AN EMPIRICAL STUDY OF TECHNOLOGICAL CHANGE IN THE ETHIOPIAN HIGHLAND FARMING SYSTEMS

by

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Dedicated to the memory
of peasant farmers who
died in the 1973 and
1984 Ethiopian famines

ABSTRACT

One of the major policy issues facing agricultural planners in Ethiopia is that of how to raise the productivity of smallholder agriculture. Improving the productivity of traditional agriculture requires at the very least an understanding of resource use patterns and technological change. Yet there has been little empirical research in Ethiopia which helps policy makers to determine existing development opportunities and to formulate a longer term agricultural development strategy.

This study was designed to explore the means and possibilities of improving existing farming systems through the introduction of new technological packages. The principal hypothesis investigated is that low productivity in Ethiopian agriculture is mainly due to the use of traditional technology and increases in farm productivity are most likely to arise from technological improvements in agricultural production.

The data for the study was taken from the farm management surveys and on-farm experimental trials. Two methodological approaches were used to test the above hypothesis in the highland farming systems.

First, an empirical investigation was undertaken to draw lessons from the experience of the impact of such technological transformation that has occurred. Methodological and data problems in technological change studies were discussed. Any shift in parameters in the production function was estimated. The relative efficiency of small and large farms was examined using translog production function. It was concluded that the introduction of new technology has increased farm income considerably. However, the findings of the relative efficiency of resource use has shown the weakening of the generally accepted inverse relationship of farm size and productivity in peasant agriculture. The extent to which appropriate economic analytical tools are needed and misleading policy implications that can be drawn from agricultural development theory are also highlighted.

Secondly, a formal modelling of the farming systems, within the framework of linear programming was carried out to examine development opportunities under existing and alternative technologies. Optimum farm plans were generated for representative farms under existing farming systems. However, a comparison of actual and optimum farm gross margin does not reveal substantial room for improvement.

From this base it was argued that a necessary condition for continued development is the introduction of new technologies. In a series of simulation experiments using recommended bio-chemical and mechanical technology, a number of technological possibilities open to policy makers interested in improving productivity of agriculture were identified. The effects of the alternative technologies on farm income and resource productivity were discussed. The sensitivity of the simulated results were assessed.

The major findings of the thesis show that the potential for increasing production and alleviation of rural poverty lies in the introduction of a range of alternative technologies in the form of HYV, fertilizers, herbicides and combine threshers/harvesters. Based on this study, it is suggested that planners and policy makers should sustain research and design strategies and programmes which would enhance smallholder agricultural development in Ethiopia.

List of Abbreviations

AAU	Addis Ababa University
ADDP	Ada District Development Project
DAP	Diammonium Phosphate
DBMS	Data Base Management System
CADU	Chilalo Agricultural Development Unit
CSO	Central Statistical Office
EPID	Extension Project Implementation Department
ESTC	Ethiopian Science and Technology Commission
FAO	Food and Agricultural Organisation of the United Nations
FMS	Farm Management Survey
FSR	Farming Systems Research
GNP	Gross National Product
Ha	Hectare
HSIU	Haile Selassie I University
HYV	High Yielding Variety
IAR	Institute of Agricultural Research
IBRD	International Bank for Reconstruction and Development
IEG	Imperial Ethiopian Government
ILCA	International Livestock Centre for Africa
LP	Linear Programming
MOA	Ministry of Agriculture
MPP	Minimum Package Programmes
PMG	Provisional Military Government
SAREC	Swedish Agency for Research Co-operation with Developing Countries
SIR	Scientific Information Retrieval
SIAS	Scandinavian Institute of African Studies
SIDA	Swedish International Development Authority
SPSS	Statistical Package for Social Science
WADU	Wallaita Agricultural Development Unit

Exchange Rate: Ethiopian Birr 2.07= US $1, EB, 3.13 = £1 (May, 1986)

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

This study focuses on economic growth at the micro or household farm level based on highland farming systems in Ethiopia. The objective was to investigate the means and possibilities of raising the productivity of smallholder agriculture through the introduction of new technological packages.

Since the nineteen fifties, economic literature has given emphasis to the importance of technological change for economic growth in general, and for the increase in factor productivity in agriculture in particular (Solow, 1957; Griliches, 1963 and 1964). Growing interest from the field of agricultural economics in the area of technological change seems to have stemmed from two contrasting major problem areas. First, the result of a rapid increase in the supply of agricultural products, relative for demand, in developed countries led to depressed farm prices and incomes (Peterson et al, 1977). This, in turn, led to several adjustment problems which initiated economists to identify the cause for rapid output growth found to be primarily technological change.

The second major problem area which initiated considerable interest in technological change was the persistent food shortage and widespread malnutrition. Since development programmes emphasising increased use of traditional inputs have contributed only modestly to agricultural output gains economists have increasingly been favouring technological change as the major "engine of growth" (Peterson et al, 1977).

However, many studies in the field of technological change in the early 1950's and 1960's were limited to modern agriculture as operated in Western countries. Traditional agriculture, from which the majority of the world's population gets its income, was not given much attention. The breakthrough in research in this important area came for the first time when a study by T.W. Schultz Transforming Traditional Agriculture put forward a hypothesis that significant growth in productivity could not be brought about by the reallocation of resource in traditional agricultural systems (Schultz, 1964). Subsequently these findings were supported by empirical investigations in LDC by Chennaredy (1967); Yotopoulos (1967); Sahota (1967); Upton (1967); Massell and Johnson (1968); Norman (1977) and the policy recommendations brought attention to the study of smallholder agriculture and the impact of new technology. In regards to the transformation of agriculture, the studies emphasised the significance of modern inputs which were quite "distinct" in their nature from traditional ones. Technological change in some shape or form was considered to be at the heart of increased productivity.

Given the recent advances in Asian agriculture following the introduction of new technology, the significant development of agriculture in Taiwan in the past decades, and the experience of the agricultural development in Japan, technological change is certainly one of the more important dynamic forces affecting the structure and income of agriculture and its role in national economy (Johnston and

Mellor, 1969). In fact, the last few years have brought a perceptible technological transformation in agriculture, particularly in Asia. The utilisation of high yielding crop variety, chimecal fertilizers, herbicides, pesticides and pumping irrigation equipment has caused substantial increase in output and total net revenue of the agricultural sector (World Bank, 1982; Eicher et al, 1984). In the Indian Punjab alone, as a result of new technology, total output roughly doubled between 1952 and 1965, and the amount of marketed output (as opposed to subsistence consumption) roughly tripled (Killick, 1981:237).

In this study, it will be argued that the agricultural sector in Ethiopia has also started undergoing a transformation, and is poised to break through the vicious circles constraining traditional agriculture through the recent introduction and generation of potential new technologies. Using Ethiopia as a case study, this study attempts to broaden the scope of knowledge concerning the role of new technology in smallholder agriculture.

1.2 Agricultural Policy and Technological Change in Ethiopia: An Over-Review

1.2.1 Agricultural Policy

Ethiopia is a nation of small subsistence farmers characterised as a poor and less developed country. The country extends over an area of 1,240,600 square kilometers, between 3 and 18 degrees north latitude and 33 and 48 degrees east longitude. In 1967 its per capita income was estimated to be US $60, while the most recent estimates, in 1984 population of 42 million, amount to US $110 (World Bank, 1986).

The agricultural sector forms the base of the economy. This sector contributes over 48 percent to the gross domestic product and has employed about 90 percent of the country's labour force. Furthermore, over 95 percent of the country's foreign exchange is obtained from the agricultural sector, of which coffee alone accounts for about 50 percent of export earnings (World Bank, 1983). Table 1.1 shows the structure and growth performance of the Ethiopian Economy.

Table 1.1 Structure and growth of production of the Ethiopian economy percent per annum

	Distribution of Gross Domestic Product		Average annual Growth Rate	
Sector	1965	1984	1965-73	1973-84
Agriculture	58	48	2.1	1.2
Industry	14	16	6.1	2.6
Manufacturing	7	11	8.8	3.5
Services	28	36	6.7	3.6
GDP (Millions of Birr)	1,180	4,270	4.1	2.3
Population (Millions)	22.55	42.44	2.6	2.8

Source: The World Bank, (1986). World Development Report 1986, Oxford University Press, pp. 182,184,228

Agriculture in Ethiopia is divided into two broad sectors, each with rather special features and problems. The first is based on traditional smallholder sector and the second on the large scale state and commercial farms sector.

The state and commercial sector currently includes 4 percent of the cultivated land and produces 6 percent of gross output. It is orientated towards the production of cash crops for export and towards domestic consumption.[1]

The country's agriculture is thus based on the smallholder sub-sector which covers for 96 percent of Ethiopia's cultivated land, producing most of the country's basic grains and providing incomes for much of the population.[2] It commands an overwhelming proportion of Ethiopia's agricultural resources and consists of individual rural households organised into peasant associations, where farming is largely individual and centred around the family (World Bank, 1983; ILCA, 1983).

The important contributions which these traditional agricultural sectors can make to the economic development of Ethiopia was not sufficiently recognised in the country's development plans and policy declarations until 1967. Although Ethiopia has used comprehensive planning for economic development over the past years, the role of the small farmer was completely neglected until the third Five Year Plan (1968 - 1974).

The First Five Year Plan (1957 - 1962) gave priority to infrastructural development. The basic stress of this plan was on transportation, communications, electric power, manufacturing, social services and housing. The agricultural orientations were aimed at creating a basis for long-term development and stimulating the increase of marketable crops and raw materials. It concentrated on surveying Ethiopia's major rivers, setting up and developing a sugar factory, improving farm labour productivity, and stimulating an export orientated livestock industry. The overall achievement of this plan was low and, although hard to document, its impact on agricultural production was virtually non-existent (Waterston, 1965, Cohen; 1975)[3,4].

The Second Five Year Plan (1963 - 1968) clearly emphasised productive investment in manufacturing, roads, telecommunications, mining and electricity. In the agricultural sector, the plan gave priority to increasing the per capita food production and raw materials to aid the balance of payments by stimulating exports and eliminating imports. The Plan also stressed a range of agrarian organisational and support areas in need of improvement such as data collection, research, experimentation, extension and training, veterinary services, and development of manpower skills necessary to maintain technical progress in the future (IEG, 1962). In this way some serious problems in the agrarian sector were at least acknowledged. Unfortunately, the Second Plan was unable to effect even these advances, nor did it make progress in other areas mentioned in the Plan, such as land reform, agricultural taxation, cadastral surveys, administration of agriculture, and the firm establishment of the Ministry of Agriculture as the general agency responsible for the agricultural sector (Cohen, 1975)[5].

During the 1958 - 1968 period, Ethiopia had only about 100 to 120 agricultural extension agents scattered across the countryside. In addition, the poor communication system, inadequate research programmes and an oppressive land tenure system (with share rents ranging from one-third to two-thirds of output) perpetrated the stagnant subsistence economy[6].

For these reasons the Third Five Year Plan (IEG, 1968) focused its efforts more on the barriers to agricultural growth. The Plan adopted two main policy strategies: one was directed towards commercial farming, which was viewed as the vehicle for rapid expansion to provide the dynamism of the agricultural sector. The policy in the commercial sector was intended to encourage domestic and foreign entrepreneurs with the expectation that rapid commercial development would have a substantial impact on the economy, generating income, facilitating the establishment of infrastructure and having a local demonstration effect (IEG, 1968). Policy for developing the traditional sector was based on the launching of package projects within clearly defined geographical areas. It adopted a multifaceted package approach, primarily to raise the real income of small farmers, to generate employment opportunities and thereby to narrow income disparities among the population. It proposed two variants of package programmes - the Comprehensive Package and Minimum Package projects - which differed in intensity and the number of package programmes. While both projects integrated the provision of credit, fertilizer and improved seeds, output marketing and extension services in a defined geographical region, the Comprehensive Package project also integrated research and provided services for the large population affected. The first three integrated package projects initiated in accordance with this plan and policy were the Chilalo Agricultural Development Unit (CADU), now known as the Arssi Rural Development Unit (ARDU), the Wallaita Agricultural Development Unit (WADU) and the Ada District Development Project (ADDP) launched in 1967, 1970 and 1972 respectively (Tecle, 1973).

