RESOURCE ALLOCATION IN TRADITIONAL AGRICULTURE IN THE ETHIOPIAN HIGHLANDS: A CASE STUDY

BY
BERHANU WOLDEKIDAN
(BSc. Agri. Econ.)

In Partial Fulfilment Of The Requirements For The Award Of The Degree Of Master Of Agricultural Development Economics

May 1985
DECLARATION

Except where otherwise indicated
this thesis is my own work.

BERHANU WOLDEKIDAN

May 1985
DEDICATION

This thesis is dedicated to my brother, Eshetu and my wife, Alasebu.
ACKNOWLEDGEMENTS

I wish to acknowledge and thank for the financial support given to me by the Australian Development Assistance Bearau (ADAB) to do my studies. I am also thankful to comrade commissioner Dawit Woldegiorgis for his approval of my sponsorship on behalf of the Ethiopian government on his work visit to Australia.

In a very special way, I owe a debt of gratitude to my supervisor Dr Dan Etherington, a Fellow in the Masters of Agricultural Development Economics (M.A.D.E) programme, for the helpful suggestions, invaluable guidance and his time given to me generously from the beginning to the end of the thesis work. I am truly grateful not only for his intellectual contribution but also for his heartfelt concern about my personal problems. I am also grateful to Dr S. Chandra, who supervised me in the early stages of the study.

I owe my deepest gratitude to Mr. Rodney Cole, a person who becomes happy on others' happiness and looks at others' problem as his, for his unfailing efforts in assisting me to commence my studies and above all in obtaining an official scholarship. I am also sincerely grateful to Professor H. Hughes, the Director of the Development Studies Centre (D.S.C.) and to Dr D.P. Chaudhri, the Director of the Master's programme, for their strong support.

I am thankful to the other member staff, particularly to Dr D. Evans and Mr K. Sawer for contributing to my knowledge in quantitative analysis. My particular thanks go to Dr. R. Tyres who extended my knowledge of econometrics and gave useful comments on my thesis. I am also thankful to Mr S. Foley for going through drafts of this work to improve my expression.

At home in Ethiopia, special thanks are due to all the farmers who patiently participated in the study and fully co-operated in undergoing monotonous interviews. Without their co-operation this study would have been impossible. Thanks are also due to the enumerators Alemu Gemeda,
Kebede Ayidefer, Isayas Alemayehu and Aesff Trro, who, despite the minimum administrative support given to the unit, put a great deal of effort on collecting reliable data.

I would like to express my appreciation of the moral support provided by my mother, relatives and friends specially, Eyayu Lulseged, Tadesse Mergia, Alemayehu Demissie, Fekadu Kidane, Kibrete Seifu, Yeshi Temesgen and Tsegaye Chernet.

I should like to express my sincere appreciation and inadequate "thank you" to my brother Eshetu Woldekidan, whose encouragement, support and personal sacrifices allowed me to further my studies.

I owe much to my wife Alasebu, who contributed substantially to my thinking through the issues raised by the sub-thesis. Special thanks to her for the unforgettable efforts she made to bring me to Australia and encourage me in both course-work and thesis-work.

Last, but not least, I extend my apologies to my son Michael and daughter Belen whom I left back home, for not giving them my paternal care which they deserve.

Though many people have contributed to this sub-thesis the errors and omissions remain mine.
ABSTRACT

This study examines the technical efficiency of the semi-subsistence farmers of Ethiopian highlands at Basona-Warana sub-district. It also looks at their allocative efficiency in the way that they equate marginal value products of inputs with the respective prices "on the average" in allocating the resources at their disposal.

Prior to examining the technical and allocative efficiencies, an overview of the study area is presented. This is followed by a theoretical and empirical literature review on technical and allocative efficiency with particular reference to less developed countries.

The study applies a complex, carefully specified, modified transcendental production function of log-semi-log (L-S-L) form to the time-series cross-sectional data to estimate the input-output relationship of the three major crops grown in the area.

The results obtained from this study do not provide evidence of inefficient allocation of resources, on the average. Accordingly, output can hardly be raised by reallocating the existing resources. The measure of technical efficiency indicates that only small proportion of the farmers are significantly different from the average farm. However, the magnitude of the technical efficiency differential between the best performing, the average and poorly performing farmer(s) is quite substantial. Hence there is some scope to raise production by improving the technical efficiency of the average and weak farmers.

To this end both the included observable explanatory variables as well as some excluded factors which are significantly related to technical efficiency were identified. The results obtained suggest that a significant relationship exists between technical efficiency and the included variables of land under wheat and horsebeans, the relationship being negative with the former and positive with the latter. Similar tests with excluded factors of farm asset holdings and number of plots
revealed that farm assets are significantly related to technical efficiency in barley and horsebeans and that number of plots under barley has a negative impact on technical efficiency in barley production. Similar technical efficiency rankings of the farmers were observed in the three different crops. There was also a marked shift in productivity between the two years analysed.
# TABLE OF CONTENTS

Declaration ii  
Acknowledgements iii  
Abstract v  

1. INTRODUCTION 1  
   1.1 Land use 1  
   1.2 Climate 2  
      1.2.1 Climate zones 2  
      1.2.2 Rainfall 2  
   1.3 Population 3  
   1.4 The Economy 3  
      1.4.1 The Agricultural sector 4  
   1.5 The study 6  
      1.5.1 The study area 6  
      1.5.2 Sample population and selection of sample farmers 8  
      1.5.3 Data collection and methodology 9  
   1.6 Justification and objectives of the study 9  
      1.6.1 Justification for the study 9  
      1.6.2 Objectives 10  
      1.6.3 Hypotheses 11  
   1.7 Outline of the thesis 11  

2. The Study Area 13  
   2.1 Resource Availability, Use and Productivity 13  
      2.1.1 Land 13  
      2.1.2 Labour 16  
      2.1.3 Capital 20  
   2.2 Crop production 21  
      2.2.1 Cropping patterns 22  
      2.2.2 Crop yield and use 22  
   2.3 Livestock husbandry 24  
      2.3.1 Livestock holdings and uses 24  
   2.4 Institutions and rural services 25  

3. LITERATURE REVIEW 27  

4. ANALYTICAL FRAMEWORK 40  
   4.1 Choice and manipulation of variables 40  
   4.2 Model selection 42  
   4.3 Statistical estimation problems 50  
      4.3.1 Simultaneous equation bias 50
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3.2 Multicollinearity</td>
<td>52</td>
</tr>
<tr>
<td>4.3.3 Management bias</td>
<td>52</td>
</tr>
<tr>
<td>5. EMPIRICAL RESULTS AND DISCUSSION</td>
<td>54</td>
</tr>
<tr>
<td>5.1 Estimates of the production function parameters</td>
<td>54</td>
</tr>
<tr>
<td>5.1.1 Coefficients of production</td>
<td>55</td>
</tr>
<tr>
<td>5.1.2 Elasticities of production</td>
<td>60</td>
</tr>
<tr>
<td>5.1.3 Marginal productivities and their standard errors</td>
<td>62</td>
</tr>
<tr>
<td>5.2 Allocative efficiency</td>
<td>64</td>
</tr>
<tr>
<td>5.3 Technical efficiency</td>
<td>67</td>
</tr>
<tr>
<td>5.3.1 The relationship of technical efficiency and use of inputs</td>
<td>71</td>
</tr>
<tr>
<td>5.3.2 The relationship of technical efficiency and other unaccounted factors in the production function</td>
<td>72</td>
</tr>
<tr>
<td>5.3.3 Spearman's rank correlation test for management ranking among crops</td>
<td>74</td>
</tr>
<tr>
<td>6. SUMMARY, CONCLUSION, POLICY IMPLICATION AND RECOMMENDATION</td>
<td>77</td>
</tr>
<tr>
<td>6.1 Summary and Conclusion</td>
<td>77</td>
</tr>
<tr>
<td>6.2 Policy implications and recommendations</td>
<td>81</td>
</tr>
<tr>
<td>Appendix A. Ethiopian Highlands and the Study Area</td>
<td>90</td>
</tr>
<tr>
<td>Appendix B. Estimates of area and production of major crops for the 1981/1982 main cropping season</td>
<td>91</td>
</tr>
<tr>
<td>Appendix C. Distribution of the Sample Farmers Within the Four Peasant Associations</td>
<td>92</td>
</tr>
<tr>
<td>Appendix D. Soil Burning</td>
<td>93</td>
</tr>
<tr>
<td>Appendix E. Fertiliser usage in Basona-Warana district 1971 to 1980</td>
<td>97</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>83</td>
</tr>
<tr>
<td>GLOSSARY</td>
<td>88</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 1-1: The Study Area And Agricultural Region of Ethiopia 7
Figure 2-1: Cropping calendar with corresponding rainfall and temperature for each crop 18
Figure 2-2: Seasonal distribution of labour in crop production 19
Figure 3-1: Farrell's efficiency measure 29
Figure 3-2: A general Production Function 35
Figure 4-1: Scattergrams of residuals and the independent variables of barley 51
Figure 4-2: Management Bias 53
Figure 5-1: The distribution of technical efficiency among farmers 69
LIST OF TABLES

Table 1-1: Population and sample farmers distribution in the Four peasant associations 8
Table 2-1: Total labour use by activities and crops, 1980 17
Table 2-2: Labour productivity per hour for major crops 20
Table 2-3: Cropping pattern of 42 sample farmers 22
Table 2-4: Crop yield of the National, Administrative Region and sample farmers for the period 1979-1982 (kg per ha.) 23
Table 4-1: Summary of Model Specification 43
Table 4-2: Test of significance in differences of the 1980 and 1981 observations 46
Table 4-3: Test of significance in technical efficiency 48
Table 5-1: Estimates of production coefficient excluding farm dummies 55
Table 5-2: Estimates of production coefficients with farm dummies 57
Table 5-3: Sample means, standard deviations and correlation matrix 58
Table 5-4: Elasticities of production 61
Table 5-5: Sum of elasticities, variance and covariance along with computed and critical t-values 62
Table 5-6: Marginal value product, prices of inputs and t-values 64
Table 5-7: Estimates of production coefficients along with farm dummy variables 68
Table 5-8: Comparison of technical efficiency (farm intercepts 70
Table 5-9: The relationship of management with variables included in the production function 71
Table 5-10: The relationship of management with variables excluded from the production function 73
Table 5-11: The relationship between the technical efficiency rankings of the three crops 75
Table D-1: Cost-benefit analysis of barley production on GYE plot 94
Table D-2: Cost-benefit analysis of barley production using fertiliser 95
CHAPTER 1

INTRODUCTION

It is evident that efficient use of resources is the central problem of agricultural economics. Nevertheless, its application to less developed countries is not only recent but also has very little coverage. The lack of such work is more severe in the least developed countries such as Ethiopia whose need for such research is possibly greatest. In Ethiopia, there is no work dealing with the problem of efficiency known to the author, not only in the field of agriculture but also in the other sectors. Given this fact this study may throw some light on the area of allocative and technical efficiency in agricultural production of semi-subsistence farmers in the country. Before coming to the core issue of the study, however, background information on the country and the study area, as well as some introductory facts are worth noting.

1.1 Land use

Ethiopia is located in Northeastern part of Africa with a total area of 1.22 million sq. km. A little more than half (53.7 per cent) of the total area of the country is rough and dry permanent pasture land. Of the remaining land 8.5 per cent is cultivated crop land, 18.3 per cent is barren land and built-up areas 9.9 per cent is water courses and 9.6 per cent forest (African Encyclopedia, 1982, p. 370).
1.2 Climate

1.2.1 Climate zones

Ethiopia is characterized by a wide range of climatological and ecological diversity with arid, semi-arid, sub-humid, dry and equatorial highlands. This diversity gives rise to the three distinct local climatological zones: "DEGA", "WINADEGA" and "KOLA". DEGA (cool zone), with an average annual temperature of 16°C covers the central, western and eastern highlands plateau of over 2400 m. (7874 ft.). That part of the highlands between 1500-2400 m. (4921-7874 ft.) is categorized as the WINADEGA, or temperate zone, and has an average annual temperature of 16'-29°C. It is estimated that over 70 per cent of the human and livestock population of the country are concentrated within these two climatological zones. These highland regions cover about 50 per cent of the country's total area (see Appendix A) and account for about 50 per cent of all the highlands on the continent of Africa.

The third climatological zone, KOLA, is considered the hot zone, with an average annual temperature lies between 27' and 50°C (The American University, 1981). It encompasses the area below 1500 m. (4921 ft.), and is characterised by a predominantly pastoral economy (Lipsky, 1962).

1.2.2 Rainfall

There are two distinct seasons in the year: "KEREMT" (rainy or wet season) which lasts for three months from mid-June to September; and "BEGA" (dry season) lasting for the remaining part of the year. The dry season is some times interrupted by irregular and unreliable short rains known as BELG which may occur between February and May.

The annual average rainfall varies for the different parts of the country from 30 to 1930 mm. depending mainly on the altitude (Central Statistics Office, 1976). It is the low rainfall areas that are most affected by desertification. Desertification, an ecological degradation caused by overuse of land and climatological deterioration has been the major factor in the occasional droughts occurring in the country, and which in turn has influenced the social, economical and political environment. As noted in Ethiopian Atlas (1981) the country's drought
has a cyclical trend, re-occurring every seven or eight years, and extending over 2 or 3 years.

1.3 Population

Ethiopia is inhabited by about 42.2 million people with a population growth rate of 2.9 per cent per annum (Office of the Population and Housing Census Commission, 1984). The population of the country, as in most less developed countries, is young; only 52 per cent of the total population are considered economically active (between 15-59 years of age). The urbanization growth rate is very high (7 per cent) mainly due to high rural-urban migration (The Ethiopian Tourism commission, 1981).

Despite the fact that the country had its own script for many centuries the overwhelming majority of the Ethiopian people (93 per cent in 1974) were illiterate. The 1974 revolution that abolished the monarchy not only put the land, including that owned by the Orthodox Christian church accounting for one third of the total land, in the hands of the people but also reduced illiteracy rate to 37 per cent in 1984 (The propaganda and cultural committee of COPWE, 1984). Ethiopia is the land of ethnic diversity where seventy languages and over 200 dialects are spoken. Because of its ethnic diversity Ethiopia has been called "an ethnic museum" (Africa Insight, 1984 p. 292). Despite their diversity in origin, history, physical appearance, dress and custom they are administered under a central government.

1.4 The Economy

Agriculture is the dominant sector from which 88 per cent of the total population gain their livelihood. It also provides direct employment for 80 per cent of the population. Furthermore, it contributes 46 per cent to the GDP and 90 per cent to the foreign export earnings of the country (CSO, 1980).

During the last two decades the share of agriculture in GDP and labour employment have declined by 19 and 8 per cent respectively. The decline in the share of agriculture has been compensated for primarily by an expansion of the service sector which grew by 14.5 per cent between 1960 and 1980 (World Bank, 1982).
During the same period the industrial sector has also undergone a small expansion of 4.5 per cent (World Bank, 1982). This indicates a slow rate of economic development. The per capita income of the country is one of the lowest in the World, estimated at about Birr 248 (US $120) per annum with an annual growth rate of 5.2 per cent (Gale Research Company, 1983 p.474).

Since 1974 the Ethiopian economy has been committed to a centralized, planned economy based on a socialist framework.

1.4.1 The Agricultural sector

Of the total land area of 1.22 million sq.km. about 68 per cent is considered as suitable for agriculture. The high degree of variation in climate, topography and soil allows the cultivation of a variety of tropical and temperate crops in different parts of the country. Accordingly a great variety of cereals, pulses, oilseed, fruits, "ENSET" and stimulants are grown (see Appendix B). The most widely used domestic food crops are "TEFF", barley, wheat, sorghum, maize, millet, and ENSET\(^1\). Coffee is the most important cash crop and constitutes about 60 per cent of foreign earnings and 8 per cent of GDP. It is followed by hides and skins, pulses and oilseeds in order of importance.

The dominant system of agricultural production is smallholder mixed farming (see Figure 1.1), mainly devoted to subsistence production. In 1982, of the estimated 5.4 million hectares of cultivated land, 93 per cent was cultivated by individual smallholders who produced 92 per cent of overall production. The remaining 8 per cent was produced by state farms and co-operatives with shares of 6.8 per cent and 1.2 per cent respectively (computed from Central Planning Office Crop Survey Report, 1982).

Given the predominant mixed farming system and sizable proportion of pastoral economy (see Figure 1.1), animal husbandry is of equal importance to crop cultivation. Consequently the country has quite a substantial number of livestock, ranking first in Africa and tenth in the World in the size of her livestock population (Mukasa, 1981). In

\(^1\)The meaning of local words are given in the glossary (p.88)
1978, the estimated livestock population was: 27.5 million cattle, 23.15 million sheep, 15.17 million goats, 1.52 million horses, 3.87 million donkeys, 1.44 million mules and 1 million camels (Third World Encyclopedia, 1982). However, economic benefits from these livestock are not as great as its size might indicate and livestock contributed only 13 per cent of the total exports and 25 per cent of the GDP in 1974 (Mukasa, 1981). Livestock are raised not only for their economic value and transportation but also for social prestige.

Despite the fact that Ethiopia has a high potential for agricultural production, and agriculture plays a major role in the economy, the productivity of agriculture remains very low. The main causes of low agricultural productivity are: absence of improved technology and the lack of efficient communication systems (about 75 per cent of the population live about a half day walk from an all-weather road). These problems are compounded by other, equally important, problems such as inadequate marketing and extension services, and the near total absence of formal credit facilities. Though many of these institutions are lacking an institution known as the Peasant Association has been recently established in the rural areas of the country among other things to provide some of these facilities.

The 1975 land reform not only made land a collective property of the Ethiopian people: not to be sold, leased, transferred or mortgaged under any circumstances, but also initiated the formation of peasant organizations in rural areas. These organizations were established throughout the rural areas of the country with the strong support of the government. It has a hierarchical structure extending from the grass-roots in the village i.e "KEBELE" level to the national level. At the lowest level a Peasant Association covers approximately 800 hectares and has a membership of about 250 households. At the national level all peasant associations come under one umbrella organization, known as the All Ethiopian Peasant Association (AEPA). In 1984 there were 20,183 peasant associations consisting of over five million households registered under the AEPA (The Propaganda and Cultural Committee of COPWE, 1984).

The peasant association is a multi-purpose organization having
social, economic, cultural, administrative and political goals. It has a wide range of functions and responsibilities that include: distribution of land among members according to family size, human-land area ratio and soil fertility (where the need arises); administration and conservation of public property; establishment of service, producer and credit co-operatives; and undertaking "villagisation"² programmes (Desalegn, 1982). Moreover, through its judicial tribunals, the peasant association handles disputes of all kinds, particularly land and family disputes. Having outlined the general background of the country it is worth mentioning a few points regarding the specific study.

The data used in this study were collected between 1979 and 1982 under the auspices of International Livestock Centre For Africa (ILCA) with the close supervision of the author. However, the complete data set was not available for this thesis. Some consequences of this are pointed out in the study.

1.5 The study

1.5.1 The study area

The study area, Basona-Warana sub-district is situated in the central highland plateau of Shoa administrative region (province), Teguletna-Bulga district. The topography of the study area are rolling hills with gentle slope (about 18'), or plateau upland with broad valley bottom land at an elevation of 2800 mt. (9186 ft.). It covers an area of 109,880 hectares with a population of 101,338 and 20,826 households. These households are organized into 100 peasant associations (District MOA, 1982) which are the basis of the sample survey in this study.

