to improved varieties and use more levels of fertilizers and herbicide to increase production. Policies and strategies should be redesigned to provide adequate support services (in technology development and distribution, provision of credit in kind and infrastructure development) to improve profitability (yield advantage) of new technologies.

Despite large number of farmers adopted the improved wheat varieties on 90% of the total wheat area, about 10% of wheat area are still planted to old improved varieties that are banned out of production by the Variety Release Committee due to their susceptibility to diseases. This practice could lead to complete crop failure and endanger the food security of the family and the country at large. Thus, the reasons why farmers continued growing these susceptible varieties should be investigated.

Results of the analyses suggest there is more research focus on wheat than on *tef* as indicated by number and quantity of improved wheat varieties distributed to farmers (six as compared to only three for *tef* and 121 tons versus 11 tons for *tef*). This clearly leads to higher adoption and intensity of use as indicated by percentage of farmers using (86% versus 35%) and area allocated to improved varieties (90% versus 20%). This implies that more research effort is needed to increase the supply of improved *tef* varieties that meet farmer’s demand in order to be adopted on the existing large *tef* areas and increase production.

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