The stated objectives of the projects were ambitious. The aims were to:

1. raise the real incomes of small farm household mainly with holdings of 20 hectares and less in their respective areas;
2. elicit the participation of small farmers and local government authorities in their development efforts;
3. control adverse employment effects and, where possible, generate new additional employment opportunities;
4. narrow prevailing income disparities by directing efforts mainly toward farmers in the lower brackets;
5. continuously search for suitable methods for furthering rural development nationwide;
6. provide data for formulating better projects in the future[7].

The initial approach was to provide improved seed and fertilizer on credit, together with extension advice which was to be channelled to the target population through a network of "model farmers" and, more recently, farmers' associations[8]. However, the first type of assistance to be provided was a marketing service which would purchase the farmers' produce at fair and reasonable prices, in stark contrast to the existing local system which was characterised by low prices and dishonest calculations.[9] The project soon expanded from this initial base to provide a wide range of facilities which included, in addition to the original services, road construction, forest development, implements research, improved livestock management, water supplies and the development of co-operatives and farmers' associations[10].

By 1970 sufficient experience had been gained, particularly from CADU, to conclude that the "intensive" package programme was too costly, in terms of both financial resources and trained manpower, for expansion on a large scale to meet the national objective of reaching about 90% of the farming population[11] A sequential approach, the Minimum Package Project (MPP) was developed in 1970 with an initial focus on crop production, for which the introduction of new varieties and fertilization was expected to spearhead improved agricultural practices. The programme provided for a minimum package of services (extension, input supply and credit) following the CADU model. It employed the methods and innovations developed and tested in the Chilalo areas and The Institute of Agricultural Research sub-station; its goals were similar to those of CADU (EPID, 1972)[12].

Until recently, many institutional reforms, such as land reform, have been made[13] and the commercial farms have been converted to state farms, while WADU and ADDP were changed to MPP since the 1974 Ethiopian revolution, the main manifestations of the Package approach to developing peasant agriculture have been based on these projects outlined. The transfer of new technology to small farmers has therefore been carried using similar policy guidelines and strategies.

1.2.2 Technological Change in Ethiopia and Some Policy Issues

Technological change in agriculture, since recent years, has become almost a rule of thumb in many areas of the world. Although Ethiopia is a latecomer in this regard, some changes have begun with the establishment of the package schemes. Since the 1970's, technology has played an active role in Ethiopian agriculture. Many authors

(Waktola, 1975; Gebre Egziaber et al 1982; Bengtsson, 1983) have observed the willingness of small farmers to adapt to technological change, and the CADU and MPP evaluation team (Hunter, et al 1975) have emphasised the point, reporting that together with favourable climatic conditions, technology has played an important role in making Chilalo area agriculture one of the most advanced in Ethiopia.

The Institute of Agricultural Research (IAR) which, is responsible for technology generation is the main research centre where new ideas and methods are tested[14]. It has branches of research stations in different ecological zones of the country[15]. Its major areas of research are crops and livestock production. The emphasis on crop production is primarily limited to variety and fertilizer trials for food crops. The importance of cultural practices, such as the date of planting and the spacing of crops have been realised, but they are yet to be subjected to detailed research.

As a whole the major efforts of technology generation in the past years has produced new technologies relevant for wheat, barley, teff, maize, sorghum, and horse beans. The recommendations for the production are tabulated in Table 1.2.

The introduction of these innovations in Ethiopia agriculture has been quite recent. They started on a very limited scale in Chilalo areas in the 1970's and spread in latter periods to areas where MPP projects were being initiated. Table 1.3 discusses the spread of farm technology among the smallholder producers in Ethiopia.

In a statistical sense the overall achievements of technology diffusion are impressive. An analysis of the number of farmers who are using technological inputs provided shows an increasing trend.

Table 1.2. Recommended Technology in Ethiopian Agricultural Extension Systems[10]

1 Crops	2 Varieties	3 Altitude	4 Type of soil	5 Rainfall in mm	6 Seed Rate kgs per ha	7 Rate and types of fertilizer per ha	8 .Expected yield per ha at research station	9 Expected yield per ha at farm level trial field
Wheat	Enkoy 6290 bulk Romany Back cross, Mamba,6106:8 6290 Bulk,CI-1439 SON64xSKE,Kenya Kanga & Dereselgne	2000-2300	Black clay loams to reddish brown clay	1200	125	70kgs as urea and 45-70kgs P_2O_5 as DAP	5300	3200-4000
Barley	Beta,EH 8B/F4.EL6L Composite 29, IAR/H/485, Bedi black 6R	2000 2300-	Red and clay soils	1000-2000	85-100	46 kgs of P_2O_5 and 41kgs of N	5700-6000	4000
Teff	DZ-01-354 DZ-01-99 DZ-01-196	1700-2400	Drained red or black	1000	25-30	40kgs N and 60kgs P_2O_5 on red soils and 60 kgs N and 60 kgs P_2O_5 on black soils.	2200-2800 2200-2800 1200-1800	1700-2200 1700-2200 1000-1200
Maize	Bako Composite,SR52 KCC,KCB Jimma Bako	1000-1800	Drained light sandy loam soil	800	25-30	76 kgs N and 75kgs P_2O_5	7700-12000	50000
Sorghum	ETS 2752,ETS 2111 KOBO Mash 76, Alemanya 70,76TI No. 14 Asfaw white, ETS 2213 ETS 3235, 76TI No. 19	1000-2000	Light soil or clay to soils	600-1225	5	100 kgs DAP 100 kgs urea	4000-7000	2500-3000
Horse beans	20DK, 38BK, 11 AK		Reddish brown clay or heavy soil	400-500	150	100-150kgs DAP	2500	1500
Field peas	Prussian blue,FP Ey DZ Mohunmafer, C5436 K Fp EX DZ	"	"	"	120	100-150kgs DAP	1600	1200

Source: IAR (1979), Handbook on Crop Production in Ethiopia; Institute of Agriculture, Addis Abbaba.

Table 1.3 Farm Technology in Smallholder Agriculture in Ethiopia

	Chilalo/Arssi Areas[1]			Minimum Package Programme Areas (MMPa)[2]		
	Amount of high yielding varieties (Quintals)	Amount of fertilizer (Quintals)	No of farmers using new inputs	Amount of high yielding varieties (Quintals)	Amount of fertilizer (Quintals)	No of farmers using new inputs
1967/68	189	42	189	-	-	-
1968/69	4540	2422	868	-	-	-
1969/70	11380	18700	4769	-	-	-
1970/71	14239	41955	14146	-	-	-
1971/72	15316	45325	12462	222	94631	4691
1972/73	5404	40129	13303	200	20174	12718
1973/74	2253	70604	25201	860	35160	25424
1974/75	11976	50705	42000	2000	78475	50375
1975/76	19572	64553	57000	NA	83748	90241
1976/77	15815	87357	50157	NA	202334	202477
1977/78	29745	68006	65000	5950	217990	244037
1978/79	18960	71236	70280	10200	261470	207311
1979/80	18964	88697	70000	3800	224690	NA
1980/81	18756	73136	70000	4320	368080	NA
1981/82	11862	66623	80000	NA	343950	NA
1982/83	16504	83091	90000	NA	NA	NA

Source: 1. SIDA (1984) ARDU: Objectives, activities, prospects and problems, Assela, pp. 9-10
2. Compiled from Ministry of Agriculture, (1982), MPP Annual Report, 1980/81; Addis Ababa, May.

The quantity of fertilizer that was distributed in 1982/83 amounted to 83,091 quintals compared to 42 quintals in 1967/68. In the same period, the quantity of improved seed has increased from 189 to 16,504 quintals. The number of farmers using new technology had also grown from 189 in 1967/68 to about 90,000 in 1982/83. Similar trends can be seen also for MPP areas. The quantity of fertilizer that was distributed in 1980/81, the highest so far, amount to 36,8080 quintals as compared to 94,631 quintals in the base year.

However, a close analysis of the table shows some fluctuation in the use of technology by small farmers. For example, in 1971 in Chilalo area, there were 14,164 reported using new technology. It declined to 12,624 in 1972 and 13,302 in 1973 before it jumped to 25,205 in 1974. The latter trends also indicate that the use of new inputs reached its peak in 1979/80 and then declined in the recent two years corresponding to its historical level of 1976/77.

There is no clear indication as to why farmers' use of new technology is fluctuating. But uncertainty created by the price of agricultural products in relation to new inputs, the risks associated with credit, problems related to land tenure and weakness of the dissemination strategy are among the explanations being hypothesized (Hunter et al 1974; Tecle, 1973; Bengtsson, 1983; World Bank, 1983). For example, the sudden increase in 1973/1974 to 25,205 is seems to be due mainly to the fluctuation of the unusually higher wheat price in 1973[17] - indicating strong correlation between wheat prices, lagged by one year, and the number of farmers using new technology. Fluctuation in latter periods, although attributed to the same economic reasons may have been caused also by the unstable economic situation in the country which resulted in higher fertilizer and lower food prices as well as the misinterpretation of the 1975 land reform by the farmers[18].

There is ample evidence indicating that the introduction of new technology has increased agricultural production. The early effects of the new inputs are summarised in Table 1.4.

A comparative analysis of pre-technological change in yield data with that of post-technological change indicates that substantial achievements have been made. Table 1.4 shows that wheat varieties have been developed, which on the average yield in 1973 over 130 percent more than the local varieties and are adopted for different ecological zones of the area. On good farms in the Chilalo area, wheat yields have tripled by using improved varieties, fertilizer and improved cultural practices (Hunter, et al, 1974; Nekby, 1971; Tecle, 1973). Furthermore, at regional levels it was reported that farmers in Chilalo area have increased production by 60 - 90 percent (Cohen, 1975)[19].

Data on per capital income also indicates a rise in farm incomes during post technological change. At the time of the start of the introduction of new technology the per capita income in Chilalo area was reported to be Eth.Birr 100 (CADU, 1966). By 1970 it was reported that the incomes of farmers who had taken new technology had increased by about 50 percent (CADU, 1971). In 1972 incomes had almost doubled in the oldest project area (Holmberg, 1973). In 1980, the average per capita income in Chilalo was estimated to US $230, which is high compared to the country as a whole (ARDU, 1980). Added to this, Chilalo is an area in one of the few regions which produce surplus over and above consumption. The marketed surplus, as a result of the new technology was estimated in Chilalo alone to be about

Tables 1.4 Farm level yield estimates of improved and traditional packages in Ethiopian highlands.[20]

	1968[3]		1973		1980		1981	
Regions	Traditional	Improved	Traditional	Improved	Traditional	Improved	Traditional	Improved
Chilalo/Arssi[1]								
Wheat	980	-	1520	2260	1130	2310	1260	1470
Barley	1300	-	1590	-	1460	-	1310	1450
Teff	-	-	-	-	-	-	970	1230
Minimum Package Zone[2]								
Wheat	823	-	766	1490	878	1520	NA	NA
Barley	902	-	902	1330	822	1370	NA	NA
Teff	517	-	600	1090	960	NA	NA	NA
Maize	1071	-	NA	NA	1066	NA	NA	NA

Source: 1. Compiled from CADU/ARDU 1968, 1973, 1980 and 1981 Crop Sampling Surveys, Assela.
2. Compiled from MOA, MPP Annual Reports (1968, 1973, 1980, 1981), Addis Abbaba
3. 1968 refers to CADU/ARDU base year and the date for minimum package area refers to 1969-71 base year.

40 percent of gross production (ARDU, 1984).

However, despite the rapidity of the changes that have resulted in the new technology in Ethiopia, it has given rise to problems and a number of controversial issues of agricultural policy. Geographical impact of the innovations introduced has been limited to a few selected areas. It has so far concentrated upon the most accessible and relatively fertile areas which have been assessed to have the highest response (Tecle, 1975). Obviously, therefore, there are disparities in income between areas reached by the new technology and those that remained untouched.