²undertaking construction works that include road work, assembly halls, reafforestation, terracing etc.
Figure 1-1: The Study Area And Agricultural Region of Ethiopia

1.5.2 Sample population and selection of sample farmers

Among the 100 peasant associations of the sub-district four of them were chosen because of their closer (within a radius of 10 km.) vicinity to the ILCA research station located at Debre Berhane (see Appendix C) and for logistical reasons. Table 1.1 shows the population distribution and the distribution of sample farmers in the four peasant associations chosen.

Table 1-1: Population and sample farmers distribution in the Four peasant associations

<table>
<thead>
<tr>
<th>Peasant Association</th>
<th>Karafino</th>
<th>Kormargfia</th>
<th>Milki</th>
<th>Fäji and Bkafia</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of farms</td>
<td>132</td>
<td>250</td>
<td>210</td>
<td>273</td>
<td>865</td>
</tr>
<tr>
<td>No of sample chosen</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>No of sample participated</td>
<td>12</td>
<td>11</td>
<td>9</td>
<td>10</td>
<td>42</td>
</tr>
<tr>
<td>Area (ha.)</td>
<td>640</td>
<td>680</td>
<td>720</td>
<td>800</td>
<td>2840</td>
</tr>
<tr>
<td>Total Pop.</td>
<td>601</td>
<td>834</td>
<td>1005</td>
<td>965</td>
<td>3405</td>
</tr>
<tr>
<td>Male Pop.</td>
<td>353</td>
<td>404</td>
<td>550</td>
<td>510</td>
<td>1817</td>
</tr>
<tr>
<td>Female Pop.</td>
<td>248</td>
<td>430</td>
<td>455</td>
<td>455</td>
<td>1588</td>
</tr>
</tbody>
</table>

An equal number of sample farmers were selected randomly from each of the four peasant associations making up about 7 per cent (60 sample farmers) of the total farms (865). The number of the sample farmers is finally reduced to 42, mainly for logistic reasons (distance from the station). Farmers who are registered and have the legal status of membership in the peasant association, regardless of sex, age and wealth of the person were selected rather than households.
1.5.3 Data collection and methodology

The data was collected by four enumerators, under the supervision of the author, who lived in the district and who had high school qualifications. Strict precautions were taken not to interfere in the farmers' decision making, to avoid giving any advisory input while collecting the information. Moreover, the data were collected with attention given to obtaining the highest possible precision.

Relevant farm management information were collected from each sample farm at least once a week over the four years, 1979-1982, with the same farmers continuing in the sample (except in few cases). However, only two years data of 1980 and 1981 that are available are used for the main analysis chapter (Chapter 5). Information on measurable inputs like seed, land and fertilizer and output were measured by the enumerators themselves. Furthermore, supportive information was obtained through formal and/or informal discussions held between the author and heads of peasant associations, elder farmers, religious leaders and government officials.

The study uses a production function approach in examining the efficiency of the farmers. The mathematical form of the production function applied is log-semi-log (L-S-L) which allows for essential and nonessential inputs unlike the conventional Cobb-Douglas function. The method of estimation follows ordinary least squares (OLS) as found in the Statistical Packages for Social Sciences (SPSS).

1.6 Justification and objectives of the study

1.6.1 Justification for the study

In 1977 World food survey, FAO (Green and Kirkpatrikck, 1981) estimates that about 38 per cent of the population of Ethiopia has a calory intake below the generally accepted level (1.2 BMR). Given this fact and that agriculture is the mainstay of the vast majority of the population, increased food production not only alleviates the food problem but also improves the living standard of the population (the farmers).

Thorough knowledge of production relationships, marketing and price opportunities of semi-subsistence farmers is vital for increasing production in inexpensive ways. But little is known about the
production relationships not only by the farmers and extension workers, but also by policy makers. Particularly with a price control policy such as is practised in Ethiopia, studies aimed at investigating the responsiveness of farmers to incentives and prices can be of significant importance in formulating policies for semi-subsistence farmers. This study aims to identify the production relationships for the important crops grown in the study area; estimate optimal rates of inputs and outputs that may be used to guide resource reallocations in the future; and examine the economic rationality of farmers. The coefficients and elasticities obtained from the production analysis can assist policy makers in their incentive planning and particularly for further studies of production functions. Besides, extension workers and farmers can use the information for reorganising inputs in order to raise production. However, as the coverage of this study is very limited a number of similar studies in different parts of the country, are required to provide a base for nation wide policy formulation.

The study gives particular emphasis to the extent of the technical efficiency differential that exists between the sample farmers. If there is a significant variation in technical efficiency among farmers, it may be possible to use this information to formulate appropriate education and extension policies. The following objectives will be pursued.

1.6.2 Objectives

Assuming there exists a systematic relationship between output and inputs, and hence that a production function is identifiable, the objectives are:

1. To determine the range of technical efficiencies among farmers.

2. To examine the allocative efficiency of farmers in crop production by investigating the way that they respond to price incentives.

These objectives are met by testing the following hypotheses.
1.6.3 Hypotheses

1. There exist significant differences in technical efficiency among farmers.

2. Given their limited resources the semi-subsistence farmers respond "rationally" to price incentives and allocate their resources accordingly.

Allocative efficiency is given lower priority than technical efficiency in this study because the farmers produce primarily for subsistence. As discussed in the next chapter, they rarely buy or sell the food crops that form the core of the study.

1.7 Outline of the thesis

The following chapter presents relevant information about the study area. It examines resource availability, use and productivity, with particular emphasis on land and labour. This is followed by an overview of crop production methods with emphasis on types of crop grown and the techniques of production used. The chapter gives detailed information on cropping patterns used by the sample farmers, their crop yields and crop use.

The chapter also provides a brief description of livestock husbandry in the study area with emphasis on livestock holdings and uses. Lastly, some insight is given into rural institutions and services. In this regard a brief discussion on traditional economic and social services is presented as well as the limitations of modern rural services such as marketing, credit and extension.

Chapter Three is a review of theoretical and empirical literature on allocative and technical efficiency. The chapter begins with a review of measures of technical and allocative efficiencies and examines different views on the relative advantages of average and frontier production functions. This is followed by a brief review of the alternative functional forms to be used in the analysis. A review of empirical studies of allocative efficiency (in particular) and technical efficiency is presented at the end of the chapter.

The analytical framework of the study is covered in Chapter Four. It includes a brief description of the variables chosen for the analysis and explains how they are manipulated. This is followed by an
analytical preview of the model selected. The chapter ends by examining the statistical estimation problems of simultaneous equation bias, multicollinearity and management bias that can be encountered in using ordinary least squares (OLS) as an estimation method.

Chapter Five presents the results of the study. It investigates whether there are significant difference in the technical efficiency (management) among the semi-subsistence farmers studied. It also examines the allocative efficiency of the farmers. Chapter Six is a summary and some concluding remarks as well as some policy recommendations are made.
CHAPTER 2
THE STUDY AREA

In the study area, as in most parts of the country, the prevalent farming system is smallholder subsistence farming, with a high degree of complementarity and interaction between crop and livestock production. This complementarity can be explained firstly by the provision of draft-power and transport by livestock, and secondly by the use of crop residues as supplementary feed for farm animals. Hence, the integration of livestock and arable crops has an important role in raising the efficiency of the resources that are available to farmers and thus supplementing overall farm productivity. Despite this, the productivity of the farming system remains at a low level, for reasons that will be outlined later in this Chapter.

2.1 Resource Availability, Use and Productivity

The three conventional factors of agricultural production, land, labour and capital are the main resource bases for both subsistence and commercial farmers (with different degrees of use and productivity). The availability, use and productivity of these resources in the study area of Debre Berhan are now discussed.

2.1.1 Land

The density of population of the four peasant associations from which the sample farmers were chosen is 92 people per square kilometer. The average land holding of the sample farmers is 4.4 hectares, ranging from 0.50 to 7.0 hectares, including the permanent communal pasture land share of 0.83 hectares each. As mentioned in Chapter 1 the size of holding is directly related to the number of people in the family and the size of land/man ratio in the peasant association to which the farm belongs. Fifty eight per cent of the farmers own from 4 to 6 hectares which exactly corresponds to the mode of the family size. The distribution is skewed to the left.
Land is relatively scarce in the study area when compared to the National Land Proclamation which sets a holding size of 10 hectares per farm. Land scarcity in the area is made more acute by its poor quality, with a substantial proportion of marginal land. However, this is not unique to the study area and is a common characteristic of the central and northern parts of the country where the majority of the population have settled. Land holding in this region are highly fragmented, with an average number of cultivated plots per farm of 10 and 9 for the main cropping seasons of 1980 and 1981 respectively. The distances between the plots and the homestead are considerable (up to 3 km.) and about 35 percent of the plots usually lie outside the radius of 500 metres from the homesteads.

The pattern of land use did not change significantly during the four year survey period of 1979-1982. Land use categories of cultivated, fallow, permanent pasture, waste land and homestead were 60, 28, 6, 5 and 1 per cent respectively. Over one-quarter (28 per cent) of the land is kept fallow every year due to poor land quality, not suitable for continuous cultivation.

Productivity of land is primarily determined by the topography. The typical physical features of the land are rolling hills, which have plateaued up-lands, followed by gentle slopes and broad valley bottoms with an elevation of 2800 mt.(9186 ft). The quality of the land declines as one goes down the hills due to soils of low permeability, poor internal drainage and high exposure to natural hazards such as frosts and hailstorms. Farmers in the area divide their land into three categories based on its productivity and natural setting. Locally these are known as "AREDA LEM", "AREDA TEF" and "YEMEDA" land in descending order of their productivity and intensity of use.

AREDA LEM, the most productive land, is situated on the gently sloped or plateaux hill tops and cropped with wheat and horsebeans. It is also occasionally sown with small crop of barley, especially "TEMENGE". Fallowing is uncommon in this area. Commonly the homestead is located here and due to its proximity to the homestead usually more attention is given to crops grown on this type of land. Unlike other types of land, though small in size, it receives farmyard manure and ash. Besides, critical farm activities such as seed-bed preparation,
Seeding and harvesting are carried out on a more timely basis on crops grown on AREDA LEM than is practised on the other land types. This type of land use occupies 24.7 per cent of the cultivated land.

The next more productive and intensively used land, AREDA TEF, is situated on the slopes of the hills. Since the upper part of this type of land has certain characteristics of AREDA LEM and the lower part that of YEMEDA all types of crops are grown in this area. It contains the smallest proportion of cultivated area, 17.7 per cent in 1981. Unlike AREDA LEM a small proportion of AREDA TEF is left fallow for short periods.

The least intensively used and least productive cropped land, YEMEDA, is seasonally waterlogged or flooded and is most exposed to frost. It accounts for 57.6 percent of the total cultivated area in one cropping season. Because of its poor quality farmers are forced to leave substantial parts of it fallow for long periods of time, ranging from 8 to 20 years with an average period of 13 years. Before it is returned to cultivation, the soil of YEMEDA land undergoes "GYE" (soil burning) practice to temporarily raise its productivity.

Soil burning improves soil structure and releases essential nutrients and raises the crop yield to almost three times that of unburnt soil of the same type. However, yield decreases drastically for the following crop season, and eventually falls to a point where it becomes not worth cultivating. A separate study on this subject shows that the economic return by the third year is nearly nil (see Appendix D). Barley is the most common crop grown on this type of land, as it matures earlier, before the onset of frost, and is relatively more frost tolerant than the other crop options. YEMEDA land is more suitable for crop growing during the short rainy season (BELG) when water logging is not severe and the risk of frost damage is minimal. However, BELG rains are irregular and unreliable. Hence, BELG production remains minimal, accounting for only about 10 per cent of the bottom land and also being cropped only once every two or three years.

The average productivity, without fertilizer application or soil burning, of AREDA LEM, AREDA TEF and YEMEDA land for cereals are estimated to be 10, 8 and 6\(^1\) quintals per hectare respectively.

\(^1\)6 refers only to barley that grows on the YEMEDA land.
2.1.2 Labour

Labour plays a very important role in the production process of any smallholder semi-subsistence farming system, and this is also true of the study area. Unlike land and capital which are fixed in the short run, labour is variable and could at least in theory be readily allocated among different uses in order to raise the efficiency of production.

Labour comes almost exclusively from the family and accounts for 80 per cent of the total labour inputs, the remaining 20 per cent comes from hired and exchange labour for the crop production. Family size, sex and age of family members have an important bearing on the crop enterprise. Average family size is 4.8 persons (48 per cent male). As explained in the introductory chapter the population is young with a typical triangular pyramid shape with only 49 per cent of the total population of the sample households are economically active people between the age of 15 and 65 years.

In 1980 average labour input per hectare is 400 hours. Of this total 82, 10, and 8 per cent comes from adult male, adult female and child labour respectively. Accordingly, about 886 hours of total labour is expended to cultivate the 2.2 hectares of main season cropped land per farm. Table 2.1 shows labour use on the different crops grown in the area and amount spent for each activity per hectare.

It can be seen from table 2.1 that the highest proportion of labour is spent on harvesting (37 per cent). This may be due to the use of a less efficient harvesting tool, sickles, rather than high crop yield. It is also evident from Table 2.1 that the least amount of labour hours are expended on weeding, except in the case of wheat and horsebeans (19 per cent) of each crop labour input) that are grown on the relatively well drained soil of AREDA LEM. Five hundred eighty labour hours (66 per cent) are spent on the production of the staple food barley (cereal) followed by horse beans (pulse), these two crops account for 82 per cent of the total labour input for average farms.

---

2At the rate of Birr 2.0 (US $1.07) /day including optional lunch and some drinks.
3A type of arrangement among farmers to work on individual farms in turn as a group. Usually food and drinks are provided by the host.
Table 2-1: Total labour use by activities and crops, 1980

<table>
<thead>
<tr>
<th>Crop</th>
<th>Labour input per ha. by activity</th>
<th>Total</th>
<th>Proportion per Ha. labour use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Barlev</td>
<td>119(30)</td>
<td>47(12)</td>
<td>12(3)</td>
</tr>
<tr>
<td>Wheat</td>
<td>91(19)</td>
<td>59(12)</td>
<td>94(19)</td>
</tr>
<tr>
<td>H.beans</td>
<td>83(19)</td>
<td>59(13)</td>
<td>86(19)</td>
</tr>
<tr>
<td>F.peas</td>
<td>53(18)</td>
<td>50(17)</td>
<td>20(6)</td>
</tr>
<tr>
<td>Lentils</td>
<td>93(23)</td>
<td>69(16)</td>
<td>6(1)</td>
</tr>
<tr>
<td>Linseed</td>
<td>51(19)</td>
<td>45(17)</td>
<td>7(3)</td>
</tr>
</tbody>
</table>

Total 490 329 225 868 408 2320 2.2 886

Per cent 21 14 10 37 18 100

Computed from primary data collected by the author in 1980.

Note: 1) Labour input is computed by simple aggregation without weighting of adult female and child labour.
2) Figures in brackets are per cent of total labour hours for the corresponding crop.
3) 1, 2, 3, 4, 5, denote to ploughing, seeding, weeding, harvesting and threshing activities respectively.

The largest proportion of labour input is used for the larger area planted with barley (1.45 ha.), rather than its labour requirement per hectare which is lower (400 Hr.) than wheat (482 hr.), horsebeans (445 hr.) and lentils (421 hr.).

It is obvious that agricultural activities are seasonal, and different activities are performed at different times of the cropping season. The crops that are grown in the study area have different biological characteristics, these are reflected in different moisture...
and temperature requirements, period of maturity etc. These characteristics have great influence on the cropping calendar for each crop. The cropping calendar for each crop, and activities performed within the prevailing pattern of temperature and rainfall for the year 1980 are shown in Figure 2.1 below. The cropping calendar determines the seasonal distribution of labour use. The average seasonal distribution of labour per hectare for main cropping season for the sample farmers is shown in Figure 2.2.

Figure 2-1: Cropping calendar with corresponding rainfall and temperature for each crop

Since crop production is rainfed, a relationship exists between labour use and rainfall distribution. Minimum labour input is expended in the

4The weather information was extracted from Abylie, 1981
wet and cold months of July, August and September when more than 70 percent of the annual rainfall occurs. Such a relationship was also observed by Chandra (1979) in Fiji, but is contrary to most tropical countries (Ruthenberg, 1977).

Figure 2-2: Seasonal distribution of labour in crop production

Figure 2.2 illustrates the seasonal distribution of labour when all crop enterprises are pooled. From this figure July, August and September, the weeding months, are relatively slack periods as only little weeding is done despite the presence of acute weed infestations. This minimum level of weeding activity could be due to wetness of land, inconvenience of weeding fields where seed is broadcasted, seasonal illness due to the cold and/or the exceptionally large number of holidays during these three months. There are about 177 holidays (most of them religious) in a year where "heavy" farm activities are not

5 According to the farmers seed-bed preparation, seeding, weeding and harvesting of crop are classified as heavy work whereas threshing, mowing of hay and transporting harvest are considered as light work.
carried out. November and December are peak months for labour input, when harvesting and threshing activities are undertaken. These two months account for 32 per cent of the total annual adult male and 52 per cent of the adult female and child labour usage over the cropping season.

The literature of conventional economics tells us that labour is the least scarce and most intensively used resource in smallholder traditional farming systems. Hence labour productivity in such a system is assumed to be low. The labour productivity per hour for the major crops in the study area is presented in Table 2.2 for 1980 and 1981 main cropping seasons. In calculating the total labour input per unit area child labour is weighted arbitrarily by one-half, whereas female labour is taken equivalent to adult male labour. The small proportion of child labour in crop production and its insignificant impact in determining production justifies its aggregation.

Table 2.2: Labour productivity per hour for major crops

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Yield (kg.)</td>
<td>46755</td>
<td>27933</td>
<td>5818</td>
<td>4530</td>
<td>14704</td>
<td>13807</td>
<td>2619</td>
<td>2140</td>
</tr>
<tr>
<td>Total Labour (hr.)</td>
<td>20196</td>
<td>19134</td>
<td>2585</td>
<td>2518</td>
<td>5134</td>
<td>5041</td>
<td>1119</td>
<td>1251</td>
</tr>
<tr>
<td>Labour Productivity</td>
<td>2.3</td>
<td>1.5</td>
<td>2.3</td>
<td>1.8</td>
<td>2.9</td>
<td>2.7</td>
<td>2.4</td>
<td>1.7</td>
</tr>
<tr>
<td>Total Yield/kg/hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Labour/kg/hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.1.3 Capital

The farmers in this area own very little capital. The overall farm assets include dwelling house(s), livestock, grain store(s), livestock shed(s), tools and trees in the backyard. These all account for a

6Only trees grown on the backyard belong to individual farmers whereas trees grown in the farm or elsewhere belong to the peasant association.
total of Birr 2469 (US $ 1230) per farm (average in 1981), of which 71 per cent is attributed to livestock and 24 per cent to buildings. However, there exists a wide variation in the amount of capital, ranging from a low of Birr 174 (US $ 84) to a high of Birr 5804 (US $ 2804), with 50 per cent of the farmers having less than Birr 2250 (US $ 1087). Few other small hand implements used for ploughing, seeding and harvesting that have an average value of Birr 48 (US $23), along with ox(en) are the few important capital assets owned by most farmers. It is worth noting that under these conditions, that the role of capital, with the exception of oxen, is minimal in a crop enterprise where a pair of oxen power productivity per hour is estimated to be nearly equivalent to that of man.