Far more important are the social tensions and policy issues that have emerged as a result of the distribution of the benefits generated and the introduction of mechanical innovations which displaced tenant farmers[21]. In general, until policy changes in 1975 large scale farmers have received a significantly larger proportion of the benefits, even though they constitute a small proportion of the target populations (Table 1.5)[22].

Debate of these issues in Ethiopia has to a considerable extent polarized on the basis of dichotomy between "efficiency" and "equity" objectives. On one hand there was a tendency to condemn the impact of new technology, and more particularly the package strategy with which it has been associated, because it has accentuated income disparities and social tensions in the rural areas. The other dominant tendency is a vigorous defence of the package strategy for transforming traditional agriculture, emphasising the vital importance of the accelerated rate of increase in agricultural output to the economy that has been achieved. This second view - point has been the dominant theme in government policy. However, it has been realised in a latter stage

Table 1.5 Distribution of Holdings and use of new technologies in Ethiopia

Hectares	Distribution (%)	% of farms using new technologies
Less than 0.10	11.3	0.7
0.11 - 0.50	24.4	6.0
0.51 - 1.00	26.5	7.6
1.01 - 2.00	23.7	10.1
2.01 - 5.00	20.1	10.5
5.01 - 10.00	3.8	23.0
More than 10.00	0.1	50.0

Source: World Bank, (1981). Second Agricultural Minimum Package Project Implementationvolume. World Bank, Washington D.C., p.38

that rural poverty is a serious problem and it has been aggravated by archaic land tenure systems in the country. To this end, since 1975 agrarian reform has been carried out to protect the interest smallholder farmers. The land reform of March 1975, made land public property and allowed a maximum of 10 ha of cultivable land to be under an individual holding and, moreover, it abolished landlord tenant relationships putting an end to the age old archaic feudal relationship, and consequently to income disparity in the rural areas (MOA, 1984:12).

According to recent studies by ARDU and its computation of income disparity before and after the agrarian reform, inequality in income distribution among the surveyed areas of Chilalo has been drastically narrowed after the reform (ARDU, 1984).

1.3. Recent Performance and Productivity Problems in Agriculture

From the foregoing discussion it has been noted the importance of agriculture in Ethiopia's economy and policy efforts to enhance agricultural development. Despite this, the performance of the agricultural sector has been deteriorating in the last decade. During the past years agriculture recorded an annual growth rate of 1.2% as compared to 2.6% in industry, 3.5% in the manufactory, 3.6% in the services sectors and 2.8% in population growth rate (see Table 1.1). yet, the major portion of the country's Gross Domestic Product (GDP) originated from agriculture.

The poor performance of Ethiopia's agriculture can also be seen in comparison with the growth performance of some comparable African countries (Table 1.6). Ethiopia falls within the category of a country of poor growth performance in agricultural production, having a growth rate of 0.1%.

Table 1.6. Growth rates of agricultural production of selected African countries, 1970-82.

%Annual Growth Rate	Sub-Sahara Countries
Less than zero	Chad, Niger, Ugnda, Mauritius, Nigeria
0 - 1	Somalia, Ethiopia, Gu nia-Bissau, Lesotho
1 - 2	Burkino Faso, Zambia, Zimbabwe, Congo
1 - 3	Burundi, Tanzania, Sierre Leone, Sengal Central African Republic
3 - 4	Mali, Gambia, Mauritania, Liberia, Botswana Cameroon
4 and over	Malawi, Kenya, Sudan, Swaziland, Ivory Coast

Source: World Bank, 1984. Toward Sustained Development in Sub-Saharan Africa. A Joint Program of Action, Washington D.C. IBRD p.58

Furthermore, Table 1.7. shows the performance record of Ethiopian agriculture on yield per hectare basis. These figures illustrate that the agricultural performance on terms of yield has not been encouraging either. Also, there is a very wide gap in yield performance when average yield per hectare as compared with the potential yield.

Table 1.7. **Annual estimates of yield of major crops[1] and potential yields[2] in Ethiopia (Kg/ha)**

Crop	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	Potential Yield in Kg/ha	Average level level of productivity % of 1981/82
Cereals										
Teff	700	700	740	780	780	960	960	810	2200	36.81
Barley	820	980	1260	870	830	1310	1290	1140	5850	19.00
Wheat	910	990	1100	870	880	1130	1150	1040	5300	19.62
Maize	1120	1870	1410	1090	1080	1810	1290	1790	9850	18.17
Sorghum	840	1130	1010	930	940	1620	1440	1440	5500	26.18
Millet	760	1000	870	890	800	950	880	870	NA	-
Pulses										
Horse bean	860	910	1260	1000	900	1500	1530	1350	2500	54.00
Chick pea	620	540	710	720	550	860	790	750	3000	25.00
Haricot bean	480	1080	650	700	670	1360	950	480	3000	25.00
Field peas	440	440	760	700	698	1160	870	940	1600	58.75
Lentils	400	680	710	560	460	730	1120	220	NA	-

Source: 1. MOA Area, Production, and Yield of Major Crops for the Whole Country and by Region Addis Ababa, 1974/75 - 1981/82.
2. IAR (1979). Handbook on Crop Production, Addis Ababa.

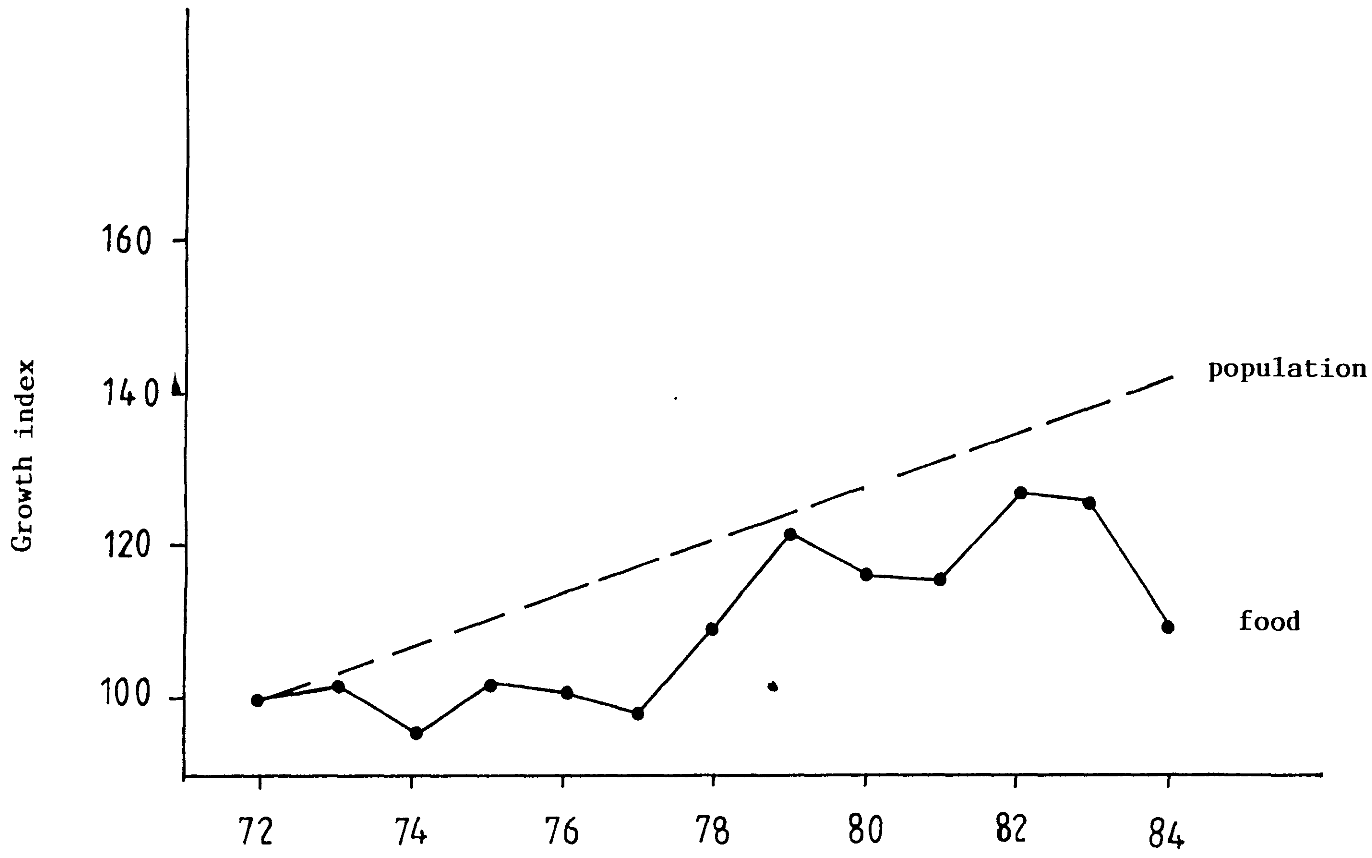
The average level of productivity simply calculated as a percentage of the potential yield, can be seen in cereals to range from a low of 18% in maize to a high of 36% for Teff.

Perhaps more important and most disturbing in the poor performance of the agricultural sector over the last year is the decline in food production in relation to population growth. Fig.1.1 demonstrates that the amount of food the country is able to produce has declined, indicating a complete variance in the direction of population growth and that of food supply. If self-sufficiency in food production is defined as the production of food enough to meet the growing demand, equivalent to that of the rate of population growth, the magnitude of the food deficit situation is witnessed. Such deficit and consequent food crises have meant that the country had to rely increasingly on food imports and/or food aid programme to make up for the shortfalls in food production. Also in the 1974 and 1984 period when the devastating draught took place the country had to face starvation and famine. This poor performance in food production being experienced over several periods has led in Ethiopian history, to what many observers are now calling an "agrarian crisis" or "Ethiopia's food crisis" (SIDA, 1984)[23].

It should be noted, however, that the above relative poor performance in agriculture was a direct result of low productivity (World Bank, 1983; Nichola, 1985).

Several factors cause low productivity in Ethiopia. Many authors (Sisay, 1980; FAO, 1982; ILCA, 1983; World Bank, 1983) cited low level farm investment as the major cause of poor performance in the agricultural sector. The result is that land and labour continue to be

Figure 1.1 Index of food production[1] and population growth[2]



Source: 1. FAO (1984). Production Statistics, Rome
2. CSO (1984). Ethiopian Statistical Abstract, Central Statistical Office, Addis Ababa

the main inputs in agricultural production in Ethiopia. The use of purchased inputs such as high yield variety, fertilizers, pesticides and herbicides is extremely low (World Bank, 1983). In 1979/80, for example, only 500 tonnes of fertiliser were used on all crops in the country. The average level of fertilizer consumption was 8.6 kg per cropped hectare[24]. This was well below the blanket recommended average of 100 kgs per hectare for wheat, barley and Teff in the highland regions (MOA, 1980; IAR, 1979).

Throughout the country the tools used in farming were ox-drawn plough and hoe. Improved oxen-plough, power equipment and large agricultural machinery such as farm tractors and combines were virtually absent in smallholder sectors. This low level of technological innovations has been cited as one of the causes for low productivity in the agricultural sector (ILCA, 1983; Gill, 1976; CADU/ARDU, 1980; Rahmato, 1985).

Other factors which may have contributed to the unsatisfactory situation in agriculture were a lack of marketing facilities, fragmentation of land holdings into uneconomic units, absence of widely applied resource conservation measures and unfavourable weather conditions (Sisay, 1980; ILCA, 1983; World Bank, 1983; Mela, 1985). Government economic policy which have made indiscriminate investment in inefficient state farms, heavy military spending and the uncertainty created by civil war situations are also cited as a major problem of Ethiopian agriculture (World Bank, 1983).

Each of the factors highlighted above resulted in low farm productivity and were potential areas of investigation. This investigation, however, was carried out to show that this low resource productivity problem could be overcome through the improvements of traditional production methods and technology.

1.4. Current Technology Policy and the Need for Research

The above discussion showed that low productivity is a major problem in Ethiopian agriculture. Farm productivity must increase not only to close the gap in the growth rate between population growth and food supply, agriculture and other sectors but also to improve the welfare of the population. The process of raising the productivity of agriculture, which is essential for economic growth, is achieved when new technology is introduced and resources are efficienty allocated on farm, regional and national level in Ethiopia.

Policy makers concern with this problem is clearly present. In the most recent Ten Year National Development Plan (PMA, 1984) the Ethiopian Government assigned high priority to the development of the agricultural sector. Furthermore, this commitment was framed within the broader objectives of increasing the farm income of the population and the alleviation of rural poverty. This statement of national purposes placed particular emphasis on the development of farm policies affecting smallholder agriculture. It proposed the improvement of agricultural productivity within the existing framework of small-scale peasant agriculture through:

1. The introduction of bio-chemical innovations such as high yielding varieties, use of more fertilizers, pesticides and other crop pests and diseases control measures and improved cultural practices;
2. The use of simple labour saving devices such as improved

oxen-ploughs, manual operated threshing machines, combine harvesters etc.;

3. Provision of credit to small farmers to purchase necessary inputs (MOA, 1982:13;FAO, 1982:8)[25]

The use of these inputs could significantly alter the relative resource requirements of crop enterprise as well as their relative net revenue. Such changes in the technical and economical circumstances within which smallholders make their decision about resource allocation could substantially affect the patterns of the allocation of farm resources. This could have a pronounced effect on cropping patterns of the farm income and on the productivities of farm resources.

In Ethiopia, although the use of modern inputs, as noted in the previous discussions, has relatively increased significantly in the last few years, results to date have been mixed and their impact on farm income and resource productivity is not yet clear. Moreover, efforts to identify policies which ensure higher income have been hindered by a lack of data on technological change and farm resource use. Relatively few attempts have been made to generate data that would enable a study of the impact of new technology on farm income and resource productity.

No national farm surveys were undertaken to study problems of resource allocation and the impact of new technology in Ethiopia until 1974 and only a few sample surveys have examined the structure of incomes at the village and farm level (CADU, 1970 and 1972; HSIU, 1974). Consequently, only fragmentary evidence on the farming systems is available in published form. From data collected during these periods, it was concluded that land and labour were the major inputs among the case farmers. Unfortunately, the case study farmers were too small and the respective household data sites were not pooled to provide a broader knowledge of the impact of the introduction of new technology. The purpose of the case studies, however, was to develop a base line understanding of farm production systems in the study areas, not to examine the impact of new technology. Therefore, while the studies provide some information on the Ethiopian highland farming systems, they do not examine the impact of technological transformation that has occurred nor the possibilities of development through the introduction of new technology.

The lack of such micro level research could widen the gap between the production unit, particularly smallholders and policy makers and planners. Upton (1973)[26] , for example, has observed the rate of agricultural development depends on the extent to which changes in the pattern and methods of production on individual farm units that make up the agricultural sector contribute to the desired development objectives. Since the ultimate objective of Government is to raise farm income and resource productivity, policy makers and planners can only anticipate and evaluate fully the effects of current agricultural development policies and strategies if they understand the improvements in resource productivity and the income of the small farm that are likely to be generated by the use of technological innovation. A study of this kind, therefore, could help to improve decision making process of policy makers and enhance an understanding of the farm level impact of new technology.

1.5 Objectives, Hypothesis, and Study Design.

1 5.1 Objectives

In view of the foregoing discussion, the following objectives will be pursued in the study:

1. To study the historical experience of the impact of new technology on agricultural production and its effects on farm resource use.
2. To identify factors that tend to constrain production of farm crops at the farm level.
3. To explore the means and possibilities of development under existing and potential new technologies.
4. To discuss the implication of the result for technology and research policy.

1.5.2 Hypothesis

In pursuing the stated objectives, a principal hypothesis has been formulated to guide the inquiry. It was hypothesised that low productivity in Ethiopian agriculture was mainly due to the use of traditional technology and that it was possible to increase farm productivity and alleviate rural poverty by means of technological improvements in agricultural production.

The acceptance of this hypothesis will provide the basis for the arguments in the thesis.

1.5.3 Organisation of the study

In accordance with the objectives laid down above, the study has been presented in eight chapters.

The objective of this chapter is to discuss, as an introduction, the background to technological change and policy issues in Ethiopia, purpose and scope of the study. A background to the case study area and the data base which provide empirical support to the study that follows are described in Chapter II.

The core of this study is organised in two parts along the main lines of inquiry. It is largely empirical in context.

Part I (Chapter III and IV) examines empirically the impact of technological transformation that has occurred. Chapter III first defines the concept of technological and then discusses methodological and data problems in technological change studies. This is followed by empirical analysis of the impact of new technology on farm income and resource productivity. In chapter IV an attempt is made for the first time to examine the widely debated issues of farm size and resource productivity in the context of Ethiopia.

Part II (Chapter V, VI, VII) is a formal modelling of the farming systems to identify constraints and explore further the production possibilities in smallholder agriculture. Chapter V explains how the farm household systems were specified in models that enabled the use of linear programming for technology evaluation. The possibilities of raising farm income and resource productivity under existing and alternative technologies are examined in Chapter VI and VII.

The last chapter contains a brief summary of major findings. This is followed by a consideration of some inferences for methodology and policy that can be drawn from the conclusions.

1.6 NOTES AND REFERENCES

1. For detailed account of the Structure of Ethiopian Agriculture, see Ethiopia, Ministry of Agriculture, Agricultural Sample Surveys, 1979/80, Vol. II Addis Ababa, May 1980; The World Bank. Ethiopia: The Agricultural Sector - An Interim Report. Vol. 1, January 1983.
2. IBID
3. Imperial Ethiopian Government, Ministry of Agriculture, Prospects for Agricultural Development in Ethiopia. Addis Ababa: Ministry of Agriculture, February 1971, p.9.
4. WATERSTON, A. (1965). Development Planning: Lessons of Experience. p. 460.
5. COHEN, J.M. and WEINTRAUB, D. (1975). Land and Peasants in Imperial Ethiopia - The Social Background to a Revolution. Assen, Netherlands: p.8.
6. For some detailed analysis on land tenure problems in Ethiopia, see: Imperial Ethiopian Government, Ministry of Land Reform and Administration. "Seminar Proceedings on Agrarian Reform in Ethiopia", Addis Ababa, 1970; HOBER, A. (1973) Land among the Amhara of Ethiopia: The Dynamics of a Cognative Descent. Chicago: University of Chicago Press, GILL, G.J. (1974) Traditional Land Tenure and New Inputs (A Case Study based on the Fertilizer Trials Programme), Ethiopian Journal of Development Research, 1 (1): 81 - 101, April; COHEN, J.M. and WEINTRAUB, D. (1975) Land and Peasants in Imperial Ethiopia - The Social Background to a Revolution, Assen, Netherlands.

7. For detailed discussion of the major objectives at initial and latter periods. See: CADU, (1969) Tentative CADU programme for 1970/75, Addis Ababa, March 1969; Nekby, B. (1971) CADU. An Ethiopian Experiment in Development of Peasant Farming. Stockholm: Presima Publishers, ARDU, (1976) Plan for 1975 - 80, Arssi Rural Development Unit, Publication No. 1, Assella.
8. IBID
9. One of CADU's earliest studies was of local marketing systems. A local farmer was provided with one quintal (100 kgs) of grain which he took to various merchants for weighing. Their scales were found to register 10 to 12 and a half percent below the true weight (CADU, 1967).
10. For detailed discussion on organisational framework, the major component of the package schemes and their achievements see: Tecle T. (1975). The Evolution of Alternative Rural Development Strategies in Ethiopia: Implications for Employment and Income Distribution, African Rural Employment Paper No. 12, Dept. of Agricultural Economics, Michigan State University, East Lansing, Michigan.
11. The Comprehensive Projects absorbed nearly 10% of the total agricultural budget.
12. Extension and Project Implementation Department (EPID) (1972). "Minimum Package programme" EPID Publication No. 6 Addis Ababa: Ministry of Agriculture, July, p.7.

13. Under the "Public Ownership of Rural Lands Proclamation No. 31/1975" that came into force as of March 4, 1975, agricultural land was nationalised. Larger commercial farms were converted to state (government) farms (some 60,000 ha at first) and the use rights to the remaining land (95%) were given to the landless and all claimants were organised into peasant associations, of from 200 to 400 families with a minimum of 800 ha of land (including grazing land).
14. The Institute of Agricultural Research Programmes are co-ordinated with those of the agricultural colleges, CADU/ARDU, the Addis Ababa University. It receives support from the Consultative Group for International Agricultural Research (CGIAR) including The International Livestock Centre for Africa (ILCA), The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Centre for the Improvement of Wheat and Maize (CIMMYT).
15. IAR has seven main research stations and about 22 testing sites. The main research effort is clustered on the Central highlands with research stations at Holletta, Bako, Nazareth, Debre Berhan and Debre Zeit. It has an additional research station in Jimma (coffee), Melka Werer (cotton), Awassa (Maize and Pulses) and Mekele (dry land farming).
16. For recommended technology in different ecological zones of the country see: Institute of Agricultural Research Publication. Handbook on Crop Production in Ethiopia, Addis Ababa, 1979.
17. Tecle, Op. Cit.

18. Until 1974, the agricultural price policy in Ethiopia was determined by demand and supply. Government intervention was minimal and in places such as CADU areas higher price for farm products were forecasted ahead to encourage farmers in the use of new technology. However, in latter periods prices were fixed and controlled by the government. One of the major problems with recent control of prices is that it is mainly aimed to protect the urban population from high food prices. Starting 1977/78 - 1981/82 it has remained static and below the free markets price of grains. During the same period, the price of fertilizer (DAP and Urea) on the other hand, has shown a dramatic increase as can be seen from the following tables.

Table 1.8 Price Changes over the period of 1977/78 - 1981/82

Input	Input Price change in %	Crop Output	Farm Gate price Change in %
1. Fertilizer			
DAP	142	Teff	-3
Urea	110	Wheat	5
2. Improved			
Teff	22	Maize	-1
Wheat	69	Sorghum	-1
Maize	21	Barley	-4
Sorghum	21		

Source: MOA (1982). MPP Annual Report 1980/81, p.21. Addis Ababa

19. Cohen, J.M. (1975). Effects of Green Revolution Strategies on Tenants and Small-scale Landowners in Chilalo Region of Ethiopia. The Journal of Developing Areas, pp. 335-358.

20. The crop yields given here are based on crop sampling surveys conducted in Ethiopia. The statistical methods used are given at

the beginning of each report. However, it should be noted that crop yields in addition to new technology can be influenced by other activites (which are not mentioned in the reports) such as the demonstration of improved cultural practices, the use of improved farm implements, the use of pesticides, and the provision of marketing services which induce farmers to increase their yields. For example, the yield of local barley in Chilalo area, where no fertilizer was applied, increased from 12.6 quintals per hectare in 1968 to 15.9 quintals per hectare in 1973. Similarly, the yield for local wheat rose from 9.8 quintals per hectare in 1968 to 15.2 in 1970. This apparent increase in yield could as well be due to favourable weather conditions, or the residual effects of fertilizer applied in previous years.

21. The sharp increases in yields due to the use of improved inputs induced large-scale mechanisation in some areas of Chilalo and Ada district between 1969 and 1974 in Ethiopia. According to Solomon Bekure, the introduction of mechanical innovation and the raising of land values contributed to the eviction of an estimated 500 to 550 tenant households. For detailed reports see Bekure, S. "A Perspective on Ethiopia's Approach to Rural Development: Implications for Socio Economic Research", Debre Zeit, 1974.

22. For the magnitude of the problem in terms of tenures see:

Table 1.9 Tenurial classification of farmers using new technology in Ethiopia (percentages).

	Chilalo Area		MPP Area	
Year	Tenants	Owner	Tenants	Owner
1968	8.5	91.5	-	-
1969	15.4	84.6	-	-
1970	27.6	72.4	-	-
1971	38.7	61.3	11.2	88.8
1972	30.4	69.6	12.1	87.9
1973	21.9	78.1	15.4	84.9
1974	24.2	75.8	N.A.	N.A.

Source: Tecle, 1975, Op. Cit.

23. For details in the issue of food crises in Ethiopia, see: SIDA (1984). Arssi Rural Development Unit, Consultant Evalutation, Report, p.1.