2.2 Crop production

Being subsistence farmers, farmers at Debre Berhan grow a number of crops that are adaptable to the physical environment, and have a primary objective of self sufficiency. Accordingly, barley (Hordium spp.), wheat (Resriticium spp.), horse beans (Vicia feba), field peas (Pisium sativium), lentils (Lens esculata) and linseed (linsum visistium) are produced in descending order of quantity, reflecting their economic importance. The nature of the crop mix is determined primarily by the terrain (up land or bottom land), onset of rainfall and occurrence of BELG (short-rains). It is also influenced by availability of seed, rotational practices and soil type. The crop mix in turn determines the importance of each crop to the household in fulfilling subsistence requirements.

The techniques of crop production are "backward" and may be referred as traditional, with minimal exposure to modern technology. Seed-bed preparation is carried out using the local plough, MARESHA, drawn by a pair of oxen, and normally a number of passes are required for proper seed-bed preparation. This is because this type of plough does not turn over the sub-soil sufficiently rather it scratches the surface of the soil. Seeding is done by broadcasting making later weeding difficult to perform. This is probably one of the reasons for only occasional weeding, despite the immense growth of weeds in the fields. Harvesting is with sickles, and the harvested crop is threshed by trampling by large farm animals.
2.2.1 Cropping patterns

Cereals (barley and wheat) account for about three-fourths of the total cultivated land with barley making up 70 per cent of the cereals. The remaining 25 per cent of cultivated land is used for pulses (21 per cent) and oil seed (4 per cent). The cropping pattern of the four year period is shown in Table 2.3.

Table 2-3: Cropping pattern of 42 sample farmers

<table>
<thead>
<tr>
<th>YEAR/CROP</th>
<th>CEREALS</th>
<th>PULSES</th>
<th>OILSEED</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Barley</td>
<td>Wheat</td>
<td>Others</td>
<td>H.beans</td>
</tr>
<tr>
<td>1979</td>
<td>73.0</td>
<td>5.0</td>
<td>0.0</td>
<td>12.0</td>
</tr>
<tr>
<td>1980</td>
<td>70.5</td>
<td>7.9</td>
<td>0.0</td>
<td>13.2</td>
</tr>
<tr>
<td>1981</td>
<td>63.0</td>
<td>10.0</td>
<td>2.0</td>
<td>15.0</td>
</tr>
<tr>
<td>1982</td>
<td>56.4</td>
<td>8.8</td>
<td>3.3</td>
<td>16.0</td>
</tr>
<tr>
<td>1979-1982</td>
<td>65.7</td>
<td>7.9</td>
<td>1.3</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td>74.9</td>
<td></td>
<td></td>
<td>20.7</td>
</tr>
</tbody>
</table>

2.2.2 Crop yield and use

Rainfall is adequate to grow the above mentioned crops with annual precipitation of 1150 mm. Severely eroded land caused by overgrazing, intensive use and deforestation, frequent occurrence of frost and hail storms and socio-economic constraints, give rise to low productivity of crop per unit measure. The average crop yield obtained per hectare for the main rainy season of the survey period are shown in Table 2.4.

Table 2.4 shows that in general the average yield (1979-82) of the sample farmers is lower than both the national average and the administrative region (provincial) average. The average yield of 1981 was particularly low because of frequent frost. This is not surprising
Table 2-4: Crop yield of the National, Administrative Region and sample farmers for the period 1979-1982 (kg per ha.)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Barlev</td>
<td>718</td>
<td>881</td>
<td>586</td>
<td>751</td>
<td>734</td>
<td>1440</td>
<td>1192</td>
</tr>
<tr>
<td>Wheat</td>
<td>950</td>
<td>804</td>
<td>594</td>
<td>756</td>
<td>776</td>
<td>918</td>
<td>1003</td>
</tr>
<tr>
<td>H.beans</td>
<td>1300</td>
<td>1277</td>
<td>1054</td>
<td>895</td>
<td>1131</td>
<td>1067</td>
<td>1347</td>
</tr>
<tr>
<td>F.peas</td>
<td>1050</td>
<td>600</td>
<td>479</td>
<td>540</td>
<td>667</td>
<td>947</td>
<td>1436</td>
</tr>
<tr>
<td>Lentils</td>
<td>--</td>
<td>286</td>
<td>141</td>
<td>175</td>
<td>200</td>
<td>719</td>
<td>639</td>
</tr>
<tr>
<td>Linseed</td>
<td>200</td>
<td>206</td>
<td>81</td>
<td>-</td>
<td>-</td>
<td>111</td>
<td>429</td>
</tr>
</tbody>
</table>

as crop failure is expected once in every three or four years. Nevertheless under a research carried out by the Institute of Agricultural Research at Shino, Debreberhan, a similar type of land yielded 2549 kg/ha. of barley and 2553 kg/ha. of wheat after camber-beded and fertilised (Institute of Agricultural Research, 1979).

Given the objectives of semi-subsistence farmers (self-sufficiency) most of the production (86 per cent) is used at home for consumption and seed requirement. Average grain consumption for an average farm family size of 4.8 persons for the year 1982 is 900 kgs of cereals and 336 kgs of pulses. This leaves only 14 per cent of the total production for sale, after the seed requirement for the coming season are met. The sale of cereals and pulses provides less than 50 per cent of average cash income from sales of farm products. The remaining income is mainly from sale of livestock, livestock products and livestock by-products.
2.3 Livestock husbandry

Animal husbandry remains an important component of the farming system, not only in the study area, but also in the whole of the country. It has equal, if not more, importance, than crop production both economically and socially.

2.3.1 Livestock holdings and uses

Unlike land, livestock is privately owned by each household without any restriction on number of stock. During the survey period the average livestock holding per farm is 6.4 TLU,\(^7\) Comprising 3.2 cattle, 1.2 sheep, 1.0 horse and mule and 1.0 donkey. These are all native breeds.

Livestock provide vital high quality food for the family in the form of meat, milk and eggs. The meat of cattle, sheep, goats (except that of the very young ones) is consumed during the non-fasting periods. There are about 139 obligatory fasting days in a year where all adults are not permitted to eat any meat or animal products (This does not include the 82 optional fasting days which are restricted to priests according to the Orthodox Christian faith which all the sample farmers follow). Animals are killed only on special occasions. In 1982, on average, 2.5 head of sheep (average value was Birr 23 (US$ 11) with a liveweight of about 20 kgs) were consumed per farm. Aside from home consumption livestock and their products and byproducts are important as a substantial source of money income. A survey of the same year shows that a total of Birr 232 (US$ 112) per farm was obtained from the sales of cattle and sheep. Typically, this money would be used mainly in purchasing non-farm consumer items and farm products not produced on the family farm. Particular importance is given to livestock as a means of security in satisfying subsistence needs in case of crop failure. This implies that livestock can be sold readily for purchasing grain. The cattle and equine animals provide important power services to the farm; Oxen are involved in seed-bed preparation, seed covering, grain threshing and drain digging. Cows are kept for reproduction and source of milk. The practice of keeping cows mainly

\(^7\)TLU stands for Tropical Livestock Unit where one LU equals 250 kg of live animal weight.
for reproduction is evidenced by the very small ratio of young to old cattle (1:9) sold by sample farmers. Equines are the only means of transportation. Whereas donkeys are used for carrying goods to and from market and fields, mules and horses are used as major means of human transportation.

Despite the economic and social importance of livestock their productivity remains very low in many aspects such as weight gain, milk production and calving intervals, due to inferior genetic strains, inadequate feed (both in terms of quality and quantity) and poor animal health.

2.4 Institutions and rural services

There exist a number of economic and social organizations in the rural villages where the sample farmers reside. The traditional economic organizations are "DEBO", "MEKENAJO" and "EKUB" (see Glossary for their definitions), in which local farmers share their labour and oxen in production, and pool part of their savings. Under the traditional social organization of "EDIR", "MAHABER" and "SEMBETIE" the farming community share their sorrows and celebrations.

Since 1979 modern organizations such as service and producer cooperatives are being established under the initiative of the socialist government of Ethiopia.

Rural services such as schools, transport systems, marketing, credit, agricultural inputs and extension services are poorly developed. As mentioned earlier, the only means of transport for both goods and human are equines.

Agricultural development programmes have been implemented in Ethiopia since the mid 1960's under the assistance of international donor agencies. Comprehensive package projects (CPP) were established in a very few sample areas to increase agricultural production through the use of modern inputs including mechanization. These projects were not only found to be too expensive to duplicate elsewhere but also substantial proportion of the benefit went to the big landowners. Neither of the minimum package programmes (MPP) established to provide fertilisers, credit, marketing and extension to farmers living along all-weather roads benefited small farmers before the land reform.
Currently aside from the technical advice and extension works which are provided by government employees, the MPP with an additional activity of road construction is being implemented by Peasant Associations (Sisaye, 1980).

Research works are also being carried out to identify inputs that raise agricultural productivity by the Institute of Agricultural Research (IAR). The International Livestock Centre for Africa (ILCA) is also undertaking a pilot research programme in the area of crop production since livestock production is an integral part of crop production in the country because of the mixed nature of the farming system. Despite ILCA's effort to raise crop production, along with livestock production, the results obtained to date are not promising mainly because of the harsh weather where the research is being carried out. Most of the farmers seem willing to accept new techniques of production provided they are convinced of the achievement of the new techniques available to them, at reasonable price and some allowance is given to risk and uncertainty.

The involvement of the farmers in the market system is very limited, both in terms of supplying agricultural products and demanding retail and rural services. The supply of agricultural products is constrained by the low productivity of agricultural enterprises, which in turn depresses the effective demand for retail and rural services. Modern agricultural inputs such as fertiliser and hybrid seeds that could raise productivity are neither in sufficient supply nor there exists enough provision of credit for their purchase by the farmers. The inadequate distribution of fertiliser and hybrid wheat to farmers in the sub-district (since their introduction in 1971) are shown in Appendix E. The problem of low productivity is further aggravated by low provision of extension services. Given the very low crop productivity and the need for working capital, which is commonly beyond the farmers capacity to fund the purchase of modern inputs, the possibility of raising productivity using the existing physical and financial resources is of significant importance in the short-run. To this end this paper attempts to investigate whether it is possible to increase farm productivity by using the resources at hand more efficiently. The literature on efficiency is reviewed in the following chapter.
CHAPTER 3
LITERATURE REVIEW

Efficiency has remained the central concern of economics ever since it has been studied. Although several authors, including Pasour (1981), argue that the concept of efficiency is ambiguous and therefore has little practical importance, a great deal of work has been devoted to measuring efficiency. Among the conventional measures of efficiency the Partial Productivity Index is the simplest measure. It is obtained by dividing output by the contribution made by each resource or factor of production. Another similar measure of efficiency is Total Factor Productivity which is total output divided by total input. A number of attempts have been made by researchers to account for quality changes over time in the efficiency index, including Griliches (1963) and Christensen (1975).

Farrell (1957) developed a measure of productive efficiency which takes into account all inputs but avoids the problems associated with traditional average productivity measures (index number problems). Farrell's method of estimation deals with the production function of an efficient firm estimated by linear programming rather than the production function of the average firm which is estimated using regression methods.

Farrell distinguished between technical efficiency and allocative efficiency. Technical efficiency is attained when either a minimum amount of input is used in producing a certain level of output or when a certain amount of input produces the maximum level of output. Technical efficiency does not take into account the effect of relative prices, rather it measures the shift in production function over time or between group of firms. Hence, measures of technical efficiency rely less heavily on the assumptions of perfect knowledge about market, perfectly competitive markets and the profit maximization objective. Allocative efficiency, on the other hand, occurs when resources are
allocated according to market prices and thus depend on the aforementioned assumptions.

If some farmers perform significantly better than other farmers using the same technologies and inputs, it implies that there is scope for raising output without investing in new technology and inputs. However, if most farmers get very similar output/input ratios with the same technology and inputs, it follows that there is a need for new investment (such as improved seed, education etc.) in order to raise output. Despite the great importance of knowledge of technical efficiency for policy making, technical efficiency has received far less theoretical treatment in the economic literature because the classical economic theory assumes technical efficiency of production processes. Works related to technical efficiency could be found for instance in Farrell (1957), Nerlove (1965), Leibensten (1966), Massell (1967), Timmer (1970), Kopp (1981), Shapiro (1983), Russell and Young (1983) and Dawson (1985) which all show the existence of various degrees of technical efficiency differentials among producers.

Under the assumption of constant returns to scale Farrell derives the efficient production frontier (unit-isoquant) where no farm is able to produce a unit of output using a combination of inputs lower than the unit-isoquant under the same technology. The unit-isoquant concept is better visualized diagrammatically (see Figure 3.1).
Assuming two factors of production, the isoquant $QQ'$ represents the various combinations of labour ($L$) and capital ($K$) used in producing a unit of output by a "perfectly technically efficient" farm. The points $E$, $T$ and $N$ represent different farms at different levels of efficiency. All farms that lie on the isoquant $QQ'$ are said to be technically efficient. Hence, since farms $E$ and $T$ lie on the unit-isocost they are 100 per cent technically efficient. Farm $N$ is, however, less than 100 per cent technically efficient since it lies beyond the isoquant $QQ'$. The technical efficiency standard for farm $N$ is that point on $QQ'$ which uses inputs in the same proportions as $N$ (i.e. farm $T$) and its technical efficiency is measured by the ratio $OT/ON \times 100$. Price (allocative) efficiency of a farmer could also be measured from Figure 3.1. The traditional price or allocative efficiency is a ratio of marginal value product to opportunity cost. A firm is said to be price efficient if the ratio of marginal value product to opportunity cost equals one among all inputs.
In Figure 3.1 price efficiency is measured relative to the isocost line PP' because it represents the minimum cost of producing one unit of output. Hence it is only farm E which is price efficient (on the isocost line). The price efficiency of farm T and N is measured by the ratio of \( \frac{OR}{OT} \times 100 \). Farrell showed that overall economic efficiency of a firm is the product of price efficiency and technical efficiency denoted by \( \frac{OR}{ON} = \frac{OT}{ON} \times \frac{OR}{OT} \).

A number of theoretical and practical difficulties have been raised with Farrell's frontier approach to measuring efficiency and some of these points are presented here. The assumption of constant returns to scale has been criticized by Nerlove (1965), Aigner and Chu (1968) and others. Bresseler (1966) argued that if there is a systematic relationship between scale and factor proportions then the validity of the frontier would be doubtful. The other problem raised by Bresseler (1966), among others, is that the frontier could be influenced by extreme observations. Accordingly, corrective measures were suggested by a number of researchers. Aigner and Chu (1968) fitted a smooth envelope function of the Cobb-Douglas form in output-input space as opposed to the efficient isoquant in input-input space developed by Farrell (1957). The advantage of Aigner and Chu's (1968) approach is that the assumption of constant returns to scale need not be made. But this is at the cost of specifying a functional form such as Cobb-Douglas. Besides, the envelope approach enables the relaxation of the deterministic process of Farrell by incorporating an estimation method of probabilistic frontiers which reduce the influence of extreme observations. Nerlove (1965 pp.93) also relaxed the assumption of constant returns to scale using a profit function. He also took environmental factors into account. Seitz (1970) refined Farrell's model so that it allows for scale differentials and conforms to the law of variable proportions. Seitz allows for economies and diseconomies of scale for estimating a frontier production function using linear programming techniques. He argues that his model does not require adjusting for environmental factors, as suggested by Nerlove (1965), prior to testing efficiency. Despite all these improvements to Farrell's model there still remain some problems such as an absence of measure of statistical significance test to the model and its inapplicability to multiproduct firms (Seitz 1970).
Timmer (1971) measures an output-based efficiency by using a Cobb-Douglas function on the frontier. Kopp (1981), while maintaining Farrell's input-based efficiency measures, estimates a parametric frontier function econometrically as opposed to Farrell's linear programming method. Fare and Lovell (1978) and Russell and Young (1983) point out that the input-based measure of Kopp (1981), and the output-based approach of Timmer (1971) yield similar results under constant returns to scale.

Mundlak (1961) and Hoch (1962) independently suggested the use of analysis of covariance on pooled time-series and cross-sectional data to account for the unobservable factor, management. That is, that interfirm differences that are observed over time reflect managerial ability (technical efficiency). Massel (1967) and Massell and Johnson (1968) used multi-product in place of time-series data in estimating technical efficiency in traditional farmers of Rhodesia (now Zimbabwe), and observed substantial (up to more than double) differences in technical efficiency among the farmers. Similarly Shapiro (1983) in his study of technical efficiency among Tanzanian cotton farmers demonstrates that there is scope to increase output by 51 per cent if all farmers achieved technical efficiency levels achieved by the most efficient farmers.

An alternative measure of non-allocative efficiency called "x-efficiency" was developed by Leibenstein (1966). The x-efficiency is measured in a similar way as technical efficiency but the x-efficiency is said to arise from non-maximizing behaviour, motivational losses and incomplete specification of the production function, in contrast to differences in knowledge assumed in measures of technical efficiency. Leibenstein's data suggest that the amount of x-efficiency is much more significant than allocative efficiency. Stigler (1976), however, argues that Leibenstein's approach does not allow effective analysis of concrete economic problems.

Average production functions estimated by statistical techniques, such as least squares, that minimize errors on both sides of the estimated function have received far more attention than frontier functions. Yet, the concept of average is not unambiguous (Aigner and Chu, 1968). Muller (1974) argues that frontier and average functions
are identical where all inputs, including information (knowledge) on
the means to use the available physical resources, are taken into
account, and if the differences in technical efficiency are not due to
random effects. Similarly, Timmer (1970) pointed out that the frontier
production functions turned out to be almost neutral transformation of
the average production functions. Where technical efficiency is also
influenced by random effects, Russell and Young (1983) suggested that
the frontier production function can be obtained from corrected
ordinary least squares (COLS) regressions. The corrected ordinary
least squares are estimated first, by applying ordinary least squares
(OLS) in order to obtain best, linear and unbiased estimates of the
parameters. Then the intercept estimate is corrected by shifting the
function till all the residuals are non-negative. Jondrow et al (1982)
decomposed the error term of the stochastic frontier model into its
components of the random error term and the non-negative error term
representing technical inefficiency thereby avoiding the disadvantage of
the stochastic production frontier over the deterministic frontiers.

Linear programming has been the dominant methodology for
estimating the most profitable farming systems, whereas partial
analysis studies, based on production functions, are useful in
analyzing numerous farm level and policy decisions (provided that other
interrelationships are of secondary importance). Additionally, the
production relationships obtained from production functions could be
good sources of information for linear programming. There are an
infinite number of functional forms that could be used in estimating
production relationships. (see Heady and Dillon (1961) for detailed
exposition of major production functions). Yet, it is not possible to
specify and fit the "true" production function, because of lack of
knowledge about the true functional form and the impossibility of
including all variables (Heady and Dillon, 1961). Hence, one can only
minimize but not avoid specification errors.

The Cobb-Douglas production function, the most widely used
function in measuring agricultural efficiency, was first applied by
Cobb and Douglas (1928) to American manufacturing industries.