24. Fertilizers used in both the smallholder and the state sectors. Detail breakdown is as follows:

Table 1.10 Fertilizer uses in smallholder and state farms

Type of Farm	Thousand Quintals of Commercial fertilizers			
	Total	DAP	Urea	Kg/ha
Smallholder	369.9	324.3	45.6	6.6
Cooperative	30.6	29.6	1.0	22.0
State farm	98.4	75.2	23.2	105.5
Total	498.9	429.1	69.8	8.6

Source: MOA,(1980) Agricultural sample survey in 1979/80, Vol II, p.34.

25. Details of the programme for developing peasant agriculture has been prepared in line with the Ten Years Development Plan. It group Ethiopia's administrative regions into five development zones under Peasant Agricultural Development Programme (PADP)

Zone 1. Gonder and Gojjam

Zone 2. Eritrea, Welo and Tigray

Zone 3. Arssi and Showa

Zone 4. Sidamo, Bale and Hararghe

Zone 5. Welega, Ilubabor, Kefa and Gamo Goffa.

The proposed project has been submitted for financial assistance to Donor Countries as of 1982. Implementation of the Peasant

Agricultural Development Programme started in 1985. The details of the objectives and means of achievement of the targets are given in: MOA (1982), Peasant Agricultural Development Programme (PADP); Project Brief, October 1982; PMA (1984). Ten Years Development Plan, Berhane Selam Printing Press, Addis Ababa.

26. Upton, M. (1973). Farm Management in Africa, Oxford University Press, London, p.268.

CHAPTER II

THE STUDY AREA AND THE DATA BASE

2.1 INTRODUCTION

For the most part, this chapter is a descriptive prelude to the study that follows. It outlines some of the background information of the study area and provides the history of the data base on which the study is based. The survey and data processing procedures are put in context - which even the reader mainly interested in theory will appreciate. Indeed, without the account of the region and the procedures in data collection and management, the study would be dry. An attempt has been made to go beyond mere description, to present critically the problems involved in data collection and management.

The first section of this chapter deals with the choice of research site and a sketch of the main features of the environments of the area under investigation. This introduces the criteria used to select the study area and examines the geographical attributes of an area to make it a suitable zone for testing the major hypothesis elaborated in the first chapter. In particular, the study area had to be an area where technological change had taken place and prior data exists. Next, the location and characteristics of the chosen site are discussed with particular attention to topography, soils, climate, human environment and land tenures.

The final section discusses the data collection objectives, methodology and management. A brief account of the sampling procedures, field organisation, data collection, processing and tabulation procedures and problems, records some of the experience of the Ethiopian Farm Management Survey (FMS). This will be of methodological interest to Social Scientists engaged in conducting field investigations in Ethiopia.

2.2 The Study Area

2.2.1 The Agricultural Systems of the Ethiopian Highlands

The highlands of Ethiopia, defined as an area above 1500m elevation or with mean daily temperature of less than 20^{o}C during the growing period, covers 490,000 km^2, or around 40% of the country and almost half of the total African highlands (ILCA, 1983). It was therefore the initial focus of this study.

Ethiopia's highland topography is rugged and complex. The central part of the country is mostly high plateau, at least 1500m above sea level with peaks rising to more than 4000m, and is dissected by gorges and broad valleys. This plateau culminates in the east in a coastal plain spreading to the Red Sea, and in the west in the White Nile Valley plain on the Sudanese boarder. Most of these lowland plains are extensive range lands inhabited by nomadic pastoralists.

Several authors have described agricultural systems in the highland regions and formulated a classification which divides the area into agro-ecological zones. Westphal (1975) identified on a technical basis, four distinct systems, seed-farming, ensete (false banana) planting, shifting cultivation and pastoralism. However, from an economic viewpoint, development potential and the resource base of the various highland systems are more important. In this regard, the World Bank (IBRD, 1976) had formulated a classification which divides the highlands of Ethiopia into four agro-economic development regions on the basis of ecological conditions, human land use and resources. These are the northern semi-arid regions, the central highlands, the Blue Nile gorges, the western regions and the highlands south and east of the rift valleys. These ecological zones have a number of characteristics which have a profound influence on the agricultural practices in each. The principal characteristics of these major agro-ecological zones are summarized in Table 2.1.

The table shows that the situation in highland agriculture is somewhat unique in respect of ecology and crops. Any generalization for the country requires a definition of appropriate areas in different agro-ecological zones of the regions and selection of a number of farms within each area. A study of many zones would enable several types of farming areas to be represented in the study. However, so far this has been impracticable in the Ethiopian context due to lack of material and human resources to collect necessary data for all the agro-ecological zones in the country.

2.3. Selection of the Study Area

In most of the farm level studies in Africa, efforts have usually been made to select the farmers interviewed by some statistical method of random choice, but the choice of the areas or regions studied have been far from random. The selection of areas was based on the purpose of the research and in many cases was focussed on areas growing

Table 2.1 Characteristics of the major agro-ecological zones in the Ethiopian highlands

	Zones				
Characteristics	Central Highlands	S.E. Highland	Blue Nile Gorges	Western Regions	Northern semi-arid regions
Altitude	2000-3000	2000-3000	1500-2500	1500-2800	1500-2500
Topography	Rolling plateau and dissected mountains, broad valley hills.	Rolling plateau and mountains	Flat plains or rolling savannah	Dissected plateau	Steep escarpment and gentle slope, low plateau.
Rainfall(mm)	950-1500	950-1500	950-1500	1000-2000	450-1000
Dry season	Oct-Feb	Oct-Feb	Oct-Feb	Dec-Jan	Oct-Feb
Dominant crops and livestock	Teff,Barley Wheat Pulses Oil crops Cattle Sheep Equines	Barley Wheat Cattle Sheep Equines	Wheat Barley Teff Oil crops Cattle	Coffee Maize Ensete Cattle	Maize Sorghum Oil crops Cattle
Climate	Humid and sub-humid	Humid and sub-humid	Humid	Humid	Sub-humid and arid

Source: IBRD (1976). Ethiopia: Agricultual Sector Review. World Bank, Washington D.C., September.

export crops or smallholder development schemes (Spencer; 1977). For the purpose of this study, five basic criteria were used to select the study areas:-

1. It was a typical cereal, pulse and livestock production area in the highland mixed farming system with representative soil condition, topography and cropping patterns.
2. Farmers have used new production inputs such as improved seeds, chemical fertilizers etc., for several years.
3. There were the requisite group of households with different farm size.
4. There were substantial data collected in the area over a period of time.
5. The area chosen needed to be in the region that was of interest for policy makers of the future.

Large farm management surveys and other studies were undertaken over a period of time in the Ethiopian highland farming systems.[1] From the surveys only two areas, namely Central Arssi and Central Shoa have satisfied the above criteria. Therefore, two areas were purposely selected to typify the Ethiopian highland farming systems. The two areas are contrasting, but both are representative of a large agro-ecological zone within the highland regions, where land is dominated by mixed smallholder rain-fed agriculture. The Central Arssi enumeration areas represent the south eastern highland farming system that is dominated by barley and wheat cultivation. While the Central Shoa enumeration areas represent the central highland farming system that is dominated by teff and barley cultivation.

For convenience in this study, the Central Arssi study area will be called farming System A and the Central Shoa study area, farming System B.

2.4 Characteristics of the Study Area

2.4.1 Location

The location of each study area is shown in Fig. 2.1. with basic environmental data in Table 2.1. The wide range of topographical and cropping patterns are evident from these data.

2.4.2 Soils

Drawing from Murphy (1959, 1963) the soils of the area are reddish brown clays and clay loams. They are comparatively rich in their potassium and organic material content, with a considerable difference between the common type of soil. In general, the soils are productive, ranging from average to good, but many years of continuous crop cultivation and erosion on the steep slopes have greatly reduced fertility. Both fallow and crop rotations, which include grain and legumes, are often employed to maintain soil fertility. Shortage of phosphorus and nitrogen (organic matter) are evident, requiring the use of DAP, urea and phosphate fertilizers.

2.4.3 Climate

Climate has been a major concern in Ethiopia, and therefore, a brief review of the subject in relation to the study area is in order. At the outset, it may be pointed out that like the Sahle regions of

Study Area

1. Central Arssi

2. Central Shoa

Figure 2.1 Map of Ethiopia showing national boundaries, provinces, and locations of case study sites.

Source: Green, D.A.G. (1974). Ethiopia: An Economic Analysis of Technological Change in Four Agricultural Production Systems. Institute of International Agriculture, Centre for African Studies, Michigan State University Press, East Lansing, Michigan.

Africa, Ethiopia has been hard-hit by massive agricultural fluctuations and human suffering, as a consequence of erratic rainfall distribution and extended droughts, particularly in the northern part. To what extent the study area has suffered from such impediments is a necessary question to be taken into account in studying the two farming systems. In view of this, meteorological observations made by the research station were closely examined to ascertain the occurrence of such climatic fluctuations.

The temperatures in the areas are fairly homogeneous, although there are some distinctive features with regard to rainfall. The temperature ranges from a minimum mean monthly temperature of 10^{o}C in Farming System A to a maximum mean monthly temperature of 28^{o}C in Farming System B. However, the temperature gets gradually colder with increased altitude and causes frost (at 3-4^{o}C) which sometimes damages crops in the higher areas during the coldest months (November and January). Thus the temperature is not a limiting factor in terms of growth, although sometimes frost occurs. Rainfall is, of course, the major limiting factor. Both areas have two distinctive rainy seasons, commonly found in the highland areas of Ethiopia. The short rains, usually occur from February to May; while the big rains come after June, ending in October, and sometimes extend to November. These are followed by a dry season from October to February. The big, rainy season is particularly crucial as it is the main growing season for most cereals cultivated in the study areas.

The study areas receive an average rainfall of approximately 1013mm in Farming System A and 1214mm in Farming System B per annum; but with a considerable annual variation in the amount and distribution