The Cobb-Douglas function can be represented in both
multiplicative and log linear forms as follows:
\[
(3.1) \quad Q = C x_1^{a_1} x_2^{a_2} \ldots x_n^{a_n} e^U \quad \text{(Multiplicative)}
\]

\[
(3.2) \quad \ln Q = \ln C_0 + a_1 \ln x_1 + a_2 \ln x_2 \\
\quad + \ldots + a_n \ln x_n + V \quad \text{(log-linear)}
\]

where \( Q = \) output;  
\( C = \) constant (efficiency parameter);  
\( X_1 = \) input;  
\( a_i = \) elasticities of output with respect to input \( X_i \);  
\( e = \) the base of natural logarithms  
\( U \) and \( V \) are random error terms.

The coefficients \( a_i (i = 1 \ldots k) \) are output (\( Q \)) elasticities with respect to factors of production (\( X_i \)) and remain constant throughout the production surface. The sum of the output elasticities measure the returns to scale and the degree of homogeneity of the function. Returns to scale are decreasing, increasing or constant depending on whether the sum of the output elasticities is less than one, greater than one or unity, respectively.

As the marginal products of this Cobb-Douglas function are not readily observed, they can be calculated from the elasticities and the average products as in equation (3.3).

\[
(3.3) \quad MP = \frac{dQ}{dX_i} = a_i C X_1^{a_1-1} \ldots X_i a_i X_i^{a_i-1} \ldots X_n^{a_n} = a_i \frac{Q}{X_i}
\]

Unlike its elasticities the Cobb-Douglas production function has variable marginal productivities. Marginal productivity decreases with increasing use of a factor other inputs held constant.

\[
(3.4) \quad \frac{d^2Q}{dx^2} = a_i [ a_i - 1 ] \frac{Q}{X^2}
\]

Since \( 0 < a_i < 1 \) the right hand-side of the equation
becomes negative denoting decreasing marginal productivity.

The Cobb-Douglas production function has been used widely because of its simple computations, convenience in interpreting elasticities of production and its involvement of fewer degrees of freedom than other functional forms, that allow for increasing or decreasing returns to scale (Heady and Dillon, 1961). Besides its properties of diminishing marginal returns to factor inputs and the law of variable proportion add to its wide usage. The classical criticisms of Cobb-Douglas functions are first, it cannot be used for data where both increasing and decreasing marginal productivity occur. Second, it allows only for either increasing, decreasing or constant returns to scale, no combination of them is possible. Third, it assumes all factors of production are essential. Therefore, the presence of one or more zero inputs such as fertiliser, pesticide etc. implies zero output. Hati and Rudra (1973) suggested the possibility of including the non-essential inputs as exponential terms rather than product form to tackle the problem of zero input in Cobb-Douglas production function. Fourth, it assumes constant and unitary elasticity of substitution between inputs. Arrow, Chenery, Minhas and Solow (1963) developed an alternative form of production function known as constant elasticity of substitution (CES) production function. This function has the Cobb-Douglas function as a special case (where the constant elasticity is unitary). However, the use of this function is constrained by its computational and interpretational difficulties particularly when the number of independent variables exceed two.

Among alternative production functions, the transcendental function is particularly flexible in that exhibits variable elasticities of production and is more consistent with the underlying theory of production. This function allows for the three traditional phases of production function as shown in Figure 3.2. As the Cobb-Douglas function shows only the second or rational phase of the production function the transcendental function is said to be the general form of the Cobb-Douglas function. The transcendental function can assume various shapes depending on the magnitude and sign of the coefficients. The general properties of this function are found in Halter et al (1958) and Sepien (1978). The mathematical form of the transcendental function is presented in equation 3.5.
Figure 3-2: A general Production Function

\[
\text{Stage I} \quad \text{Stage II} \quad \text{Stage III}
\]

\[
\text{TP (Total product)}
\]

\[
\text{AP (Average product)}
\]

\[
\text{MP (Marginal Product)}
\]

Output

Input

\[
(3.5) \quad Q = C \times x_1^a_1 w_1 x_1 \times x_2^a_2 w_2 x_2 \ldots \times x_n^a_n w_n x_n \times U
\]

Where:
- \(Q\) = quantity of output
- \(X_i\) = quantity of input
- \(C, a_1 \ldots a_n, w_1 \ldots w_n\) are parameters
- \(e\) = the base of natural logarithm
- \(U\) = the error term

The marginal productivity is obtained as in equation 3.6 and its elasticity of production, in turn, would be calculated from equation 3.6 as in equation 3.7.

\[
(3.6) \quad \frac{dQ}{dX_i} = Q \left( \frac{a_i}{X_i} + w_i \right)
\]

\[
(3.7) \quad E_{X_i} = \frac{Q}{X_i} \left( \frac{a_i}{X_i} + w_i \right) \frac{Q}{Q}
\]

Since the transcendental function does not allow for distinction between essential and non-essential inputs Sepien and Etherington (1980) have developed a modified form of transcendental function that accounts for this distinction. This modified transcendental (M-T) is
the basis for the present study since there are both essential and non-essential inputs applied in the production process. Its functional form could be presented as follow:

\[ Q = C \prod_{i \in EA} a_i x_i + \prod_{i \in EB} b_i x_i + r_i x_i . U \]

Where:
- \( b_i \) and \( r_i \) are parameters;
- \( A \) and \( B \) are sets of essential and non-essential inputs respectively and
- other symbols maintain their earlier definitions.

Early works examining production efficiency focused more on allocative efficiency than on technical efficiency. Heady and Dillon (1961) presented a number of works on measuring allocative efficiency in various agricultural enterprises in developed countries. Schultz (1964) is the most widely quoted person to work on the problem of allocative efficiency in less developed countries by presenting his hypothesis of "efficient but poor". The hypothesis of "efficient but poor" states that: there are no significant misallocations of existing resources in the traditional agricultural production of less developed countries. In other words traditional farmers in these countries, as anywhere else allocate their resources efficiently in order to maximize their profit. Hence, output cannot be increased by reallocating existing resources, it rather requires introducing new techniques of production.

Many empirical studies in some less developed countries have supported the hypothesis of "efficient but poor". Welsch (1965) working with data from rice farmers in eastern Nigeria concludes that the farmers allocate the present factors of production efficiently. Hopper (1965) also tested the rational profit maximization allocation of factors of traditional Indian agriculture and concluded that there are only few allocative errors. Similarly, Chennareddy's (1967) empirical evidence on South Indian agriculture indicates that traditional farmers are aware of efficient use of traditional inputs. Sahota (1968) arrives at a similar conclusion after examining Indian agriculture for different crops, farm sizes and across different
states. With few exceptions the study supports the hypothesis that resources are efficiently allocated. Yotopoulos (1968) evaluated intrafarm allocative efficiency and concluded that there is no significant misallocation of resources in the traditional agriculture of Epirus, Greece.

Dillon and Anderson (1971) in their reappraisal of some evidences of profit maximizing efficiency using an economic (decision theory) rather than statistical (significant testing) criterion have given mixed support to the hypothesis of profit maximizing behaviour of traditional farmers. They found that Hopper's (1965), Chennareddy's (1967) and Yotopoulos (1968) data are inconclusive, non-supportive and supportive respectively, of the profit maximization hypothesis. They concluded that these mixed results could be due to differences in attitude towards risk. Dittrich and Myers (1971) working with data of North China during the late 1930's, showed that farmers allocate their land and labour efficiently despite the market uncertainty they face. Shapiro (1983) reanalyzed the studies on allocative efficiency in traditional agriculture that had been reappraised by Dillon and Anderson's (1971) analysis. In contrast to the original authors' findings, Shapiro's analysis show significant divergence between marginal value products of inputs from the marginal factor costs. He found a divergence, on the average, of more than 40 per cent between these indicators which was far too low to be claimed efficient. Chandra (1979) and Sadhu and Hahajam (1982) among others show that different farm sizes allocate their resources differently. Thus, a resource efficiently allocated in certain size of holding may not be so allocated in smaller or bigger holdings size. Chandra (1979), in his study of smallholder semi-subsistence farmers in the Sigatoka Valley, Fiji found that on the whole the farmers allocated their resources efficiently, although the Fijian farmers were less efficient than the Indian farmers.

As these studies used production functions in estimating the allocative efficiencies, reservations are raised about the underlying assumptions of the production function (for instance see Upton, 1979). The assumptions of perfect competition in factor and product markets and the objective of profit maximization have received greater
criticism. Under these assumptions all technical and price efficient farmers lie on a single point of the production function. But in reality there are many reasons to believe that observations are rather scattered for instance (see Etherington, 1973 pp 21). Vandenborre and McCarthy (1967) show that failure to use the correct method of estimation, such as assuming all input supply is infinitely elastic, whereas in reality there are restrictions on input supply, could lead to greater resource misallocation. Lau and Yotopoulos (1971) have also argued that the classical measure of economic efficiency has such major shortcomings that it does not make possible a realistic comparison among firms that have different degrees of profit maximization objective. It also fails to allow for differences in the initial endowment of fixed factors. Accordingly, they developed a measure of economic efficiency which allows for differences in resource endowment and environmental factors among farmers. Their model also takes into account differences in degree of maximizing profit and the possibility that different farms face different market prices. As a result of attempting to apply their approach at the farm (as opposed to the regional) level, Junankar (1983) became extremely critical of the profit function approach. It is particularly difficult to apply in the present situation where 86 per cent of crop production is for own consumption. It was also argued that the conventional measures of efficiency ignore management bias, this was elaborated by Hoch (1958) and Mundlak (1961). Lingard et al (1981) apply covariance analysis to cross-sectional and time-series data in an attempt to estimate a bias free production function. They obtained lower production elasticities, marginal products and equiproportionate returns to all factors by allowing for an efficiency differential between farms than is obtained without including a management variable.

The foregoing discussion points out that, by and large, the literature suggests there exists substantial differences in technical efficiency among producers. However, there is great controversy regarding the allocative efficiency of traditional farmers. The hypothesis of poor but efficient is neither confirmed nor disputed. It rather demands more theoretical and empirical work in the agricultural economics of the less developed countries. The empirical results
obtained from the present study are given in Chapter 5. But before discussing the results the analytical framework of the study is outlined in the following Chapter.
CHAPTER 4

ANALYTICAL FRAMEWORK

According to micro-economic theory the traditional production function represents the maximum output obtainable at a given level of input combination (technically efficient). Assuming that production function exists i.e there is a technical relationship between output and a set of inputs, an attempt is made to represent, at least roughly, this relationship.

4.1 Choice and manipulation of variables

The general form of the production function could be represented as in equation (4.0):

\[ Q_j = F(X_{1j}, X_{2j}, X_{3j}, X_{4j}, X_{5j}, M_j) \]

where

- \( Q_j \) = output of farm \( j \);
- \( X_{1j} \) = land area under crop of farm \( j \);
- \( X_{2j} \) = number of labour days spent on seed-bed preparation on farm \( j \);
- \( X_{3j} \) = number of labour days spent on weeding of farm \( j \);
- \( X_{4j} \) = amount of chemical fertilizer applied on farm \( j \);
- \( X_{5j} \) = number of pair of oxen days spent on farm \( j \);
- \( M_j \) = management variable of farm \( j \).

\( Q_j \), output of both grain and straw are considered and measured in quintals (100 kg). In order to facilitate aggregation of grain and straw, as well as comparability among crops, the physical output of both grain and straw of each crop is weighted by its respective average annual price. Since we are dealing with two years data potential changes in price are important. The price of barley, wheat and
horsebeans for 1980 were 40, 75 and 36 Birr per 100 kgs respectively with corresponding prices of 47, 74 and 36 Birr per 100 kgs for 1981. The price of straw was constant for all crops and for the two years at 2.5 Birr per 100 kgs.

\[ X_{i,j} \] land area refers to land under crops measured in hectares. It is hard to claim homogeneity of land, particularly in this study (see Chapter 2). However, there is also little reason to assume substantial difference of fertility of land among crops of the same kind. But differences in fertility of land among crops still remains. This is because fertility of land is very closely related to the topography of the land, and the topography of the land in turn determines what type of crop to grow. For instance, the bottom land where the poorest quality of land is found, is cropped with barley (90 per cent) by almost every farmer.

\[ X_{2,j} \] and \[ X_{3,j} \] represent labour used in preharvest operations of seed-bed preparation and weeding measured in man days. Harvest and postharvest labour input are excluded for two reasons. First, the inclusion of harvest and post harvest labour creates a simultaneous equation bias (dealt with later in this Chapter); second, virtually all potential output of matured crop is harvested. Hence, harvesting labour is not a constraining factor in production. The primary reason for disaggregation of seed-bed preparation labour (\( X_{2,j} \)) and weeding labour (\( X_{3,j} \)) is to minimize the aggregation problem of combining dissimilar labour inputs. It is not only that the two types of labour are dissimilar but also they are employed at different times of the cropping season and hence they are not substitutable. The distinction between the activities also illustrate differences in productive efficiency between male and female labour. Male labour is primarily involved in seed-bed preparation, seeding, fertiliser application and drainage; female labour is employed for weeding. However, both sexes are involved in harvesting and post-harvesting activities with a greater degree of involvement by males. The returns to seed-bed preparation and weeding labour in this study, refer as well to returns to different sexes.

\[ X_{4,j} \] the amount of chemical fertiliser applied, is measured in quintals (100 kg).
$X_{ij}$, pair of oxen power, is used in seed-bed preparation, seed covering and threshing. For similar reason given for disaggregating human labour, only that part of oxen power used in seed-bed preparation need to be accounted for in the analysis of this study. However, as oxen are jointly employed with seed-bed preparation of human labour their separate treatment would lead to the estimation problem of multicollinearity. Hence, they are estimated jointly and the return to seed-bed preparation, refers to both labour and oxen power. Capital inputs other than oxen are not included in the study, primarily because they constitute only an insignificant part of the farm inputs in crop production. Besides, since they are jointly used with oxen and labour, their separate treatment would again pose the estimation problem of multicollinearity.

$M_j$, the management variable has no units and is thus measured as an index. This variable is included to capture the differences in technical efficiency between farmers. Its specific method of application is discussed below with the specific model selected.

4.2 Model selection

As mentioned in Chapter 3, despite the existence of numerous production functions it is not possible to find a particular production function that perfectly fits a certain production relationship. Keeping this in mind an attempt was made to identify a model which reflected the logic of the production process in question as closely as possible, and which simultaneously had computational manageability. The most general such function is the transcendental production function as indicated in Chapter 3 which, as a mixture of logarithmic and exponential variables, allows for extreme flexibility in shape depending on the signs of the coefficients. As an extreme, if the exponential terms ($w_ix_i$) of this function as shown in Table 4.1 equation 4.1 are zero then equation 4.1 reduces to the conventional Cobb-Douglas function as shown in equation 4.4 below.

Nevertheless since there are many farmers in this study who did not use chemical fertiliser, and who had not practised weeding on some of the crops the modified form of the function (4.2) following Sepien and Etherington (1980) that accounts for both essential and
Table 4-1: Summary of Model Specification

4.1 Transcendental (T)

\[ q_j = C_0 + M_j + \sum_{i \in E_A} (a_i X_{ij} + w_i X_{ij}) + V_j \]

4.2 Modified Transcendental (M-T)

\[ q_j = C_0 + M_j + \sum_{i \in E_A} (a_i X_{ij} + w_i X_{ij}) + \sum_{i \in E_B} (b_i X_{ij} + r_i X_{ij}^2) + V_j \]

4.3 Log, Semi-log (L-S-L)

4.3A \[ q_j = C_0 + M_j + \sum_{i \in E_A} (a_i X_{ij}) + \sum_{i \in E_B} (b_i X_{ij} + r_i X_{ij}^2) + V_j \]

4.3B \[ q_j = C_0 + M_j + \sum_{i \in E_A} (a_i X_{ij}) + \sum_{i \in E_B} (b_i X_{ij}) + V_j \]

4.4 Cobb-Douglas (C-D)

\[ q_j = C_0 + M_j + \sum_i (a_i X_{ij}) + V_i \]

Where

- \( q_j \) = log of value of output on farm \( j \);
- \( M_j \) = farm specific variable;
- \( A \) and \( B \) are sets of essential and non-essential inputs respectively;
- \( x_{ij} \) = log of inputs;
- \( X_{ij} \) = inputs in natural numbers;
- \( C_0 \) = constant
- \( a_i, w_i, b_i, r_i \) = input coefficients.
- \( V_j \) = error term

non-essential inputs is selected as the basic functional form for this study. The modified transcendental function (4.2) reduces to a linear log, semi-log (L-S-L) function of the form in equation 4.3A and 4.3B in Table 4.1 when the exponential terms of the essential inputs (\( w_i X_{ij} \)) are omitted (i.e if the coefficients are not significant). Similarly equation 4.2 collapses to equation 4.3B when both the exponential terms of the essential (\( w_i X_{ij} \)) and the squared terms of the non-essential (\( r_i X_{ij}^2 \)) inputs are omitted.
On the basis of observations during data collection, over the four year period, certain inputs are known to be more important for some enterprises than for others. Thus, for example, fertiliser is not applied to horsebeans while particular effort is expended on seed-bed preparation (an "essential" input) for barley. Furthermore, a fairly substantial amount of labour time is spent on weeding of wheat and horsebeans.

On the one hand because of the expected positive contribution of these inputs to output the signs of $a_1$ and $b_1$ are anticipated to be positive. On the other hand since the essential inputs and weeding are traditional, farm-based, inputs and farmers are assumed to have good knowledge of their application they are assumed to work in the rational phase of the production function where output is increasing at a decreasing rate (decreasing marginal product but greater than zero). Hence the signs of $w_1$ and $r_1$ are expected to be negative. However, in case of the new (purchased) input, fertiliser, the expected sign of $b_1$ may not be followed by a negative $r_1$ since farmers apply fertiliser at well under the recommended rate.

It is required to pool the cross-sectional time-series data in order to account for the non-observable variable of management (technical efficiency). However, difficulty arises in applying ordinary least squares (OLS) procedure on pooled data, if there exists significant differences between the two periods, since OLS assumes homogeneity both in intercept and slope coefficients. Accordingly, tests for homogeneity in both intercepts and slope between the two periods were done using the Chow test (Chow, 1960). To test whether there was no significant difference between the estimates of the two years the null hypothesis tested was:

$C_0 = C_0', \quad A_1 = a_1 \ldots \ldots, \quad A_k = a_k$

$B_1 = b_1 \ldots \ldots B_k = b_k', \quad R_1 = r_1 \ldots \ldots R_k = r_k$

where $C_0', \quad A_1 \ldots \ldots A_k, \quad B_1 \ldots \ldots B_k, \quad R_1 \ldots \ldots R_k$

refer to 1980 data and

$c_0, \quad a_1 \ldots \ldots a_k, \quad b_1 \ldots \ldots b_k, \quad r_1 \ldots \ldots r_k$

to 1981 data.
This null hypothesis was tested against the alternative hypothesis that at least one of the equalities does not hold true. The test was performed by comparing the residual sum of squares of the estimates of the two periods as indicated by the $F$-statistic.

$$F = \frac{(SSE_c - SSE_1 - SSE_2)}{(K)}$$

$$= \frac{(SSE_1^+ SSE_2)}{(N+M-2K)}$$

where: $K$ denotes the number of regressors used including the intercept;

$N$ refer to the number of observations in year 1980;

$M$ refer to the number of observations in year 1981;

$SSE_c$ is the residual sum of squares for the estimated equation on all observations combined;

$SSE_1$ is the residual sum of squares for the estimated equation of 1980 data;

$SSE_2$ is the residual sum of squares for the estimated equation of 1981 data.

If the calculated value of the $F$-statistic is larger than the theoretical value of $F$ at 5 per cent level of significance with $K$ and $N+M-2K$ degrees of freedom, the null hypothesis is rejected. Hence the data cannot be pooled without including a time dummy variable. The residual sum of squares, the calculated and tabulated values of the $F$-statistics at the respective degrees of freedom at 5 per cent level of significance for the three crops is shown in Table 4.2.

The calculated value of the $F$-statistics is less than the critical $F$ value in only Horsebeans, the test of overall homogeneity is not rejected, therefore the time-series and cross-sectional data were legitimately pooled for this particular crop as in equation (4.5). For the remaining two crops, however, the computed $F$ statistics is greater than the theoretical $F$ value and thus the null hypothesis is rejected. Accordingly it is necessary to include time shift dummy variables when pooling the time-series and cross sectional data for both barley and
Table 4-2: Test of significance in differences of the 1980 and 1981 observations

<table>
<thead>
<tr>
<th></th>
<th>Barely</th>
<th>Wheat</th>
<th>Horsebeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSE$_1$</td>
<td>2.577</td>
<td>4.038</td>
<td>5.662</td>
</tr>
<tr>
<td>SSE$_2$</td>
<td>5.001</td>
<td>4.072</td>
<td>4.430</td>
</tr>
<tr>
<td>SSE$_C$</td>
<td>9.264</td>
<td>12.702</td>
<td>10.192</td>
</tr>
<tr>
<td>K</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>N</td>
<td>33</td>
<td>23</td>
<td>28</td>
</tr>
<tr>
<td>M</td>
<td>33</td>
<td>23</td>
<td>28</td>
</tr>
<tr>
<td>Cal.F</td>
<td>2.49</td>
<td>4.076</td>
<td>0.171</td>
</tr>
<tr>
<td>Crit.F</td>
<td>2.39</td>
<td>2.48</td>
<td>2.580</td>
</tr>
</tbody>
</table>

wheat as in equation (4.6)$^1$ and (4.7) respectively. Although the full modified transcendental production function will be attempted now, with time and management dummies the final production functions for the pooled data are likely to be one of the following:

(4.5) \[ q_j = C_0 + M_j + a_1x_{1j} + a_2x_{2j} + b_3x_{3j} + v_j \]

(4.6) \[ q_j = C_0 + M_j + a_1x_{1j} + a_2x_{2j} + b_3x_{3j} + b_4x_{4j} + T_j + v_j \]

(4.7) \[ q_j = C_0 + M_j + a_1x_{1j} + a_2x_{2j} + b_3x_{3j} + r_3x_{3j}^2 + b_4x_{4j} + T_j + v_j \]

$^1$ Though the Chow test does not differentiate between homogeneity in slope and intercept there is no theoretical ground to have different elasticities in consecutive cropping seasons. Hence only the shift dummy is included which captures mainly the weather factor. This assumes that (lower) output is proportional to the level of any input under harsh weather conditions like frost.
where:

$q_j = \text{log value of output on the farm } j$;

$M_j = \text{farm specific dummy for farm } j$;

$x_{1j} = \text{log of land input (essential) of farm } j$;

$x_{2j} = \text{log of labour input (essential) employed for seed-bed preparation of farm } j$;

$x_{3j} = \text{labour input employed for weeding of farm } j$;

$x_{4j} = \text{fertiliser input of farm } j$;

$T_j = \text{shift dummy variable which takes the value of one for 1980 observations and zero for 1981 observations}$

$C_0$ is constant and $a_i, b_i, r_1$ are parameters and $\nu_j = \text{error term}$.

Note that $b_3$, $b_4$, $r_3$ and $r_4$ are used instead of $b_1$, $b_2$, $r_1$ and $r_2$ to maintain consistency with the corresponding variables of $x_3$ and $x_4$ and all the functional forms are L-S-L.

The inclusion of farm specific dummy variables to cross-sectional time-series pooled data implies that management remains constant over time.

In estimating equation (4.5), (4.6) and (4.7) it is required to use $(N-1)$ farm dummy variables. The remaining one is omitted to avoid perfect collinearity among the explanatory variables (Pindyck and Rubinfeld, 1983 pp. 254). Therefore, $M_j = 1$ for $j = 2 \ldots n$ and zero otherwise. Since this study has available multi-crop time-series observations, it was possible to apply either Hoch-Mundlak model using pooled cross-sectional time-series data for each crop separately or Massel's model by pooling cross-sectional crops for the two years separately. An attempt has been made to apply Massell's model in accounting for the nonobservable variable, management ability, by pooling crops instead of time. Nevertheless the method of accounting for crops of different elasticity (see Massell and Johnson, 1968) gave rise to inaccurate estimates which were detected from the average
values. As a result this study shifted to the more familiar model of Hoch-Mundlak.

Analysis of covariance is used to test whether there exists significant differences in technical efficiency among the farmers. The null hypothesis tested is all $M_j$ equal zero ($M_j = 0$), against the alternative hypothesis that at least one "$M" is not equal to zero ($M=0$). In testing this hypothesis the ratio of the residual variance estimated without farm dummies ($SSE_1$) to that of with farm dummies ($SSE_2$) is tested using the F-test. If the F value that was obtained in this test (with the respective degrees of freedom) is larger than the critical value of F-statistics at 5 per cent level, it suggests that the null hypothesis be rejected and there is significant difference in technical efficiency among farmers. The results obtained for the three crops indicate that there are indeed significant differences in technical efficiency among the farmers at 5 per cent level of significance. The results are tabulated in Table (4.3).

Table 4-3: Test of significance in technical efficiency

<table>
<thead>
<tr>
<th>Crop</th>
<th>$SSE_1$</th>
<th>$SSE_2$</th>
<th>DF</th>
<th>Calculated F</th>
<th>Critical F at 5 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>8.046</td>
<td>1.530</td>
<td>32,28</td>
<td>3.72</td>
<td>1.86</td>
</tr>
<tr>
<td>Wheat</td>
<td>11.637</td>
<td>2.901</td>
<td>22,18</td>
<td>2.46</td>
<td>2.17</td>
</tr>
<tr>
<td>Horse-beans</td>
<td>10.192</td>
<td>2.224</td>
<td>27,25</td>
<td>1.98</td>
<td>1.96</td>
</tr>
</tbody>
</table>

Accordingly the inclusion of farm-specific dummy variables is justified for all crops.

Although the focus of this study is upon technical efficiency because of the subsistence nature of production, an attempt will be made to check on allocative efficiency. Hence, the efficiency of the

---

Massell and Johnson, however, have not reported the average values of the variables used in the production function.
farmers in allocating their resources among different crops was tested from statistical results obtained after the farm specific variables are included. It is only the allocative efficiency of those inputs that have a statistically significant relationship with output are tested. The estimated parameters of the production function are used to compute the marginal product for each factor of production. Efficient resource allocation holds if the marginal value product of an input equals the price of the input, equation (4.8).

\[(4.8) \quad MVP_x = P_x\]

where
- \(MVP_x\) is marginal value product of input \(x\)
- \(P_x\) is price of factor (input) \(x\)

Comparison of marginal value product with the marginal cost of the factor indicates the prevailing degree of allocative efficiency. The most efficient allocation holds when the ratio of marginal value product to price equals one among all inputs (equation 4.9).

\[(4.9) \quad \frac{MVP_{x_1}}{P_{x_1}} = \frac{MVP_{x_2}}{P_{x_2}} = \ldots = \frac{MVP_{x_n}}{P_{x_n}} = 1\]

The estimated allocative efficiency measures indicate the average performance of the farmers in allocating their resources among different uses efficiently. The technical efficiency of the individual farmers are estimated by the farm-specific dummy variables and ranked accordingly. The assumption here is that the farmers have the same production function they only differ in their technical efficiency which is a shift variable.

Furthermore it is investigated whether the technical efficiency is correlated with high (low) use of inputs by regressing the farm-specific coefficients on the independent variables. It is also tested whether the technical efficiency ranking between the different crops varies greatly using Spearman's rank-correlation test.

The study uses ordinary least squares (OLS) as its method of estimation. The OLS is best, linear and unbiased (BLU) only if certain assumptions are made. Violation of these assumptions then will lead to statistical estimation problems. The major problems which have direct bearing on this study are briefly discussed below.
4.3 Statistical estimation problems

4.3.1 Simultaneous equation bias

Application of ordinary least squares (OLS) to the single equation of the production function could lead to simultaneous equation bias. Simultaneous equation bias arises when the error term is correlated with any of the explanatory variables which violates the OLS assumption of homoscedasticity (constant variance of the disturbance terms) (Koutsoyannis, 1977 pp 181-196). It is argued that correlation of explanatory variables with the disturbance term (known as heteroscedasticity) makes the estimated variance of the least squares estimators biased. Simultaneous equation problems occur because farmers do not select inputs randomly, rather they choose inputs in order to maximize output or profit. Hence as in equation (4.10) output, Q is determined by inputs, X. Simultaneously the level of input use, X is a function of output, Q and price of input, P (equation 4.11).

\[(4.10) \quad Q = f( X, u ) \]
\[(4.11) \quad X = f( Q, P ) \]

Simultaneous equation bias becomes a problem when a farm chooses its inputs at the same time or after the output have been realized. Therefore the dependent variable, Q, in (4.10) will be the same as the independent variable, Q, in (4.11). For instance, this problem could be encountered if one takes harvesting or/and post harvest labour activities as an explanatory variable of output. In these cases not only is realized output a function of labour, but also labour is a function of realized output. For this reason, the harvesting and post-harvesting labour are omitted from the estimation. In relation to the other inputs the time lag between application of input and realization of output in crop production makes the farmer apply the inputs at his disposal to maximize anticipated rather than realized output. Furthermore test for heteroscedasticity is made by regressing the residuals on the independent variables which in all cases zero correlation was observed. The absence of correlation between the residuals and the independent variables is further exemplified by the scattergram of the independent variables and the residuals of the main crop, barley. Since the scattergrams of the remaining two crops are not very different from that of barley they are left...
unreported. Consequently, there arises no simultaneous equation bias in this study and hence OLS can be applied to the single equation and the estimates remain consistent.
4.3.2 Multicollinearity

Linear relations among any of the explanatory variables, called multicollinearity, could make the estimates of the coefficients indeterminate and enlarge the standard errors of ordinary least squares estimates (Koustsoyannis, 1977 p. 234). This may lead to rejection of an important explanatory variable because of its apparently high standard error. It does not, however, cause bias on the estimated coefficients of the OLS. The problem of multicollinearity is in terms of its severity rather than its existence or non-existence. Partial correlation coefficients provide indication of the degree of multicollinearity. Heady and Dillon (1961 p. 136) suggest that multicollinearity of greater than 0.8 could be taken as sufficient to cause problems. Others (Foot and North, 1977 p. 107) would suggest that a correlation coefficient of greater than 0.9 as being harmful. Accordingly examination of our model for the presence of a high degree of multicollinearity, can be detected by examining the correlation coefficients between the independent variables. Correlation coefficient matrices for each of the three crops are reported along with the estimates to show the degree of multicollinearity among independent variables.

4.3.3 Management bias

Under the assumption that better managers not only obtain higher output with the same inputs but also use more inputs, the omission of the management variable leads to a type of specification bias known as management bias. The pioneers of this work Hoch (1958) and Mundlack (1961) suggest the inclusion of this variable in order to obtain consistent estimates.
Figure 4.2 illustrates this bias. If the production estimates are done without accounting for management the interfarm function would be as represented by $f^1$. However if better managers use more inputs and produce more output the production relationship for better and weaker managers would be as represented by $f_2$ and $f_1$ respectively. As mentioned earlier in this Chapter this study includes the management variable as farm specific shift dummy variables. The next Chapter presents the results obtained following this methodology on the data obtained from the farmers of Debre Berhan in the cropping years of 1980 and 1981.
In this Chapter the results of the production function analysis are dealt with. Section 5.1 examines the estimates of the production function parameters and looks at the returns to scale. Section 5.2 deals with allocative efficiency followed by the measures of technical efficiency among farmers in section 5.3.

As has been discussed in the preceding Chapter, the production function parameters are estimated under the assumptions of no simultaneous equation bias, specification errors that arise from omitting farm specific factors and multicollinearity. It is also evident from Chapter four that log-semi-log (L-S-L) production function which takes both essential and non-essential inputs into account is applied and the equations are estimated using Ordinary Least Squares (OLS) method.

5.1 Estimates of the production function parameters

As mentioned in the preceding Chapter output of each crop is weighted by the corresponding farm gate price primarily to facilitate aggregation of output of grain and straw. The inputs are, however, given in their physical quantities.

Estimates of each crop were done after pooling the time-series cross-sectional data and were specified on total rather than per hectare basis. A specification on per hectare basis was also estimated but did not yield better goodness of fit ($R^2$) therefore not reported here.
5.1.1 Coefficients of production

Table 5.1 presents the estimates of the average production coefficients using modified transcendental function (M-T) as well as the accepted models of log-semi-log (L-S-L) production function.

Table 5-1: Estimates of production coefficient excluding farm dummies

<table>
<thead>
<tr>
<th>Input/Crop</th>
<th>Barley</th>
<th>Wheat</th>
<th>H.beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land (x1)</td>
<td>a1</td>
<td>.5316*</td>
<td>.6274***</td>
</tr>
<tr>
<td>(hec)</td>
<td></td>
<td>(1.65)</td>
<td>(5.38)</td>
</tr>
<tr>
<td>(X1)</td>
<td>w1</td>
<td>.0273</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.118)</td>
<td>(1.02)</td>
</tr>
<tr>
<td>SBP (x2)</td>
<td>a2</td>
<td>.5433**</td>
<td>.2924***</td>
</tr>
<tr>
<td>(md)</td>
<td></td>
<td>(2.15)</td>
<td>(3.05)</td>
</tr>
<tr>
<td>(X2)</td>
<td>w2</td>
<td>-.0086</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.18)</td>
<td>(.32)</td>
</tr>
<tr>
<td>WD (X3)</td>
<td>b3</td>
<td>.1640*</td>
<td>.0668**</td>
</tr>
<tr>
<td>(md)</td>
<td></td>
<td>(1.91)</td>
<td>(2.02)</td>
</tr>
<tr>
<td>2(X3)</td>
<td>r3</td>
<td>-.0198</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.28)</td>
<td>(2.72)</td>
</tr>
<tr>
<td>Frt. (X4)</td>
<td>b4</td>
<td>.5202*</td>
<td>.2009</td>
</tr>
<tr>
<td>(100 kg)</td>
<td></td>
<td>(1.80)</td>
<td>(1.63)</td>
</tr>
<tr>
<td>2(X4)</td>
<td>r4</td>
<td>-.2437</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.12)</td>
<td>(1.77)</td>
</tr>
<tr>
<td>Time dummy</td>
<td></td>
<td>.2872***</td>
<td>.2194***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.84)</td>
<td>(3.01)</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>3.9640</td>
<td>4.5826</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>.76</td>
<td>.73</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>.72</td>
<td>.71</td>
</tr>
<tr>
<td>F-ratio</td>
<td></td>
<td>19.7</td>
<td>33.0</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>66</td>
<td>66</td>
</tr>
</tbody>
</table>

Note: Prmt., hec, md, SBP, WD and Frt. denote parameters, hectares, man days sed-bed preparation labour, weeding labour and fertiliser respectively.

Figures in brackets refer to t-values

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

The estimates are done from cross-sectional time-series pooled data excluding farm specific variables (farm dummy), applying equation 4.5, 4.6 and 4.7 for horsebeans, barley and wheat respectively.

The results are very encouraging: the coefficients in the modified transcendental functions are of expected signs with the
exception of $w_1$ in barley and horsebeans, and $w_2$ in wheat. Since farmers apply fertiliser well below the rate recommended it was anticipated that the sign of $r_4$ might not be negative but it was negative for both barley and wheat, but not statistically significant in the former. The parameters of the L-S-L functions of each crop are obtained by reestimating the functions after omission of the non-significant variables, particularly the exponential terms of the essential inputs and the squared terms of the non-essential inputs. Since these variables are entered into the modified transcendental function in order to indicate whether the production process is taking place in either increasing or decreasing marginal productivities phase, their exclusion is justifiable if they are not statistically significant.

It is evident from Table 5.1 that the explanatory power of the chosen function (L-S-L) is high for barley and horsebeans and moderate for wheat with 73, 81, and 63 per cent respectively of the variation in output being explained by the included observable independent variables. The F-statistics is also significant at 1 per cent level.

For the essential inputs, Table 5.1 also indicates that land is the most important factor in explaining variations in output of barley and horsebeans. With wheat land and Seed-bed preparation labour are of almost equal importance (judged by the size of the elasticities). Seed-bed preparation labour is also an important variable in barley but not in horsebeans. Weeding labour is an important variable in determining the variations in output of all crops whereas fertiliser is significant only in case of wheat.

As the estimates in Table 5.1 are done excluding farm specific variables, the equations are not fully specified and hence the results obtained from this specification are of little use for further analytical purposes. Better specified relationships are obtained by including 32, 22 and 27 farm specific dummy variables to shift across 33, 23 and 28 farms of barley, wheat and horsebeans respectively. The results of the estimates of observable inputs obtained after including farm specific dummy variables are tabulated in Table 5.2. The parameters of the L-S-L are obtained as in Table 5.1 by re-estimating the modified transcendental functions. Despite its high level of
significance in the M-T function, seed-bed preparation labour on barley, \( w_2 \), (entered in the exponential form) was excluded from the L-S-L estimates on grounds of high multi-collinearity with land. Its exclusion then made the coefficients of land and weeding labour significant. The estimates of the farm specific dummy variables will be reported on in section 5.3 since they have no immediate importance for the present analysis.

Table 5-2: Estimates of production coefficients with farm dummies

<table>
<thead>
<tr>
<th>Input/Crop</th>
<th>Barley</th>
<th>Wheat</th>
<th>H.beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land ((x_1)) ( a_1 )</td>
<td>.1122</td>
<td>.4799***</td>
<td>.6128</td>
</tr>
<tr>
<td>(ha.) ( (x_1) ) w_1</td>
<td>.0637</td>
<td>--</td>
<td>-.2573</td>
</tr>
<tr>
<td>SBP ((x_2)) ( a_2 )</td>
<td>1.067***</td>
<td>.4389***©</td>
<td>-.1367</td>
</tr>
<tr>
<td>(md) ( (x_2) ) w_2</td>
<td>-.0201***</td>
<td>--</td>
<td>.0124</td>
</tr>
<tr>
<td>WD ((x_3)) ( b_3 )</td>
<td>-.0776</td>
<td>.0583**</td>
<td>.1307**</td>
</tr>
<tr>
<td>(md) ( (x_3) ) r_3</td>
<td>.0224</td>
<td>--</td>
<td>-.0053*</td>
</tr>
<tr>
<td>Frt. ((X_4)) ( b_4 )</td>
<td>-.2546</td>
<td>.0651</td>
<td>2.2650</td>
</tr>
<tr>
<td>(100 kg) ( (X_4) ) r_4</td>
<td>.2281</td>
<td>--</td>
<td>8.2240</td>
</tr>
<tr>
<td>Time dummy</td>
<td>.3889***</td>
<td>.3620***</td>
<td>.2849*</td>
</tr>
<tr>
<td>Constant</td>
<td>2.443</td>
<td>4.179</td>
<td>5.427</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>.96</td>
<td>.95</td>
<td>.91</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>.91</td>
<td>.88</td>
<td>.72</td>
</tr>
<tr>
<td>F-ratio</td>
<td>17.5</td>
<td>14.2</td>
<td>4.8</td>
</tr>
<tr>
<td>N</td>
<td>66</td>
<td>66</td>
<td>46</td>
</tr>
</tbody>
</table>

Note:© denotes the coefficients that have increased in magnitude with the inclusion of farm specific dummy. The remaining symbols are as defined earlier in Table 5.1. The actual farm dummies are presented in Table 5.7.