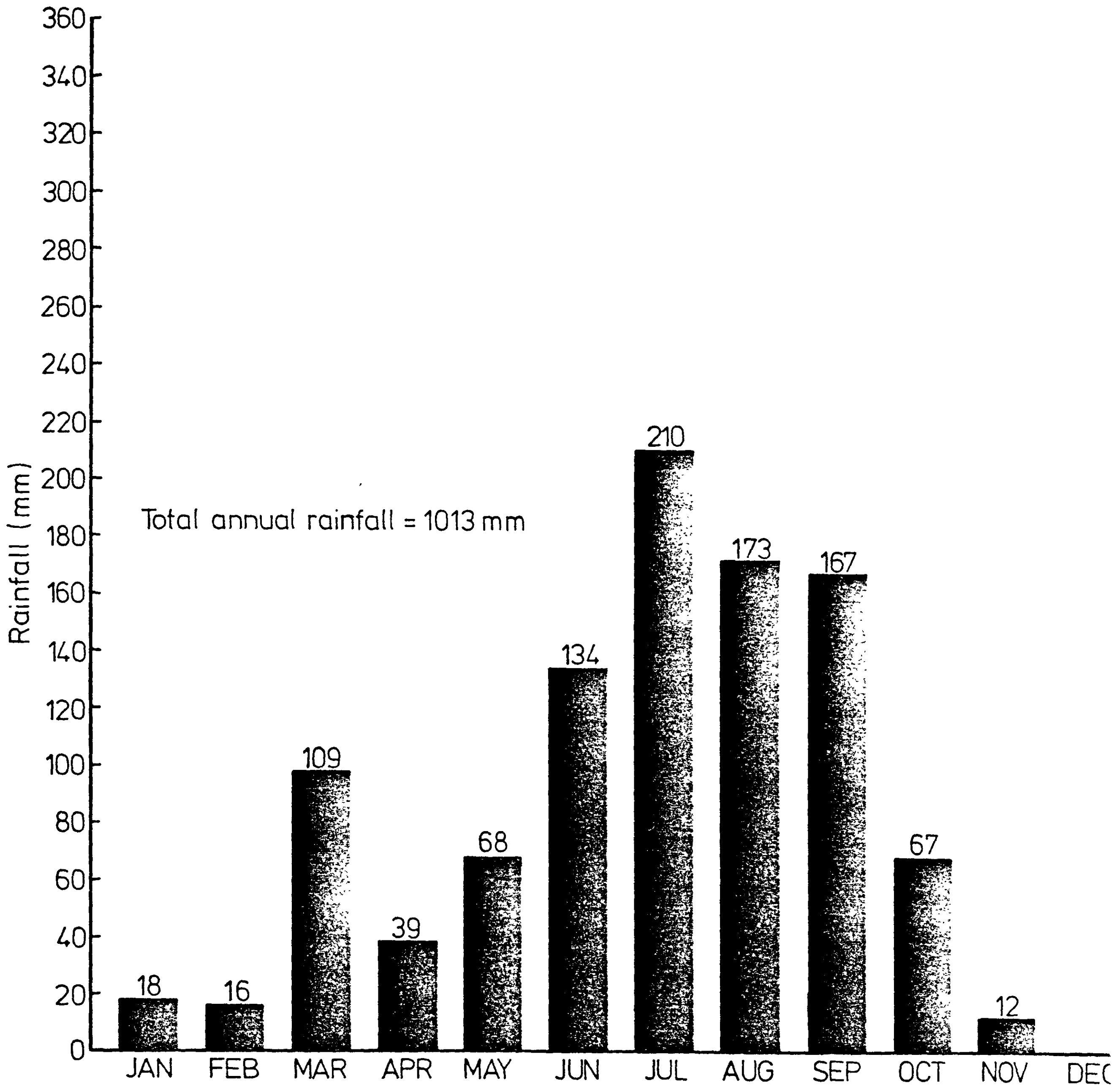


Fig. 2.2 Average monthly rainfall, Farming System A

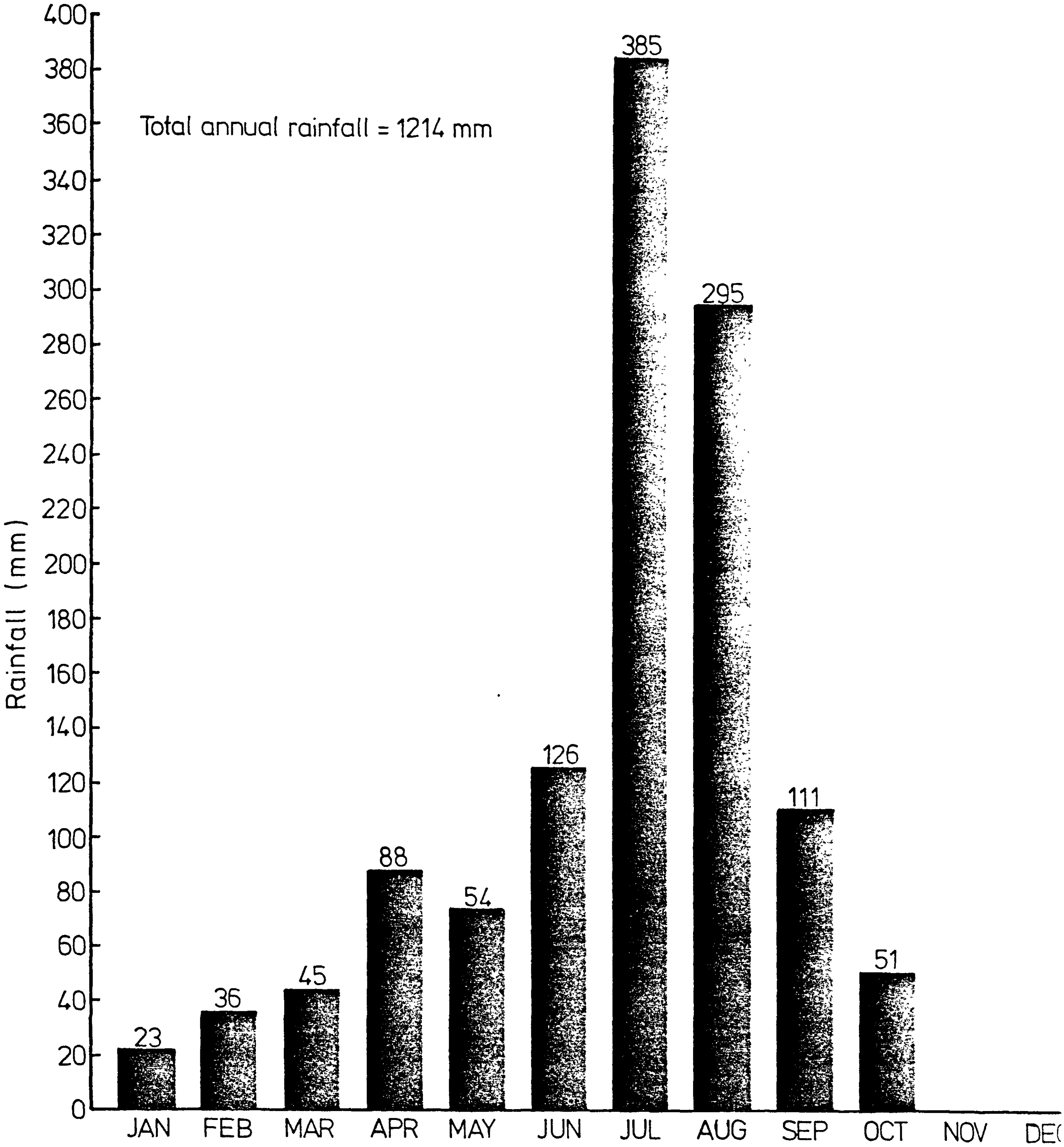


Fig. 2.3 Average monthly rainfall, Farming System B

of rainfall as shown in Fig. 2.2 and 2.3. Of even greater concern is the irregularity of rain at the beginning and at the end of the rainy periods. The climatic regime, particularly with respect to one short growing season and limited and unstable rainfall over the years, places considerable restriction on the types of crops that can be grown in the area.

2.4.4 Social Settings

2.4.4.1 Human environment

The rural population in the areas as in most of the highland regions, consists of largely Oromo speaking poplulation. They constitute over 87% of the population of both farming systems, 40% of the population of Ethiopia (Cohen, 1974). The concept of Oromo is both ethnic and linguistic and refers to those who belong to the Oromo ethnic group and from birth speak the Oromo language. The dominance of the Oromo is illustrated by the fact that an estimated 16 million speak the language in the whole of Ethiopia and they form one of the largest linguistic and ethnic groups in Sub-Saharan Africa. Their religion is predominantly orthodox Christian, but a Moslem population are found in Zone A. In spite of the differences in religion, the Oromo people as a whole, have a high degree of cultural and linguistic uniformity.

2.4.4.2 Land tenure systems

In the year prior to 1974, a notable feature in the agriculture of the case study areas was the existence of an agrarian stucture inimical to the interests of peasants. The land tenure was closely linked with the political power structure and social class organization existing at the time. The major landowners were the landed nobility, the Church, the royal families and tribal leaders (Demie, 1981; Gilkes, 1974). Various authors, including Cohen (1975), have studied the pre-revolution system and have identified that private tenure under landlords and tenant relationships was the predominant tenure system. This private land tenure was based on a share-cropping system. The most prevalent share-cropping system was the "Ekul" and "Siso", where the tenant paid one-half and one-third respectively of his harvest to the landlord. Between 1971-1974 however, the half sharing system became more common, particularly in Farming System A due to the stiff competition the traditional tenant were facing from big contract farmers who started farming during CADU project periods. In addition to the rent, itche was paid to landlords and personal services in the form of free labour were rendered. Most tenancy agreements were oral, and there was a total absence of either traditional or legal security of tenure for most tenants. Thus, the landlord had the right and power to evict his tenants at will (Cohen, 1975; Demie, 1981).

There were conflicting figures with respect to the proportion of landlords and tenants. It can however, roughly be estimated that in the central highland regions, 55% of the farmers were tenants, 15% tenants and owners and the rest owner occupiers, and in Farming System A, 40% of the farmers were landowners, 39% tenants and 21% mixed status. In addition, it was estimated that the tenants cultivated only 20% of the total land under production. The average area cultivated was 4.7 hectares, with landowners averaging 5.6 hectares and tenants 3.8 hectares. However, although the general plough culture mode of production utilizing oxen predominated, there was especially in the north of Farming System A, an increased number of mechanized farmers, some farming up to 5,000 hectares (Cohen, 1975; ESTC, 1980)

Since the political revolution in 1974, the Ethiopian government has transformed the institutional and social basis of production in agriculture. The land reform proclamation of 1975 (noted in Chapter I), dissolved all existing tenancy relationships and abolished private land ownership (PMA, 1975) . In theory at least, a farmland ceiling of up to 10ha was secured for each peasant to use. The institutional vehicles to implement these reforms were the peasant associations (PAS), established by the same proclamation and formed on a voluntary basis by smallholder farmers in later periods.

Each peasant association formed had 200 or 300 families within a total land area of around 800ha (ILCA, 1983; Rhamato, 1984). Starting in 1976/1977 cropping year, land was allocated successfully to individual smallholders within a range of 0.50ha to 7ha. Distribution of land took into account the different fertility levels of the soils and the family size within the land area of peasant associations. This policy, although fair in principle, in practice contributed to the fragmentation of each farmer's cropping area.

It should be added here that the intention of government policy in recent periods is to promote a co-operative mode of production, but to date most land has been allocated individually and the farmers in the area can still be regarded as individual smallholders (ILCA, 1983).

Mention must be made also of the payment of what is called a land use fee to the government, which was instituted after land reform to replace the share cropping system. At present, all peasants pay this and, for all individual cultivators, irrespective of size of holdings or quality of land, it is set at 10 Birr per year. They also pay an agricultural income tax, which is assessed at a graduated rate based on the annual income of each cultivator, with the minimum set at 10 Birr. This new system has some drawbacks: it does not make allowances for inequalities of holdings, differences in the quality of land, and the mini-holder as well as the large holder are made to pay the same amount. Consequently, some peasants, particularly the poorer ones, complain that it is unfair, that in effect it discriminates against small peasants (Rahmato, 1984).

2.5. The Data Base

2.5.1 Primary data sources and period of the survey

This study has drawn heavily on diverse sources of data, both primary and secondary.

The primary data used was based on farm management surveys (FMS) conducted in the study areas to generate a data base for planning and policy purposes. The main objectives of these surveys were to:

1. Identify the major farming problems and constraints.
2. Analyse the existing situations and practice of farming.
3. Identify the productivities of farm resources.
4. Suggest and develop alternative farming systems consistent with the goals and objectives of the farm fa mily (IAR, 1974 and 1981).

With these objectives, the preliminary FMS in the highland regions was carried out by the HSIU 1969/70 and CADU between 1967/68. Detailed descriptions of the conduct of the survey are available elsewhere and need not be repeated here (HSIU, 1974; CADU, (1969). On the whole, the author regards the survey despite its small sample size of only 30 farms, as having been competently conducted and the data to be reasonably consistent and by Ethiopian standards, of a reasonable quality.

The second detailed sample survey was the large FMS carried out over two years from March 1974 to April 1976 by FAO/IAR in collaboration with EPID and CADU (IAR, 1974; Solomon, 1979; CADU, 1976)

The third preliminary survey used was undertaken by IAR and ILCA under highland research programmes between 1979/80 (IAR, 1981; ILCA, 1983).

Secondary materials have also been used including books, manuscripts and published reports by other scholars working on Ethiopia and the varied output of the many arms and agencies of the Ethiopian government, notably the Ministry of Agriculture - EPID, IAR, CADU/ARDU and CSO.

These secondary sources were readily available and are listed in the references at the back of the thesis. In this section only a brief description of unpublished original material collected as part of the FMS highland programme is provided.[2]

2.5.2 Method of data collection

The vast majority of smallholders in Ethiopia do not keep records of their activities. As a result it was not possible to use farm account books or the farm business survey methods which are used in many developed countries. In many of the Ethiopian farm management surveys carried out by CADU (1969), HSIU (1969/70), IAR/FAO (1974/76) and ILCA and IAR (1979/80), the cost route method was used. The enumerators made weekly visits to each farm and recorded all the activities the farmer and his family performed during the previous weeks. These methods have two distinct advantages:-

1. The enumerator cultivates friendship with the farmers by visiting them weekly, and
2. He records events as they occur and thus does not have to rely on farmers memories.