Related statistics of sample means, standard deviations and correlation matrix are given in Table 5.3.

With the inclusion of farm specific variables the explanatory
Table 5-3: Sample means, standard deviations and correlation matrix

Sample means and standard deviations

<table>
<thead>
<tr>
<th>Sample means and standard deviations</th>
<th>Barley</th>
<th>Wheat</th>
<th>Horsebeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output (GM Birr)</td>
<td>442.75(1.97)</td>
<td>130.32(2.12)</td>
<td>134.16(2.57)</td>
</tr>
<tr>
<td>Land (GM hec.)</td>
<td>1.41(1.76)</td>
<td>.2339(1.96)</td>
<td>.3389(2.11)</td>
</tr>
<tr>
<td>Seed-bed pr. (GM md)</td>
<td>32.92(1.97)</td>
<td>3.78(2.36)</td>
<td>4.32(3.19)</td>
</tr>
<tr>
<td>Weeding (AM md)</td>
<td>.708(1.41)</td>
<td>2.36(4.13)</td>
<td>4.65(6.97)</td>
</tr>
<tr>
<td>Fertiliser (AM 100 kg)</td>
<td>.394(.40)</td>
<td>.023(.06)</td>
<td>-----</td>
</tr>
</tbody>
</table>

Correlation matrix of coefficients

<table>
<thead>
<tr>
<th>Land</th>
<th>SBP</th>
<th>WD</th>
<th>FR</th>
<th>Land</th>
<th>SBP</th>
<th>WD</th>
<th>FR</th>
<th>WDD</th>
<th>Land</th>
<th>SBP</th>
<th>WD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP</td>
<td>.687</td>
<td>1</td>
<td></td>
<td>.628</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>.543</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WD</td>
<td>.126</td>
<td>.048</td>
<td>1</td>
<td>.239</td>
<td>.236</td>
<td>1</td>
<td></td>
<td></td>
<td>.334</td>
<td>.257</td>
<td>1</td>
</tr>
<tr>
<td>FR</td>
<td>.321</td>
<td>.220</td>
<td>.031</td>
<td>1</td>
<td>.271</td>
<td>.341</td>
<td>.234</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WDD</td>
<td>.190</td>
<td>.236</td>
<td>.909</td>
<td>.368</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Figures in brackets refer to standard deviations; GM and AM refer to geometric and arithmetic mean and WDD stands for the squared term of weeding labour on wheat.

The power of the functions as indicated by the coefficient of determination adjusted for degrees of freedom ($R^2$) is raised from .71, .56 and .80 to .88, .76 and .83 in barley, wheat and horsebean respectively. This signifies once again the importance of farm specific variables in explaining the variations in output.

The coefficients in all the three crops have signs consistent with economic theory with the exception of seed-bed preparation labour in wheat (L-S-L function). Similarly with the exception of this variable all the coefficients which were significant prior to inclusion of farm dummies have also maintained their significance afterwards. Fertiliser still remains an unimportant variable in barley production. This might be due to the use of fertiliser well below the rate recommended by physical scientists which is also indicated by the positive sign (increasing marginal product) of $r_4$ in the function. As is observed from Table 5.3 the overall average use of fertiliser on barley fields
is only 39.4 kg. per farm\(^1\) (or 35.8 kg. per hectare with a range of 0 and 89 kg per hectare). This compares to the recommended average rate of 120 kgs. per hectare (IAR, 1979). The effectiveness of the fertiliser applied might be further hampered by the use of low yielding local seed varieties instead of using improved seeds (which are not yet available for any of these crops in this area of the country). Though the fertiliser rate applied on wheat is not very different from barley the estimate suggests that fertiliser is more important variable in wheat production. As indicated in Chapter 2 farmyard manure is applied on wheat but it is not accounted for in production function because of the lack of data on the amount used. Only if the amount of manure applied was proportional to the fertiliser used would the effect be captured in the fertiliser variable. This is unlikely. Manure is then an omitted variable which will influence the measure of technical efficiency.

The time dummy variable in both barley and wheat is positive and significant indicating that the output obtained in the normal year (1980) was significantly higher than the bad year (1981) when frost occurrence resulted in lower output. The estimates indicate that the constant in barley was 4.179 (65.3) in 1981 and 4.541 (93.8) (constant plus time coefficient) in 1980 which shows 30 per cent higher output in good year (1980) than in 1981.\(^2\) The difference between the constant of wheat in the two years, however, is not as big as that of barley which was 5.308 (202) in 1981 and 5.592 (268) in 1980. That is, output was 25 per cent lower in 1981 than 1980. The estimates are consistent with the empirical fact that barley is the most exposed crop to frost since it is sown on the bottom land where frost occurrence is highest.

The inclusion of farm dummies in the estimates have also altered the magnitude of the coefficients of the variables. Out of the eleven coefficients of all the three crops estimated, eight of them show the expected decline while the remaining three have increased. This implies that those which have declined are positively correlated with

---

\(^1\)This is the average of those farms which actually applied fertilizer.

\(^2\)Figures in bracket are antilogs.
This can better be observed in relation to management elasticity. Yotopoulos (1976) has shown that the elasticity of management with respect to factor inputs can be obtained by subtracting the elasticity of output with respect to a factor input including management from the elasticity obtained excluding management. For instance in case of land in barley the elasticity of management will be 0.15 implying that better managers use more land to increase output. Accordingly better managers use more of the eight inputs which have declined with the inclusion of farm specific variables and less of the other three inputs in raising output.

Elasticities of production are obtained from the production coefficient estimates.

5.1.2 Elasticities of production

Elasticity of production with respect to an input represents a percentage change in output with respect to a percentage change in input. In a log-linear function the regression coefficients of production equal the elasticities of the respective inputs. In the log-semi-log (L-S-L) production function used in this study, only the coefficients of those variables entered in log-linear form, that is, land and seed-bed preparation equal to the elasticities of their respective inputs. The other variables, weeding and fertiliser, included in exponential form their elasticities are obtained by multiplying the regression coefficient $b_i$ and $b_i + r_i$ by the mean value of input as shown in equation 5.1 and 5.2 respectively.

\[
\frac{\partial Q}{\partial X} = e^{b_i X}
\]

\[
E = f_1^3 X/Q = b_1 X_1 i \frac{b_i X}{e^{b_i X}} = b_i X
\]

\[
Q = e^{b_1 X_1 i + r_i X^2}
\]

\[f_i \] refers, in this case, to marginal value product since $Q$ is in money value.
\[ \frac{dQ}{dx} = e_1 X_i + r_1 X_i^2 \]

\[ E = \left( f_1 \right) X_i / Q \]

\[ = b_1 X_i + r_1 X_i^2 \]

\[ = b_1 X_i + 2r_1 X_i^2 \]

The coefficients are multiplied by \( \bar{X} \) (arithmetic mean) instead of \( X_i \) in order to obtain the elasticities at average values. The elasticities of production obtained this way are tabulated in Table 5.4.

**Table 5-4: Elasticities of production**

<table>
<thead>
<tr>
<th>Input</th>
<th>Barley</th>
<th>Wheat</th>
<th>H.beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>.480</td>
<td>.574</td>
<td>.869</td>
</tr>
<tr>
<td>Seed-bed pre.</td>
<td>.439</td>
<td>-.090</td>
<td>.073</td>
</tr>
<tr>
<td>Weeding</td>
<td>.041</td>
<td>.245</td>
<td>.096</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>.026</td>
<td>.092</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td>.986</td>
<td>.821</td>
<td>1.038</td>
</tr>
</tbody>
</table>

The sum of elasticities indicate increasing, constant or decreasing returns to scale depending on whether the elasticities sum up to greater than one, one, or less than one respectively. Returns to scale entail the direction of change in output when inputs are changed simultaneously in the same proportion. For instance, in case of increasing returns to scale a simultaneous increase in inputs in certain proportion gives rise to a more than proportional change in output, and similar argument holds for decreasing and constant returns to scale.

As this study is dealing with semi-subsistence agriculture there are no significant indivisibilities that may give ground for "a priori" anticipation of increasing returns to scale. Accordingly constant returns to scale is hypothesized. The results in Table 5.4 are indicative but for completeness the statistical test is presented. The null hypothesis tested is that the elasticities sum to unity in each crop against the alternative hypothesis that they are different from unity. For each crop:
H₀: \[ \sum S_i \cdot 1 = 0, \]
Hₐ: \[ \sum S_i \cdot 1 \neq 0, \]
\[ t = \frac{\sum S_i \cdot 1}{\text{Standard error of the coefficients}} \]

where \( S_i \) = the sum of elasticities
\( i = 1, 2, \ldots k \) and \( k \) are the number of explanatory variables.

The statistics relevant to compute the t-ratio of the sum of the elasticities along with the computed and critical t-values are presented in Table 5.5.

<table>
<thead>
<tr>
<th>Table 5-5: Sum of elasticities, variance and covariance along with computed and critical t-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
</tr>
<tr>
<td>Sum of elasticities</td>
</tr>
<tr>
<td>Sum of the variances</td>
</tr>
<tr>
<td>Sum of the covariances</td>
</tr>
<tr>
<td>Standard error of the Coe.</td>
</tr>
<tr>
<td>Computed t-values</td>
</tr>
<tr>
<td>Critical t-values</td>
</tr>
</tbody>
</table>

The results obtained for all the three crops are consistent with the null hypothesis at 5 per cent level of significance and that constant returns to scale do indeed prevail in the production of all the three crops.

5.1.3 Marginal productivities and their standard errors

Marginal value productivities can be derived from the estimated coefficients for the different functional forms as shown below.

\[ (5.3A) \quad \text{MVP}_{X_i} = \frac{a_i Q}{X_i} \quad \text{(for } x_i \text{ i.e log } X) \]
\[(5.3B)\quad \frac{\text{MVP}}{\text{iEB}}_{X_i} = b_i \frac{Q}{X_{i}} \quad (\text{for } X_i)\]

\[(5.3C)\quad \frac{\text{MVP}}{\text{iEB}}_{X_i} = (b_i + 2r_i X_i) \frac{Q}{X_{i}} \quad (\text{for } X_i + X_i^2)\]

where:

- MVP\(_{X_i}\) refers to the marginal value product of input \(X_i\);
- \(i \in A\) and \(i \in B\) indicate a set of essential and non-essential variables respectively;
- \(Q\) stands for output;
- \(X_i\) refers to the input \(X_i\);
- \(x_i\) refers to the log input \(X_i\) and
- \(a_i\), \(b_i\) and \(r_i\) stand for parameters.

\(Q\) and \(X_i\) are taken at their geometric means for the loged variables of land and seed-bed preparation. They are calculated at their arithmetic means for the variables entered in the exponential form, weeding and fertiliser.

It is worth noting that only the marginal value productivities of those variables which were statistically significant in explaining the variation in output (see Table 5.2) are accounted for. The standard errors of the marginal value productivities are obtained by taking the square root of the respective variances. The variances of the marginal value productivities are computed applying the formula developed by Carter and Hartley (1958).

\[(5.4)\quad \text{Var} \left( \frac{f_{X_i}}{X_i} \right) = \left( \frac{Q}{X_i} \right)^2 \text{Var} \left( \frac{E_{X_i}}{X_i} \right) + \]

Where \(\left( S_{i} \right)^2\) refers to the unexplained variance in log \(Q\);

- \(n\) stands for the number of observations
- and the other symbols are as defined earlier.

The marginal value productivities and their standard errors computed in this manner along with calculated and critical t-values are tabulated in Table 5.6.
Table 5-6: Marginal value product, prices of inputs and t-values

<table>
<thead>
<tr>
<th></th>
<th>Marginal value products (Birr)</th>
<th>Price of inputs (Birr)</th>
<th>T-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Calculated</td>
</tr>
<tr>
<td><strong>Barley:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>151 (54.39)</td>
<td>60.00</td>
<td>1.67</td>
</tr>
<tr>
<td>Seed-bed pre.</td>
<td>6 (2.00)</td>
<td>5.00</td>
<td>.449</td>
</tr>
<tr>
<td>Weeding</td>
<td>26 (18.5)</td>
<td>2.00</td>
<td>1.28</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>N.S</td>
<td>86.00</td>
<td>N.A</td>
</tr>
<tr>
<td><strong>Wheat:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>320 (173.7)</td>
<td>426.00</td>
<td>-0.61</td>
</tr>
<tr>
<td>Seed-bed pre.</td>
<td>N.S</td>
<td>5.00</td>
<td>N.A</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>N.A</td>
<td>86.00</td>
<td>.04</td>
</tr>
<tr>
<td>Weeding</td>
<td>13.5 (8.25)</td>
<td>2.00</td>
<td>1.64</td>
</tr>
<tr>
<td><strong>H.beans:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>344 (105.7)</td>
<td>270.00</td>
<td>0.28</td>
</tr>
<tr>
<td>Seed-bed pre.</td>
<td>N.S</td>
<td>5.00</td>
<td>N.A</td>
</tr>
<tr>
<td>Weeding</td>
<td>2.77 (.799)</td>
<td>2.00</td>
<td>.99</td>
</tr>
</tbody>
</table>

Note N.S and N.A refer to not significant and not applicable. Values in brackets are standard errors.

It is not relevant to test the allocative efficiency of fertiliser application in wheat because its application has not yet reached the economically important region of stage II of the traditional production function. This is detected by the positive coefficient, $r_4(8.22)$ indicating that the marginal product of fertiliser is increasing.

5.2 Allocative efficiency

Rational allocation of resources occur when the marginal value products are equated to the respective price of input. The test for equality between marginal value productivities and price of the corresponding input is made at 5 per cent level of significance. The null hypothesis tested is that there is no difference between the
marginal value productivity and the price of the corresponding input against the alternative hypothesis that there is difference:

\[ H_0 = \text{MVP}_{X_i} - P_{X_i} = 0 \]

\[ H_a = \text{MVP}_{X_i} - P_{X_i} \neq 0 \]

Where \( P_{X_i} \) is the price of inputs \( X_i \).

\[
 t = \frac{\text{MVP}_{X_i} - P_{X_i}}{\text{standard error of } MP_{X_i}}
\]

The prices of all inputs with the exception of land are taken at their market values. Price of seed-bed preparation is set at 5 Birr because a man with a pair of oxen is hired for 5 Birr a day. Similarly, the weeding price of two Birr is the wage rate paid for hired labour per day. Despite the fact that substantial amount of the labour comes from the family members use of market wage rate as price of labour assumes that if they do not work on their own farm they can hire out their labour at the market wage rate.\(^4\)

Nevertheless land requires different treatment. As was mentioned in the earlier chapters land belongs to the rural people and is not subject to any form of exchange, instead it is distributed to the farm families by the peasant association of the respective village. Consequently land does not have market price and is valued at its opportunity cost. The opportunity cost of land in growing each crop is the alternative use of that land foregone because of growing that specific crop. The opportunity cost of barley land is taken at 60 Birr per hectare which is the estimated average value of hay per hectare.\(^5\)

\(^4\)Output prices are not affected much by the bad weather because the frost occurred mainly in the study area which is located on a major trade route to Addis Ababa. The actual annual average prices for the crops are given on page 40. Given this circumstance and the subsistence nature of the farming system there would be no variations in the wage rate.

\(^5\)since there is no cost involved in growing hay except harvesting labour, the value of hay is accounted net of harvesting labour
This is because if barley is not grown on barley land no other crop is grown on it and is left fallow except in few cases where minor crops are grown. Hence the value the farmer gains from leaving his barley land uncultivated is mainly the value (sale) of hay from that land. Wheat and horsebeans are however grown on the same type of land. Accordingly the opportunity cost of wheat land is taken as the return to land in growing horsebean and vice versa.\(^6\)

As shown by the calculated and critical t-values there is no significant difference between marginal value products of inputs and their respective prices indicated by lower calculated than critical t-values. This implies that there is little misallocation of resources by the semi-subsistence farmers. Consequently output cannot be significantly raised by reallocating the existing resources.

However, great caution has to be taken in interpreting these results for at least two reasons. First, in the case of weeding in barley and wheat the associated standard errors of the coefficients are high. The t-test inclines not to reject the null hypothesis that there is no significant difference between the marginal value product and the respective input price, particularly the reliability of the test becomes more questionable with high standard errors of the marginal value product. Besides the estimates obtained from a production function like log-semi-log indicate the performance of the farmers on the average not to the performance of individual farmers. Secondly, the assumption of single opportunity prices of the inputs may be called into question in a traditional agricultural situation where there is little monetary exchange but much more "informal" exchange of labour.

In all cases with the exception of land in wheat the marginal value products are higher than the respective prices and economic theory suggests that the use of such inputs could be increased. The converse would be true in the case of land in wheat where the marginal value product is lower than the price.

---

\(^6\) The return to land is obtained by deducting all the costs except that of land from the average revenue obtained from a hectare of land in growing that particular crop. However, this measurement is only a proxy to the real measurement. The real measurement is more complex since they use both crops for diet and rotationally.
Having presented an overview of the average allocative efficiency of the semi-subsistence farmers, the study now examines the degree to which farmers differ in their technical efficiency, this does not require such strong assumptions as competitive markets as analysis of allocative efficiency.

5.3 Technical efficiency

As the estimation method in this study has included farm specific dummy variables in an attempt to specify fully the production relationship, the coefficients of the farm specific dummy variables indicate the technical efficiency differential of each farm from the base farm. The estimated coefficients of the observable inputs along with farm specific coefficients of the three crops are tabulated in Table 5.7. The distribution of the technical efficiency of the farms in the three crops can also be observed from the scattergrams in Figure 5.1. It is evident from Figure 5.1 that most of the observations are clustered around the mean value. It is only those observations which are also indicated by the regression coefficients (see Table 5.7) as significant that are placed away from the cluster. This results is expected since in order to have a more or less equal distribution of farms on both sides (positive and negative) of the base farm, the average farm is taken deliberately as the base farm (that is, the farm whose dummy variable is omitted to avoid a singular matrix). Accordingly the base farm is ranked 17, 13 and 13 in barley, wheat and horsebean respectively. It is evident from Table 5.7 that only a few farmers are significantly different from the base farm but substantial difference exists between the best, average and worst farm in all the three crops.