The only data used in this study that was collected using a single visit study was the 1979/80 survey in Farming System A zone. Even here, in order to avoid biases which might arise from the inability of some farmers to recall and estimate reasonably some of the inputs and outputs, the field work was conducted in two parts. The first was carried out between June and July 1979, immediately after planting when information concerning fixed and variable inputs for land preparation and planting were recorded. The second was carried out immediately after harvesting, ie. between December and February 1980 and information concerning operations such as weeding, harvesting, threshing, transplanting and output were recorded.

2.5.3 Sample Size and Enumerators

In practice, the number of farms in the survey was mainly determined by the variability of the local conditions, the degree of precision required, the funds and time available for the survey (Yang, 1965; Collinson, 1972). Upton (1973) suggested for most purposes a sample size of thirty farms in FMS in each enumeration is probably adequate. In FMS in the two zones, attempts have been made to collect data from 100 farmers in period II survey and 135 farmers in period III.

The enumerators were agricultural college and high school graduates. They were permanently employed from the local area for the purpose of the survey and were trained first for 2 weeks.

2.5.4 Sampling Procedure

The sampling method used in the Ethiopian farm management survey was a multi-stage random sample.

In the 1974/76 survey an attempt was made to select a statistically random sample of farm households using the following procedures.

First, the survey areas were delineated using aerial photographs and approximately 1:25,000 scale maps that were available for the study areas. First enumeration was selected and the coverage for each enumeration area was 80 to 100sq. kms. The principal considerations for the delineation of the area were, 1) accessibility, 2) relative homogeneity of the cropping patterns and 3) settlement patterns of the farming community.

Secondly, local chiefs who had a knowledge of the population were contacted through the local extension worker, and for each area, a list of heads of all households living in the delineated areas were prepared.

Thirdly, since the farmers had to be visited weekly throughout the study period, it was necessary for the farms selected to be accessible all year round, at least with 4 wheel drive vehicles or by horse or mule. The initial survey included villages within the enumeration areas. The next step was to select along the routes, farmers within walking distance of main roads and feeder roads.

Finally, from these lists of farm households, 25 required samples of households in each enumeration area with 10 reserve for early dropout were selected using a simple random sampling procedure. Then the selected farmers were contacted individually to explain the purpose and scope of the study.

In the 1979/80 survey however, some improvement was possible regarding the sampling frame. Given the availability of peasant associations, the list of members of the farmers association has been used as the sample frame. At the first stage of multi-stage random sampling, enumeration areas were selected. At the second stage, with the help of extension agents, all farmers' associations were identified and located on a map and inaccesible ones were eliminated. Using the total list of each association, which served as a sampling frame in the third stage, all farmers who were accessible throughout the survey period were selected. From the lists, the required number of farmers in each enumeration area were selected at random. The number of sample units selected in all surveys in each enumeration area was limited by the decision to station enumerators, the resource available and the number of visits and supervision required.

2.5.5 Questionnaire and type of data collected.[3]

In Ethiopia, IAR with the help of FAO had developed a standard questionnaire used to collect information from various farming systems. The design of the questionnaire was a compromise between the number of questions necessary for ascertaining the required data and the time available for an interview. Most questions in the questionnaire were open.

Before the final version of the questionnaire was decided upon, a pilot survey was carried out in the case study areas. Through this test of the questionnaire, corrections and reformulation of questions, removal of irrelevant ones and inclusion of new ones was made.

A manual was also prepared for the questionnaire as a guide for the survey, and wording of questions to be asked to supplement the questionnaire. The questionnaire was in English, translated during the survey by the enumerator to local languages. It consisted of three parts:

1. The inventory (stock data) and its evaluation to be recorded at the beginning of the crop season. This part included data on farm household members, farm resources, farm products in store, farm capital, farm livestock and household consumption.
2. The recovery of past production activities.
3. The flow data that covered the crop seasons of the periods under investigation, which included records of inputs and outputs and household consumption and expenditure as reported by farmers/farm families on a weekly basis. Specific operations on the farm included labour hours spent on farm and off the farm, oxen pairs hours spent , material inputs, crop-livestock outputs, general expenses on consumption and other items, general farm income and sales and inventory changes.

Added to these, the weekly price of agricultural products that prevailed in the local market of the enumeration areas were successfully collected by questionnaires especially prepared for this purpose. Also, scattered weather data was available covering varying periods of time for areas close to agricultural research stations and other locations where public development projects were underway. In this study, only information provided on farm household members, farm resources and detailed information on input-output relationships for various enterprises were used.

2.5.6 Measurement of input-output data and some problems encountered

The rural residents in Ethiopia are predominantly illiterate so that many types of units of measurement were unfamiliar to them. However, farmers, through generations of usage have established local standard units for land, labour inputs and seeds in their agricultural operations.Cadastral surveys of agricultural land are a rarity in Ethiopia. Traditional farmers have only a vague concept of the size of a hectare and they usually use local measure of an area which can be converted to hectares. Land units are measured in terms of timad among the peasant agriculturalists of the central part of the Ethiopian highlands and eastern highlands where traditional oxen plough culture has been practised for generations. The timad (also known as Kert in the study areas) is defined, according to farmers as an area that can be ploughed with a pair of oxen in one day. The unit, obviously is dependent upon factors such as the constitution and condition of the animals, type and condition of soil, climate, the customary working hours, drainage, specific seasons and topography of the land. Thus, this unit of measurement can vary greatly from area to area. It has been found that a timad varies from around one-fourth of a hectare in one location to around one-tenth of a hectare in another location. In addition to a complete lack of cadastral surveys and the absence of recent aerial photographs, land measurement was made difficult by the suspicious nature of peasant agriculturalists and their refusal to obtain measurements using tapes. As far as possible, in most of the studies, farm size was determined by pacing around the farmers' fields or plots and calculating the average area from these reported Timads.

Here labour inputs are reported in terms of man-hours although the use of man-days as a measure of labour input could be used as an alternative unit. Peasant farmers in Ethiopia seem to have a fair concept of time, and with some margin of error, the farmers' timing can be consistently geared to the clock hours of the day, although they do not own watches in most cases. Within the household, every member above the age of six participates in at least one of the agricultural activities. Adult males' main activities were ploughing land, planting, weeding , harvesting and threshing. Generally, younger boys and sometimes girls are given the task of herding sheep, goats and small herds of cattle. Young boys help during ploughing until about the age of 15, the age at which they are expected to handle the plough and manage a pair of oxen as effectively as an adult. Women participate in agricultural operations, particularly in activities such as weeding and harvesting of crops. However, a large proportion of their time is spent on household activitites such as cleaning house and animal stalls, fetching water and gathering firewood and food preparation. Local mutual groupings are found in almost every small peasant community (known as jigi, debo) that engage in labour exchanges to meet critical labour demand. Seasonally hired labour is an insignificant source of labour input in the survey areas.

Seeds used for planting are measured by containers (kuna) which are woven baskets. Here, these types of containers have been standardized and converted to kilogramme units.

An attempt has been made during the survey period in the study areas to estimate crop yield by taking samples of plots from fields under various crops using the crop cutting method. The methodology and the results of these surveys are reported in many publications (MOA, 1976 and 1980; ARDU, 1976 and 1982) but there is a widely held belief among experts that there is an upwards bias to yield derived by the field plots method[4]. Also, if fields are heterogeneous, no accurate yield data will be derived and this method cannot be utilized. In Ethiopia, most of the fields were quite heterogeneous and the yield plot method was not used as part of FMS.

Therefore, in the study area crop outputs were estimated indirectly by asking the amount of crops obtained in local measurement and then converted to the standard unit of kilogrammes.

2.5.7 Data processing and computational techniques

2.5.7.1 Processing of questionnaire and compiled data

In all the surveys it was considered expedient to undertake a certain amount of editing of the completed questionnaire to ensure completeness, accuracy and uniformity. Any inconsistencies in the questionnaire were rechecked with the farmers at the time of the survey. In this study, it was reported that major consistency checks concerning the data of the sample farms were made at the field level by supervisors and enumerators hired for each enumeration area. On the basis of the exercise, some corrections have been made through time and farmers with major problems have been dropped (Solomen, 1979; Mela, 1982 and 1983). After the survey had been completed, the data were compiled in the Department of Socio-economics of I.A.R. The data on the questionnaire were then coded for processing. All data were coded in the same units as they were collected during the field survey. A subset was sent to the FAO data bank.

The author received the punched data on tape from FAO and the original record sheets from IAR to counter check the quality and consistency of the data.

However, it is worth noting that the data processing work was delayed for over a year due to the temporary loss of the FAO codebook in Rome and the need for securing additional FMS data from the study areas. Although research started in October 1982, it was not until September 1983 that another copy of the code was traced in Ethiopia. Finally, the codebook and the vital original survey record books and other additional research materials was received in February 1984.

At Wye, all data processing was carried out using facilities of the University of London Computer Centre (ULCC) with which Wye College has a terminal link. The data of the original tape were first transcribed onto tapes compatible with the ULCC machines and edited for the relevant data fields to prepare for processing. Additional data were also compiled and punched.

In the course of the exercise, data completeness and uniformity and punching error were checked by comparing with the original records. Many punching errors were detected and edited and farmers with inconsistent doubtable information were dropped. In the final analysis, all sample farms in period I, only 90 farmers in period II and 129 farmers in period III were included. Furthermore, because of the sheer size of the original data file (61153 records on tape) a reduction to manageable file size was necessary. Initially, all data were processed and checked. The final working files were limited only to data which were considered relevant to the present study. Hence, nearly all the data on consumption and expenditure, off-farm income and activities; 1974 single visit surveys from the case study regions; 1974/76 surveys from other enumeration areas; 1972 to 1973 multi-visit survey data from Zone B were discarded. All other weekly input-output data were aggregated as monthly and annual values by sample farmers and used in this thesis.

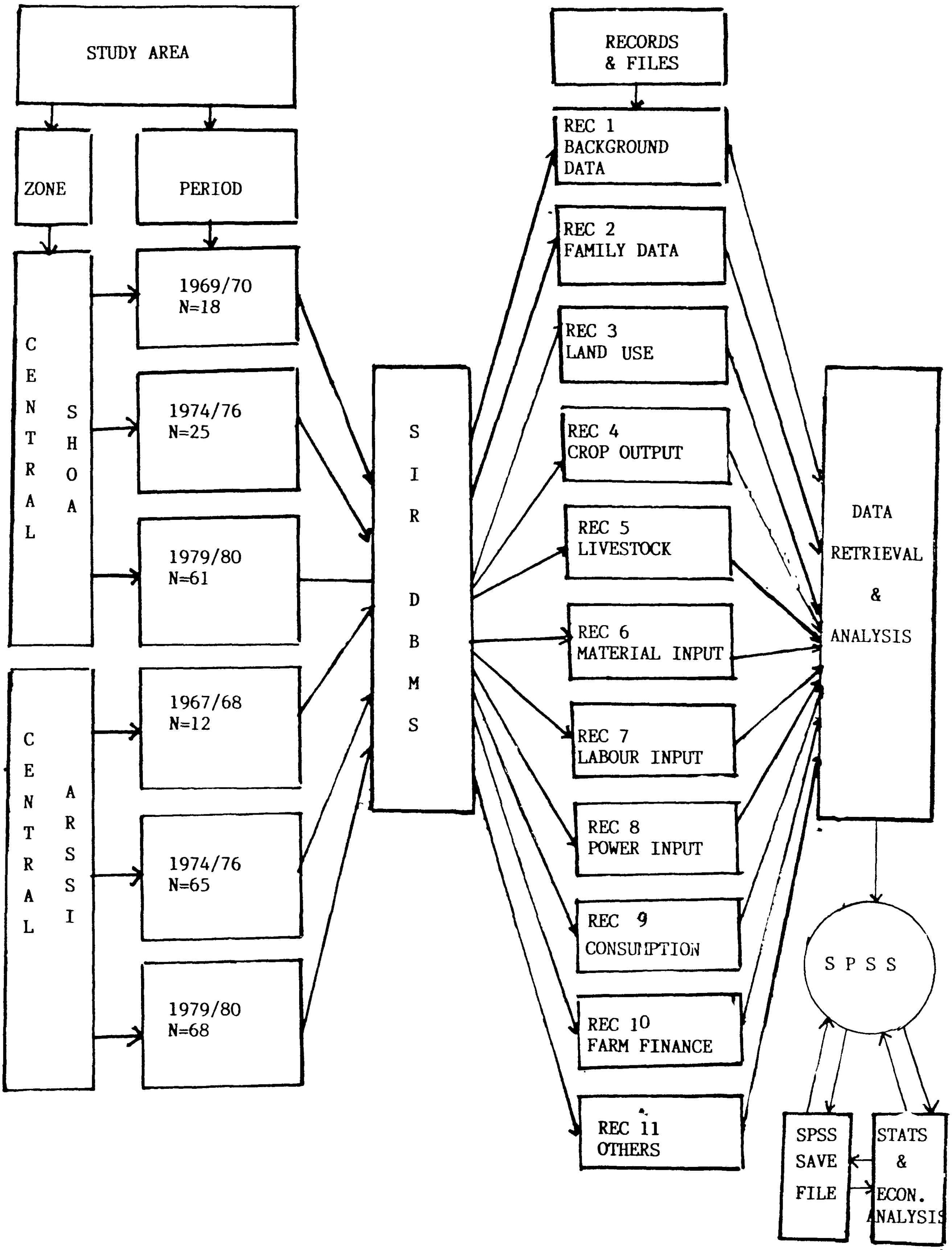
2.5.7.2 **Data management and problems**