In barley, the performance is symmetric about the average. Thus the average farm produces twice as much as the worst farm using the same input (see Table 5.8) and the best farm produces about twice (2.1) as much as the average. When comparison is made with the top and the bottom ten per cent, the top ten per cent produces three times as

---

7The comparison is made between the antilogs of the farm intercepts (farm specific coefficient plus constant).
Table 5-7: Estimates of production coefficients along with farm dummy variables

<table>
<thead>
<tr>
<th>Input/Crop</th>
<th>Barley</th>
<th>Wheat</th>
<th>H.beans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prmt. coeff.</td>
<td>rank</td>
<td>coeff.</td>
</tr>
<tr>
<td>Land((x_1))</td>
<td>a1 .4799(3.06)***</td>
<td>.7429(2.42)**</td>
<td>.8688(5.98)***</td>
</tr>
<tr>
<td></td>
<td>a2 .4389(3.30)***</td>
<td>-.1385(.78)</td>
<td>.0726(.88)</td>
</tr>
<tr>
<td>Weed((x_3))</td>
<td>b3 .0583(2.00)**</td>
<td>.0259(1.11)</td>
<td>.0206(1.78)*</td>
</tr>
<tr>
<td>Weed((x_3^2))</td>
<td>r4 --</td>
<td>-.0052(2.30)**</td>
<td>--</td>
</tr>
<tr>
<td>Fert.((x_4))</td>
<td>b4 .0651(.45)</td>
<td>3.1070(1.90)*</td>
<td>--</td>
</tr>
<tr>
<td>T. dummy</td>
<td>.3620(4.67)***</td>
<td>.2899(2.09)**</td>
<td>--</td>
</tr>
</tbody>
</table>

|         | Prmt. coeff. | rank | coeff. | rank | coeff. | rank |
| F1      | -.2995(1.22) | 27   | -.0399(0.10) | 14   | .1482( .34)** | 10   |
| F2      | -.6902(2.50)** | 33   | -- | -- |
| F3      | -.5695(1.93)* | 32   | -- | -.2697(0.67) | 23   |
| F4      | -.4859(1.82)* | 31   | -.0851(0.23) | 15   | -- |
| F5      | -.2046(0.87) | 22   | -- | .0000 |
| F6      | .0711(0.25) | 15   | -- | -.0887(0.23) | 16   |
| F7      | -.1544(0.61) | 20   | -- | -.4021(0.90) | 25   |
| F8      | .2189(0.61) | 8    | .6370(1.56) | 4    | .2556(0.56) | 5    |
| F9      | -.0564(0.16) | 18   | -- | -- |
| F10     | -.5639(2.04)** | 30   | -.2068(0.55) | 17   | -.5903(1.50) | 27   |
| F11     | .2501(0.84) | 7    | .2935(0.76) | 10   | .2369(0.60) | 7    |
| F12     | .0000 | 17   | -.3237(0.88) | 20   | -.1802(0.45) | 19   |
| F13     | .1710(0.57) | 12   | -- | -.8966(2.27)** | 28   |
| F14     | .3177(1.15) | 4    | -.3484(0.95) | 21   | -.1461(0.33) | 18   |
| F15     | .2022(0.70) | 10   | .9171(2.43)** | 1   | .3141(0.78) | 4    |
| F16     | .0426(0.16) | 16   | -.9177(2.07)** | 22   | .2367(0.54) | 8    |
| F17     | -.4383(1.56) | 29   | -- | -- |
| F18     | .2852(1.00) | 5    | -- | -.2479(0.63) | 22   |
| F19     | .2086(0.81) | 9    | .4524(1.24) | 8    | .6009(1.51) | 2    |
| F20     | -.2385(0.82) | 24   | .4723(1.00) | 6    | -.0283(0.07) | 14   |
| F21     | .4525(1.40) | 2    | .0000 | 13   | -.1087(0.28) | 17   |
| F22     | .2678(0.95) | 6    | .4641(1.23) | 7    | .2109(0.52) | 9    |
| F23     | .1823(0.68) | 11   | .4502(1.12) | 9    | .2550(0.64) | 6    |
| F24     | .3763(1.34) | 3    | .7352(1.76)* | 3   | .5294(1.37) | 3    |
| F25     | -.1974(0.69) | 21   | -.2412(0.42) | 18   | -.2077(0.49) | 21   |
| F26     | .0759(0.28) | 14   | .0981(0.21) | 12   | .0784(0.18) | 12   |
| F27     | -.3059(1.26) | 28   | -.3094(0.81) | 19   | -- |
| F28     | -.2392(1.01) | 25   | -- | -.0321(0.08) | 15   |
| F29     | -.1305(0.47) | 19   | -.0960(2.14)** | 23   | -.3064(0.76) | 24   |
| F30     | .7607(2.96)** || 1   | .7649(1.68) | 2    | .7117(1.79)* | 1    |
| F31     | .0977(0.33) | 13   | -.0895(0.24) | 16   | .1228(0.32) | 11   |
| F32     | -.2287(0.88) | 23   | .5060(1.23) | 5    | -.5063(1.27) | 26   |
| F33     | -.2732(1.06) | 26   | .1772(0.47) | 11   | -.1932(0.48) | 20   |
| CONSTANT | 4.1797 | 5.308 | 5.6550 |
| \(R^2\) | .95 | .96 | .83 |
| F-ratio | 14.2 | 6.3 | 10.1 |
| N       | 66 | 46 | 56 |

Note: This Table is an expansion of Table 5.2.

Great as the worst ten per cent and a little less than (1.7) times that of the average.
Figure 5-1: The distribution of technical efficiency among farmers

More or less similar results are obtained from horsebeans where the best farm produces five and two times as great as the worst and average farm respectively. The greatest variation in technical efficiency occurs in wheat production. The best farm produces more than
Table 5-8: Comparison of technical efficiency (farm intercepts between the best, average and worst farms)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Wheat</th>
<th>Horsebeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best</td>
<td>4.934 (139.77)</td>
<td>6.221 (503.2)</td>
<td>6.367 (582.3)</td>
</tr>
<tr>
<td>Best(10%)</td>
<td>4.709 (111.01)</td>
<td>6.145 (466.4)</td>
<td>6.269 (528.1)</td>
</tr>
<tr>
<td>Average</td>
<td>4.179 (65.35)</td>
<td>5.304 (201.1)</td>
<td>5.655 (285.8)</td>
</tr>
<tr>
<td>Worst</td>
<td>3.489 (32.78)</td>
<td>4.208 (67.2)</td>
<td>4.759 (116.6)</td>
</tr>
<tr>
<td>Worst(10%)</td>
<td>3.598 (36.52)</td>
<td>4.297 (73.5)</td>
<td>4.991 (147.1)</td>
</tr>
</tbody>
</table>

Note: The number in parentheses are antilogs of the farm intercepts seven times as much as the worst farm but only two and half (2.5) times that of the average farm. The result is not very different when average farm is compared to the top and bottom ten per cent.

The practical importance of these differences in technical efficiencies in increasing output depends on the feasibility of pushing the very poorly performing farms at least to the average level and more importantly the average performing farms which constitute the majority of farms, to the best or to the best 10 per cent level. In order to improve the technical efficiency of the farms it is necessary to know the source of their technical efficiency differential. An attempt is made to identify the sources first by examining whether the technical efficiency variable is associated with more (less) use of certain inputs. Certainly the conventional discussion of management bias (Hoch, 1957) and the decline in eight coefficients between Table 5.1 and 5.2 suggests a generally positive association between management and input levels. Second whether the technical efficiency differential is related to some other factors such as number of plots and size of asset holdings.

---

8 Average performing farms refer to the farms which are not statistically different from the average farm as shown in Table 5.7
5.3.1 The relationship of technical efficiency and use of inputs

The coefficients of farm specific dummy variables were regressed on the included and statistically significant observable inputs in estimating the production relationship and the results obtained are tabulated in Table 5.9. Linear regressions in log of multivariate are applied in the estimation. Massell and Johnson (1968) using this approach did not find any significant relationship between management and included inputs in Rhodesia.

Table 5-9: The relationship of management with variables included in the production function

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Wheat</th>
<th>Horsebeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>.135(1.30)</td>
<td>-.259(2.06)**</td>
<td>4.836(1.65)*</td>
</tr>
<tr>
<td>Seed-bed pre.</td>
<td>-.128(1.55)</td>
<td>N.S</td>
<td>N.S</td>
</tr>
<tr>
<td>Weeding</td>
<td>.005(0.17)</td>
<td>.018(1.08)</td>
<td>-.2018.74</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>N.S</td>
<td>-.267(2.08)**</td>
<td>N.S</td>
</tr>
</tbody>
</table>

Values in parentheses are t-values
N.S refers to not significant in determining variations in output

The results in Table 5.9 are consistent with what was discussed in section 5.1. Management is negatively related with seed-bed preparation in barley, weeding in horsebeans as well as with land and fertiliser in wheat. Nevertheless the relationship with management is significant only in case of land and fertiliser in wheat. Among the remaining four coefficients to which management is positively related only land in horsebeans is statistically significant. Hence, the only variables that are important in explaining variation in output and have also statistically significant relationship with management are land in horsebeans and fertiliser as well as land in wheat. Table 5.9 suggests a rather unexpected result that better managers apply less fertiliser on wheat, expend less labour on weeding horsebeans and put less cultivated land under wheat and more cultivated land under horsebeans. This is also consistent with what is suggested under the allocation of resources earlier with the exception of fertiliser which was then
positive. Since land is allocated by the farmer association, this result has important policy implications which will be discussed again under the policy conclusions. As noted in Section 5.1.1, no account was taken of the application of farmyard manure since these data were not available. The surprising results for fertiliser and wheat may be explained by this omitted variable.

5.3.2 The relationship of technical efficiency and other unaccounted factors in the production function

Technical efficiency also could capture the effect of certain variables which are not included in the estimation of the production function. In this particular study, it is anticipated that the number of plots and size of farm asset holdings could have negative and positive relationship respectively with management. Land in the study area is fragmented ranging from 4 to 19 plots with an average of 10 plots per farm. It is anticipated that the farmers who have fewer number of plots could manage their farm better than those with bigger number of plots. This was examined by regressing farm specific coefficients on overall number of plots as well as plots in each crop.

Overlapping farm activities of the different crops necessitate to consider the total number of plots in each farm as well as the number of plots in each crop as factors influencing technical efficiency. Negative relationship was observed, though not statistically significant, between technical efficiency and total number of plots in all the three crops (see Table 5.10). However different associations are observed between technical efficiency and plots in each crop. The suggested negative and significant relationship between barley plots and technical efficiency could be because of the large number of plots cropped with barley, consisting of more than 70 per cent of the total number of plots. The relationship between technical efficiency and number of plots under wheat is not significant but positive. The lack of significance is not unexpected since most of the farmers have one or two plots under wheat and therefore number of plots might not be an important factor in case of wheat. Negative but low significance is observed from the relationship between technical efficiency and horsebeans. As the land distribution is done by the peasant association
Table 5-10: The relationship of management with variables excluded from the production function

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Wheat</th>
<th>Horsebeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of plots</td>
<td>-.008(0.41)</td>
<td>-.022(.52)</td>
<td>-.024(1.17)</td>
</tr>
<tr>
<td>(Overall)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of plots</td>
<td>-.067(2.16)**</td>
<td>.370(.29)</td>
<td>-.014(.21)</td>
</tr>
<tr>
<td>(Each crop)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm assets</td>
<td>.0001(3.34)**</td>
<td>.0001(1.38)</td>
<td>.0001(3.0)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values in parenthesis are t-values

the number of plots a farmer owns is not within the control of the farmer. Hence, the causation could only be in one direction, that is, having a fewer number of plots enables farmers to be better managers.

"Farm assets" were defined as dwelling house(s), livestock, grain store(s), livestock shade(s), tools and trees in backyard. Their value was very small (see Chapter 2) nevertheless a positive association was observed between size of farm asset and technical efficiency of all crops. But in this case, unlike the number of plots, the direction of the causation could be either way. On the one hand those farmers having larger assets are likely to be better managers because they may have better opportunities to carry out the farm activities in more timely fashion. For instance farmers who own a pair (or more) of oxen have a better chance of preparing their land at the right time than those farmers who hire or borrow a pair of oxen. On the other hand more technically efficient farmers may have more assets because they have been consistently "better farmers". It is also possible that this result is linked to an omitted variable: manure.

It is evident from the foregoing discussion that farm specific coefficients are estimated for each crop separately. It is worth examining whether certain farmers are generally better at producing all crops. This will be tested as the null hypothesis and could be done by applying Spearman's rank correlation test.
5.3.3 Spearman's rank correlation test for management ranking among crops

Spearman's rank correlation test was performed on the technical efficiency ratings among the three crops, two crops taken at a time making up three tests for the three crops. Spearman's rank correlation coefficient is computed applying the formula in equation 5.5.

\[
(5.5) \quad r' = 1 - \frac{6 \sum D^2}{n(n^2-1)}
\]

Where \( D \) refers to the difference between ranks in technical efficiency in two crops and \( n \) stands for the number of observations.

As the number of observations differ in the three crops the rankings were computed by omitting observations which are not present in both crops under comparison. Accordingly 23, 28 and 21 observations are accounted for in the ranking correlations between barley and wheat, barley and horsebeans as well as wheat and horsebeans respectively. Because of the semi-subsistence nature of the farming system in the study area there is no "a priori" ground to expect that there is crop specialization in the sense, that some farmers are significantly better in producing a certain crop than they are in other crops. This is examined by doing a test of significance of the rank correlation coefficient.

The null and alternative hypotheses are:

\[ H_0: \quad \rho = 0 \quad \text{and} \quad H_1: \quad \rho \neq 0 \]

and the t-statistics are found by using the formula:

\[ t = r \sqrt{\frac{n-1}{1-r^2}} \]

Rejection of the null hypothesis implies that the relationship between the ranks is significantly different from zero. The rank correlation coefficients along with their standard errors and the t-values are presented in Table 5.11.

Table 5.11 suggests that the relationship between the technical efficiency rankings of the three crops is significant at 5 per cent level. This implies that the technical efficiency rankings of farmers are similar in different crops.
Table 5-11: The relationship between the technical efficiency rankings of the three crops

<table>
<thead>
<tr>
<th></th>
<th>Barley and Wheat</th>
<th>Barley and H.beans</th>
<th>Wheat and H.beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank correlation coefficient</td>
<td>.44</td>
<td>.51</td>
<td>.61</td>
</tr>
<tr>
<td>Standard errors of the Coeff.</td>
<td>4.69</td>
<td>5.20</td>
<td>4.47</td>
</tr>
<tr>
<td>Calculated t-values</td>
<td>2.06</td>
<td>2.65</td>
<td>2.73</td>
</tr>
<tr>
<td>Critical t-values</td>
<td>1.72</td>
<td>1.70</td>
<td>1.73</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>22</td>
<td>27</td>
<td>20</td>
</tr>
</tbody>
</table>

It is of some interest to examine the relationship between the technical efficiency rankings obtained from the coefficients of farm specific dummy variables and those rankings done during the survey by the author. This ranking of technical efficiency was based on observations as to whether the farmers applied soil conservation measures and the timely completion of farm activities. It could, however, incorporate subjective values as well. Together with a subjective judgment on the general manner and attitude of the farmer towards his farm, farmers were ranked arbitrarily without scale. The rank correlation coefficients for barley, wheat and horsebeans obtained are .42, .36 and .62 respectively. They are all significant at 5 percent level implying that the ranking according to the coefficients of farm specific dummy variables are not statistically different from the ranks done by the author.

The results obtained from this study did not give any evidence that output could be raised substantially by reshuffling the existing resources. But there is some scope to increase production if the weak and average farms can perform as good as the best few farms. However, since the difference in the technical efficiency of the farmers is not solely due to managerial ability and is also influenced by factors such as number of plots, size of farm assets and other factors that might be outside the control of the farmers the increase in output achieved by
improving managerial ability would be much less than what is shown by the calculated differences in technical efficiency.
This chapter gives a summary of the main issues raised in the study and presents concluding remarks followed by policy guidelines that might be deduced from the study.

Ethiopia is an agricultural country where agriculture contributes a substantial proportion (46 per cent) to the GDP and the population at large (88 per cent) earn their livelihood from agriculture. These coupled with the shortage of food problem prevailing in the country calls for means to raise agricultural productivity by either using the existing resources or by introducing new technologies or by a combination of both.

Even though agricultural development programmes have been implemented since mid 1960 they were unsatisfactory both in terms of coverage and effectiveness.

Though the main theme of this study is to examine the technical efficiency of the semi-subsistence farmers of the Ethiopian highlands of the sub-district of Basona-Worona attention is also given to their allocative efficiency on the average. The study was based on farm management data collected by the International Livestock Centre for Africa (ILCA) under the supervision of the author over a period of four years. This study uses a modified transcendental (M-T) production function which can be reduced to a form Log-semi-log (L-S-L), and estimates are computed using the method of Ordinary Least Squares (OLS).

6.1 Summary and Conclusion

In the area of technical efficiency, by and large the literature supports the proposition that there are significant differences in the technical efficiency of farmers in underdeveloped areas.
literature on the allocative efficiency of farmers (meaning that they equate the marginal value products of inputs with the respective input prices) is, however, inconclusive. Nevertheless most of the literature is consistent with the hypothesis of "poor but efficient".

No study of this nature, known by the author, has ever been conducted in Ethiopia. The present study is believed to have some importance in providing information on the allocative and technical efficiency of the farmers under study. More importantly it serves as a guide for further investigation of production relationships, economic efficiency and the returns to productive factors.

Though the statistical estimation problems of simultaneous equation bias, management bias and multicollinearity are believed to be avoided, the assumption of perfect competition under which the allocative efficiency hypothesis is estimated is highly restrictive. With these qualifications, the main findings of the sub-thesis are as follows:

By pooling time-series and cross-section data the results confirm that these farmers live in an uncertain environment, an environment which has made Ethiopia notorious. Output levels of wheat and barley were 25 and 30 per cent higher in 1980 compared with 1981. The 1981 low yield is mainly because of the frequent frost occurrence, hail storm, and untimely rain.

The production function analysis indicates that land is the most important factor of production in producing all three crops. The production elasticities in their order of decreasing importance in barley production were land, seed-bed preparation labour and weeding labour. Fertiliser is not found to be an important factor in producing barley. Similar ordering in wheat production, would be land, weeding labour and fertiliser. In case of horsebeans weeding labour is the only important factor of production other than land. The production function indicates constant returns to scale in all the three crops implying that the outputs just pay the factors of production.

The results obtained suggest that there is little discrepancy between marginal value products of inputs and their respective prices. Hence, there is no evidence, on the average, of inefficient resource allocation. Consequently, the results do not provide evidence that
output could be substantially raised by re-allocating the existing resources within the farms. Not much confidence, however, could be put on the allocative efficiency measure because of certain conceptual problems aside from the high values of standard errors of the marginal value products. Furthermore, a major problem arises in assuming that all inputs and outputs are marketed in a farming system where 86 per cent of the production is for home consumption and about 80 per cent of the labour input comes from family labour. Although far from ideal, this assumption was maintained because of lack of a better alternative method of weighting the output and inputs. Furthermore, the inelasticity of input supply, particularly that of land imposed by the land tenure system and the topography of land is inconsistent with the assumption of perfect competition which the allocative efficiency assumes implicitly. These drawbacks associated with imperfect knowledge of the market and the risky nature of the production process constrain deduction of firm conclusions regarding the allocative efficiency of the semi-subsistence farmers. Nevertheless, the results obtained from this study highlight returns to productive factors.

Technical efficiency, the less restrictive measure of efficiency, was believed to be the more appropriate measure of efficiency for a semi-subsistence farming system as in the study area. As indicated by the coefficients of the farm dummy variables the technical efficiencies of substantial proportion of the farmers (about 80 per cent) are not significantly different from the average farm. However, wide variations in magnitude existed between the few farmers who performed significantly better or worse than the average farmer. The best farmer produces four, five and seven times as much as the worst farmer in barley, horsebean and wheat respectively. The best farmer produces about twice as much as the average farmer in all the three crops. This suggests that total output could at least be doubled if all farmers could achieve the technical efficiency of the best farmer.

In order to raise the technical efficiency of all farmers to the best performing level it is essential to know which variables technical efficiency is related to. Positive relationship between technical efficiency and all the included statistically significant observable inputs was observed, except with seed-bed preparation labour in barley,
weeding on horsebeans as well as fertiliser and land in wheat. This indicates that better managers use more of all inputs except seed-bed preparation labour in barley, weeding on horsebeans as well as fertiliser and land in wheat in raising output. However, it is only the relationship between technical efficiency and fertiliser in wheat as well as land in wheat and horsebeans which are statistically significant.

A check was made to examine whether technical efficiency was related to the excluded variables: number of plots in each crop, total number of plots and farm assets. Though a negative relationship was observed in case of barley and horsebeans plots, the relationship is significant only with barley plots. Positive and very low level of significance was observed with wheat plots indicating the wheat plot variable is unimportant. The technical efficiencies in all crops is found to have negative but not significant relationship with total number of plots. Furthermore, farm asset is positively related to technical efficiency in all crops the relationship being significant with only barley and horsebeans.

As the technical efficiencies were estimated for each crop separately it was tested whether the technical efficiency rankings of farmers differ significantly among the three crops. The Spearman's rank correlation test carried out suggests that the technical efficiency rankings of farmers are similar in different crops. Finally, similar test was done between technical efficiency rankings as obtained from the coefficients of farm specific dummy variables and those rankings given by the author which also did not show significant difference. Although the author has four years experience of collecting data from these farmers, he believes that efficiency rankings by qualified observers could be made by some form of "rapid rural appraisal" so that the techniques of the best farmers could be studied more closely.

The foregoing discussion indicates that the technical efficiency of farmers could be improved through less use of seed-bed preparation labour in barley, as well as fertiliser and land in wheat, and more use of the remaining variables which are significant in explaining the variations in output. Moreover, having fewer numbers of plots and bigger asset could also shift their technical efficiency upwards.
There are only three or less number of farmers which have performed significantly better than the average farmer. These few farmers might have special advantages such as better soils. If this is the case the source of technical efficiency cannot be passed on to others. Consequently, in practice, output could only be raised partially. It would unreasonable to expect that output could be doubled.

6.2 Policy implications and recommendations

Since the study provides no evidence that output could be substantially raised by reshuffling the existing resources, the policy implications and recommendations are only related to technical efficiencies of farmers. as noted above the farmers could be advised to expend less labour on seed-bed preparation of barley as well as land in wheat and more of the other inputs which are also significant in explaining the variations in output. It is particularly advisable to give more emphasis to use of less land for wheat and more land for horsebean. Though the study suggests, as well, better managers use less fertiliser on wheat, this might be because of the very low rate of application per hectare which could make the fertiliser ineffective in increasing output and has led to erroneous conclusion. The results suggest the need for well designed on-farm fertiliser response trials in a farming systems framework prior to establishing firm recommendation for fertiliser use on wheat.

Further investigation is also required on the relationship between omitted variables such as farmyard manure and a measure of soil fertility with technical efficiency. Moreover, as the study area is a particularly frost prone area, there is a great deal of risk associated in the decision making of the farmers. This has not been accounted for in this study. To fill this gap there is need for further research to examine how farmers "insure" against such risk and uncertainty.

It is within the power of the peasant associations to attempt to minimize the number of plots distributed to a farm rather than continue to allow land fragmentation to increase through the redivision of farm lands every season (year) to accommodate new farmers. Besides,
changing one's plot from year to year in the process of the redivision would discourage farmers from investing in improvements on their land and could possibly aggravate soil degradation which is still one of the major problems in the study area.

As little weeding is done despite the existence of an immense weed problem, and weeding is a significant input in increasing output, suggestions are made to encourage weeding particularly on barley and wheat. Extension services could encourage row seeding in order to facilitate weeding. A further constraint on weeding is the occurrence of many religious holidays during the weeding season. A reduction in the number of these holidays could increase output but this is likely to be a gradual process.

The suggestions mentioned so far might raise the output to some extent but overall the results of this study are not optimistic. It is hard not to conclude that in order to bring about substantial increases in output, adoption of modern technologies such as high yielding, early maturing and frost resistant varieties of seed; improved farm implements; fertiliser, as well as soil conservation practices, are indeed necessary. One also has to bear in mind that the introduction of modern technology packages has to be accompanied by output-input price ratios that provide sufficient incentives to farmers to move beyond mere subsistence.
REFERENCES


BERHANU WLODEKIDAN Notes on Traditional Farming System Around the ILCA Station at Debre Berhan Addis Ababa, 1981 (Unpublished).


------------- Handbook On Crop Production in Ethiopia Addis Ababa, 1979

JONDROW, J. et al "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model" Journal of


MASSELL, BENTON F. and R. W. M. JOHNSON. "Economics of Smallholder Farming in Rhodesia: A Cross Section Analysis of Two Areas." Food Research Institute Studies Supplement to Vol. VIII, 1068.


NERLOVE, MARC. Estimation and Identification of Cobb-Douglas Production Functions Chicago, IL: Rand McNally and Co., 1965


VANDENBORRE, R.J. and W.O. McCARTHY. "Determination of Optimal Input


WORLD BANK World Development Report, 1982 USA.


Glossary

AREDA LEM A term given by the farmers to the most productive part of agricultural land located on plateaux hill tops or gentle slopes in the study area. The term is also particular to the study area and nearby villages.

AREDA TEF The type of land which is next to AREDA LEM in productivity, situated on the slopes. This terminology is also particular to the study area and the nearby villages.

BEGA Dry season of the year, extending from mid-September to mid-June.

BELG Short and irregular rainy season which may occur between February and May.

DEBO Pooling of farm labour and perform as a group on ones farm when the work is excessive to be handed by individual farm.

DEGA Cool climatic zone with an annual average temperature of 16°C and situated at an altitude of over 2400 m above sea level.

EDIR A local insurance of a small community in case of death of a family member. In rural areas it also includes insurance in case of death of cattle.

EKUB Traditional way of money saving where one pays a fixed amount of money at a given time interval so that each member gets a total sum of the members payment at any one time in turn.

ENSETE A drought resistant plant that looks like banana without edible fruits. Its root is the major part that is used as staple food for over 5 million people.

GYE Soil burning practice on marginal land in order to raise the productivity of the land temporarily.

KEREMET Rainy season of the year, extending from mid-June to mid-September

KOLA Hot climatic zone, with an average annual temperature between 27 and 50°C and covers the area below 1500 m above sea level.

MAHABER or SENBETE A spiritual organization found by a group of people who have strong belief in a particular saint that would be celebrated every month in each individual members' house in turn by providing local drinks and food as a feast.

MARESHA Locally made wooden plough drawn by pair of oxen.

MEKENAJO Pairing of oxen owned by two individuals to use the pair in turn.

TEFF A tiny indigenous grain crop belonging to a grass family and is known by the scientific name Eragritus Abysinica. It is the most favoured staple food of the people of Ethiopia.
TEMENZE  A local variety of barley.

WINADEGA  Temperate climatic zone with an average annual temperature of 16 °C - 29 °C and with an elevation of 1500-2400 m above sea level.

YEMEDA  The least productive agricultural land located on the bottom land.
APPENDIX A
ETHIOPIAN HIGHLANDS AND THE STUDY AREA
### APPENDIX B

**ESTIMATES OF AREA AND PRODUCTION OF MAJOR CROPS FOR THE 1981/1982 MAIN CROPPING SEASON**

<table>
<thead>
<tr>
<th>Crops</th>
<th>Area '000 ha.</th>
<th>Per centage</th>
<th>Production '000 qt.</th>
<th>Per Centage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cereals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teff</td>
<td>1311.08</td>
<td>25.04</td>
<td>10666.78</td>
<td>18.34</td>
</tr>
<tr>
<td>Barley</td>
<td>704.55</td>
<td>13.45</td>
<td>8400.07</td>
<td>14.45</td>
</tr>
<tr>
<td>Wheat</td>
<td>573.17</td>
<td>10.95</td>
<td>5751.15</td>
<td>9.89</td>
</tr>
<tr>
<td>Maize</td>
<td>564.33</td>
<td>10.78</td>
<td>10103.81</td>
<td>17.38</td>
</tr>
<tr>
<td>Sorghum</td>
<td>804.96</td>
<td>15.37</td>
<td>11776.42</td>
<td>20.25</td>
</tr>
<tr>
<td>Millet</td>
<td>226.49</td>
<td>4.32</td>
<td>1971.76</td>
<td>3.39</td>
</tr>
<tr>
<td>Oats</td>
<td>59.47</td>
<td>1.14</td>
<td>539.58</td>
<td>0.93</td>
</tr>
<tr>
<td><strong>Pulses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horse beans</td>
<td>348.91</td>
<td>6.66</td>
<td>1011.16</td>
<td>1.74</td>
</tr>
<tr>
<td>Chick peas</td>
<td>133.08</td>
<td>2.54</td>
<td>1614.99</td>
<td>2.78</td>
</tr>
<tr>
<td>Field peas</td>
<td>171.25</td>
<td>3.27</td>
<td>496.99</td>
<td>0.86</td>
</tr>
<tr>
<td>Lentils</td>
<td>69.11</td>
<td>1.32</td>
<td>107.24</td>
<td>0.18</td>
</tr>
<tr>
<td>Haricot beans</td>
<td>21.69</td>
<td>0.41</td>
<td>213.72</td>
<td>0.37</td>
</tr>
<tr>
<td>Vetch</td>
<td>32.29</td>
<td>0.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neug</td>
<td>150.77</td>
<td>2.88</td>
<td>503.11</td>
<td>0.87</td>
</tr>
<tr>
<td>Linseed</td>
<td>60.11</td>
<td>1.15</td>
<td>257.95</td>
<td>0.44</td>
</tr>
<tr>
<td>Rape seed</td>
<td>0.82</td>
<td>0.01</td>
<td>5.88</td>
<td>0.01</td>
</tr>
<tr>
<td>Fenugreek</td>
<td>4.16</td>
<td>0.08</td>
<td>22.47</td>
<td>0.04</td>
</tr>
<tr>
<td>Sunflower</td>
<td>0.54</td>
<td>0.01</td>
<td>0.93</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>All crops</strong></td>
<td>5236.78</td>
<td>100.00</td>
<td>58143.38</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Source: Central Statistics Office, 1982  
Note: Excluding state farms production which accounts about 5%.
APPENDIX C

DISTRIBUTION OF THE SAMPLE FARMERS WITHIN THE FOUR PEASANT ASSOCIATIONS
APPENDIX D
SOIL BURNING

The clay soils of the bottom (barley) land, characterised by a shallow top horizon and with poor drainage, are called "GYE" soils. An indigenously developed technology for dealing with these soils is to burn them. This practice is also referred to as GYE. Detailed soil analysis at ILCA has shown that soil burning raises productivity of the land temporarily mainly through improving the texture of the soil and raising the levels of minerals, mainly Phosphorus and Potassium.

Soil burning is a very tedious practice and includes activities of three to five criss-cross ploughings, breaking clods, soil collection, hollowing and burning and then spreading out the burnt soil. A great amount of human labour and oxen power is expended to accomplish these activities. The total labour requirement on one hectare of barley under GYE is 925 man hours which is more than three times greater than that devoted to a non-GYE plot, (280 man hours per hectare). Similarly, oxen power requirement on a GYE plot is nearly twice as much as that on a non GYE plot: 414 and 220 hours respectively for a pair of oxen for the former and the latter.

Studies (Murphy, 1957 and Woldekidan, 1981) have shown that soil burning makes the soil more porous by aggregating the clay into sand sized particles. It also liberates substantial amount of minerals such as Phosphorus and Potassium. However, it reduces substantially the amount of organic matter. The combined effects of these actions makes the yield of barley following GYE very high but yields decline rapidly in the second season and third season. GYE land is left fallow for 8 to 15 years before it could be used for another crop. The process of soil burning and leaving it fallow for many years continues on this basis. It is generally believed that the long fallow period is needed to restore the soil's organic matter and soil micro-organisms that have been destroyed through the soil burning process.
Soil burning practice raises the output of barley substantially, 18 and 10 quintals per hectare, for the first two seasons following soil burning. But it gives marginal output on the third year of only 6 quintals per hectare and has to be left fallow afterwards for an average of 12 years till it recovers its productivity and get ready for another burning. As more than 60 per cent of the cultivable land is subject to soil burning practice at some stage, it would be worthwhile to look at the cost-benefit analysis of GYE and non GYE plots so as to see how beneficial soil burning is in the traditional agricultural system. Since the land is left fallow for about 12 years following GYE practice, no cost of production is involved for that period. The fallow land could, however, be used as communal pasture starting on the fourth year. The revenue from a hectare of land is estimated at 60 Birr (US $29.00) which is the value of hay per hectare. The cost-benefit analysis of barley production on GYE plot is presented in Table A2.1.

Table D-1: Cost-benefit analysis of barley production on GYE plot

<table>
<thead>
<tr>
<th>Year</th>
<th>Seed</th>
<th>Labour</th>
<th>Ox power</th>
<th>Tot.cost</th>
<th>Grain</th>
<th>Straw</th>
<th>Gross rev.</th>
<th>Net rev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>82.81</td>
<td>236.80</td>
<td>157.32</td>
<td>476.93</td>
<td>594</td>
<td>83.85</td>
<td>677.85</td>
<td>179.42</td>
</tr>
<tr>
<td>2</td>
<td>86.29</td>
<td>96.24</td>
<td>88.00</td>
<td>271.19</td>
<td>346.5</td>
<td>54.24</td>
<td>400.74</td>
<td>103.25</td>
</tr>
<tr>
<td>3</td>
<td>91.29</td>
<td>80.08</td>
<td>75.60</td>
<td>246.97</td>
<td>218.3</td>
<td>30.81</td>
<td>249.09</td>
<td>1.51</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>38.16</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.98</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>548.78</td>
<td></td>
</tr>
</tbody>
</table>

Note that the net revenue is discounted by 12% discount rate, the official rate for the country.

It is obvious from this table that the first two seasons after GYE practice bring high net return to the farmer. However, the net return from the third season is very small. That could be the reason why not all the farmers crop their field in the third year.

The cost incurred in barley production and the corresponding return on this type of land (bottom land) without GYE practice, is the same as the cost and return from the third year after GYE practice. The
net benefit for the third year is found to be only 1.51 Birr per hectare which is also equivalent to the net benefit obtainable without practising GYE. The total net benefit that could be obtained from soil burning is 548.78 Birr whereas the corresponding amount if the land was cropped without burning the soil would be only 14.46 Birr. It is evident from this that soil burning practice is much more economical than cropping the unburnt soil. Hence the farmers are rational in practising soil burning on the poor land given the traditional farming system. But of course, this practice has to be replaced by modern techniques of production such as the use of a compound fertiliser and a method of preventing the problem of water logging such as constructing camber bed in order to crop the land continually.

The cost-benefit analysis of barley production using fertiliser is tabulated in Table A2.2.

**Table D-2: Cost-benefit analysis of barley production using fertiliser**

<table>
<thead>
<tr>
<th>Year</th>
<th>seed</th>
<th>labour</th>
<th>ox-power</th>
<th>fert.</th>
<th>tot.cost</th>
<th>grain</th>
<th>straw</th>
<th>gr. rev.</th>
<th>net rev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>82.81</td>
<td>87.04</td>
<td>83.60</td>
<td>79.90</td>
<td>333.35</td>
<td>379.5</td>
<td>59.34</td>
<td>438.84</td>
<td>94.20</td>
</tr>
<tr>
<td>2</td>
<td>86.95</td>
<td>90.78</td>
<td>88.00</td>
<td>84.00</td>
<td>349.73</td>
<td>398.5</td>
<td>62.38</td>
<td>460.85</td>
<td>88.56</td>
</tr>
<tr>
<td>3</td>
<td>91.29</td>
<td>97.24</td>
<td>92.40</td>
<td>88.09</td>
<td>369.02</td>
<td>418.4</td>
<td>65.41</td>
<td>483.78</td>
<td>81.71</td>
</tr>
<tr>
<td>14</td>
<td>156.13</td>
<td>163.54</td>
<td>158.40</td>
<td>150.66</td>
<td>628.73</td>
<td>715.6</td>
<td>111.92</td>
<td>827.56</td>
<td>40.76</td>
</tr>
<tr>
<td>15</td>
<td>163.94</td>
<td>170.68</td>
<td>165.00</td>
<td>158.19</td>
<td>657.81</td>
<td>751.4</td>
<td>117.44</td>
<td>868.85</td>
<td>38.62</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>937.36</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: net revenues are discounted.

It has been indicated that soil burning practice gives a much higher net benefit on poor soil than using it unburnt. However, it is an inferior practice to using modern fertiliser. The net benefit of applying fertiliser could be much higher if it had been used with improved varieties of seed rather than with local low yielding varieties and with techniques to improve soil structure.

Nevertheless the producers have little opportunity to improve the existing practice. They are poor farmers and can not afford to purchase

\[14.46 \text{ is obtained by summing up the discounted value of 2.12 Birr, the net revenue obtained without soil burning, for 15 years}\]
fertiliser without access to credit facilities. These are not currently available for individual farmers. Secondly, even if they get credit for their fertiliser, the bottom land where soil burning is carried out extensively is exposed to frost and therefore there is high chance of crop failure. Hence, not only is credit required but also some sort of concession on the cost of fertiliser in the event of crop failure. Furthermore, barley is the only suitable crop for the bottom land and it has a relatively low price compared to other crops grown on the top and intermediate land. Given this condition the farmers are likely to apply the fertiliser on the higher valued crops. In the long-run it might be possible to make the bottom land suitable for the higher valued crops. Frost protection might be achieved by planting tree belts on these lands.

As has been mentioned earlier, one of the causes of low productivity is the poor drainage of the soil. If the farmers are made aware of methods of improving the drainage capacity of the soil, this accompanied by use of fertiliser could raise the crop productivity even much higher than obtained from the use of fertiliser only. However, if the government is not able to help the farmers in these ways, the outlook is not bright since raising crop productivity in this area would appear to be too complex an issue for the farmers to do it by themselves.
APPENDIX E

FERTILISER USAGE IN BASONA-WARANA DISTRICT 1971 TO 1980

<table>
<thead>
<tr>
<th>Year</th>
<th>DAP (kg)</th>
<th>Urea (kg)</th>
<th>Compound (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>2100</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1972</td>
<td>6550</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1973</td>
<td>2955</td>
<td>2200</td>
<td>--</td>
</tr>
<tr>
<td>1974</td>
<td>1200</td>
<td>6200</td>
<td>--</td>
</tr>
<tr>
<td>1975</td>
<td>--</td>
<td>--</td>
<td>27120</td>
</tr>
<tr>
<td>1976</td>
<td>18100</td>
<td>450</td>
<td>50</td>
</tr>
<tr>
<td>1977</td>
<td>71300</td>
<td>250</td>
<td>--</td>
</tr>
<tr>
<td>1978</td>
<td>88700</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1979</td>
<td>202550</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1980</td>
<td>192800</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture Teguletena-Bulga District
(Unpublished)