To sort out the data base, carry out consistency checks, aggregate and tabulate and prepare data for analysis, the data base required a special data management package. Most of the original data was in FAMDCAS/FARMAP, which is designed for the rapid and flexible processing of rural survey data (Dixon, 1983; FAO, 1977). The package consists of a precoded questionnaire and has a simple means for validation (ie. checking within records and between records, input and output range and value checks, correcting and modifying data), aggregation and reorganisation of data and tabulation in the processing stage. The programmes produce a specific format of print-outs for the farm, crop, livestock and supporting analyses (FAO, 1977). The major strength of the package is the printing out of a net worth statement, an income statement, a time and resource use statement, a selected set of efficiency and productivity analysis for each farm, and an enterprise budget for each crop of each farm. The data output files in the package can also directly serve as input files for SPSS or other statistical packages. Unfortunately, this package was not available within the University of London Computer System. Instead, an alternative package, the Scientific Information Retrieval (SIR) was chosen for data management. SIR/DBMS is an integrated data base management system that has been designed specifically for scientific research. It is capable of handling hierachical and network data structures and of interfacing directly with other packages.

A hierarchy, as defined by Robinson et al (1979) is a structural collection of data in which one record is said to own many other records in a top-down or tree-like structure. Hierarchies occur naturally in many disciplines. In this study, the hierarchy was established through the data and the usage of the data as in Fig. 2.4. The structure of the data kept the natural inter relationship between the different data types studied. As the two major functions of the data management system (DBMS) are data storage and retrieval, DBMS in theory must provide a variety of means for updating deleting and controlling the contents of the data file. SIR/DBMS has these facilities, which proved very useful in this study.

The data retrieval capabilities facilitated the performance of both simple and highly complex retrievals and was used to interface with the SPSS package to perform statistical and economic analysis on the data. The report generator command of SIR/DBMS was used to compu te simple and complex tables, to aggregate data and make necessary editions and finally retrieve. In spite of the usefulness of SIR/DBMS it is a very complex system for the new user and has several disadvantages for FMS data processing.

Figure 2.4 Structure of data management system



Firstly, the main purpose of computer packages is to try to protect the user from the need to know how computer systems work and yet enable him to undertake all the commonly required tasks for analysis. Yet the SIR package is a very complex system which makes great demands on the new user in terms of time and patience required to understand its processes.

Secondly, complex FMS based data can not be handled unless some modification is made. Our attempt to write the FARMAP type data and to retrieve failed. We realized the number of variables involved was too complex to be handled in the SIR hierarchical structure[5]. The solution was to create many records and sort the data code by code. This tedious approach was used and it has, as a result, consumed large amounts of the research period.

Computations were mainly carried out using the Statistical Package for Social Science (SPSS) for regression. The LPFARM package was also used for linear programming.

2.5.7.3 Conversion of weights and measures

In the labour data to facilitate analysis, it was considered necessary to adopt a suitable weighting procedure for direct comparisons of the different types of labour during the processing stage. Two main alternatives are suggested in the literature for weighting different types of labour, namely, weighting by task and productivity. It has been suggested by Norman et al (1979) that weighting by task could be more desirable since it relates directly to ease and efficiency with which a particular task is done. They note, for example, that women picking cotton are generally more productive than men in West Africa. However, no suggestions appear to be forthcoming as to exactly how the numerous tasks performed in farming could be conveniently weighted.

The alternative to weighting by tasks is weighting by productivity based on sex and age differentiation. In this approach male adults equivalent are assigned as a standard in measuring the productivity of the farm household members. The weighting of this nature presupposes that labour done by women, young children and old people is less than is done by men (Norman, 1973).

It has almost become conventional to use productivity weights of labour on sex and age differentiation in peasant agriculture since it is considered simple and straightforward. However, this approach also has its own weakness. As will be pointed out in later chapters, ages data are not accurately known in most cases in traditional farm families. Furthermore, experience from various previous farm surveys in Ethiopia suggests it is simpler for a farmer to give accurate information if asked to classify members of his family according to the farm operation they perform (HSIU, 1974; IAR, 1979; ILCA, 1983). Therefore, in this study consideration was given to this approach. The weighting used to compute family labour availability in terms of adult man-equivalents during the processing stage, were as follows:
Adult male = 1.00, adult female = 0.75, adult school children available for part-time work = 1.00, other young children = 0.50. This weighting approach may be criticized for elements of arbitrariness in evaluating labour force used and available but it is a practical and simple approach in the context of Ethiopia.

2.5.8 Reliability of Data

Establishing a good relationship with the farming community and the respondents was a prerequisite for getting acurate data. In the case of this study data base, the sample of households was first contacted through influential village and community leaders and local extension agents. In the initial stages, before the start of the survey, the purpose of the investigations, the use that would be made of the information to be collected and how the respondents were selected and the expected (although indirect) benefits were explained to the co-operating farmers. They were told that the data was being collected in order to study the impact of a project which had been started, or was about to be started in the area and was for the use of the IAR, CADU/ARDU,EPID with which most of the farmers were familiar. They were also assured that the survey had nothing to do with taxes. The respondents were made aware of the continuity of the investigation and the procedure of data collection and told that their full co-operation would be needed for the period of study. Many farmers in the area under investigation had already been involved in various earlier surveys conducted by CADU/ARDU, IAR and HSIU/AAU.

Regarding the data quality Solomon(1979), Mela(1983)[6] and Dixon (1982,1983)[7] who participated in the supervision stage confirmed that the multi-visit interviews conducted once a week during the crop season provided fairly accurate data on crop and livestock production. However, a large question mark has been put against consumption data (Demie, 1984), income other than crop production (Demie, 1984 and Solomen 1979), single visit survey data (Demie, 1984 and Dixon, 1982).[8] These data were not used in this study. Taking into consideration the possibilities of error in any survey result, the reliance was placed by the author on combinations of careful judgement and his own surveying experience in the area before using the other data. Most of the data obtained from the sample farmers used in this study made sense, and collectively they fitted into a coherent pattern. This was further confirmed by comparison of the mean of some key input-output such as farm size, family size, livestock population, crop yields, seeds and fertilizer inputs of the data used in this study with secondary published sources (eg. Bengtsson, 1983; CADU/ARDU; 1976 and 1982; MOA, 1976,1979 and 1980). In most cases the findings of the mean of the major input-output data fall in the same general range of other surveys findings in the area, which gives credibility to the answers of the respondents.

However, in view of the fact that information from illiterate peasant farmers was always difficult to collect, (no matter which method was used) the errors of recording could not be avoided. Studies of this kind suggest that the finite level of the reported figures cannot be regarded as absolutely exact.

2.6 Conclusions

As is clear from this, the research areas selected in the Ethiopian highland farming systems provide an opportunity to test the hypothesis of this thesis. The next chapter deals with the ex-post impact of new agricultural technology on farm income and resource productivity in a case-study farming systems.

2.7 Notes and References

1. For a detailed account of the FMS in the Ethiopian highlands, see in Bibliography section IAR (1974,1973,1981,1982); Ebba (1970); the survey conducted by the author HSIU (1974); CADU (1969,1972,1976); ILCA (1983) and appendix F
2. The discussion in the following section, unless stated, is based on records by Solomon (1979), IAR (1974) and Demie (1984).
3. For questionnaire and instructional manuals discussed here, see in the Bibliography Demie (1984), pp. 11-57.
4. Some discussion regarding the reliability of the crop-cutting survey by CADU/ARDU has been made between the author and leading SIDA and SAREC experts, Lars Lender and Bengstsson Bo in August 1985 in Stockholm. Both of them argued that CADU/ARDU has doubled the yield of wheat (if not as reported between 19-23 quintals per hectare), while Bengtsson disagreed on the basis of his farm survey in 1966 and 1980 that 11-12 quintals (as compared to 8 quintals in 1966) are the most that can be achieved at farm level in post-technological change.
5. For the details of the variables involved in FMS see Demie (1984), pp.58-84.
6. Discussion about the data on many occasions at Wye College.
7. Personal letter communications in January 20, 1982 and January 19, 1983. Also discussion at Wye College during his visit here to give me a background view about the structure of the data base.
8. Some random range checks of these data by the author in comparison with secondary published material and his own experience in the area indicated that they are under-reported. Some data (eg. off-farm income) are sensitive to collect accurately because of the countries laws which prohibits any off-farm activities.

PART I EX-POST ANALYSIS

CHAPTER III

TECHNOLOGICAL CHANGE IN THE ETHIOPIAN HIGHLAND FARMING SYSTEMS

3.1. INTRODUCTION

The main purpose of this chapter is to give empirical content to the change in agricultural production from the introduction of new technology in the Ethiopian highlands. Empirical evidence is based on farm level data for the years 1967/70, 1974/76 and 1979/80, as already discussed in Chapter II.

Section 3.2 introduces the concepts of technological change. This is followed by Section 3.3. which discusses data and methodolgical problems of studying technological change in traditional agriculture. Emphasis has been made here to assess critically the aprropriateness of the existing often untested methodological tools such as a case studies method, comparative cross-section method (with and without) and comparative time series method (historical method or before and after), in data generation at micro level. This section ends with the presentation of the production models used in the study.

In Section 3.4 aggregate production functions are estimated for the area under study. An attempt is made to determine empirically the parameters of change from the base line to the post-technological change period. Finally, the summary, conclusions and policy implications of the results are presented.

3.2. Technological change defined

There is surprisingly little standardisation in the use o terms in the literature on technological change. Authors define their own meanings and the definitions differ from one writer to another. Many authors use the terms technical change and technological change interchangeably. We can take advantage of this anarchy to design vocabulary which best fits the case we are studying. Change in production technology is a fundamental component of the structural alteration and adjustment in the use of resources that comprises economic development. This is true for both the agricultural and the emerging industrial sectors of a developing economy. Technological change is accepted as being an alteration in 'the employed or operative knowledge of means of production' (Yudelman, 1971) and is manifested by additions to (and substraction from) the set of inputs employed in production, and thus by consequence changes in the techniques of production available. An essential characterstic of a change in technology (as opposed to merely a change in technique) is that it implies the use of a new input-either an input that is wholly novel, or one that is new in the sense of being an improved version of a traditional input. This distinction between technique and technology, and the meaning of each term can be expressed in conventional production economics. This is highlighted in Figure **3.1**

If in the production relationship . it is assumed that the isoquant Qo represents two inputs that may be employed to produce a given level of output, then the shift from factor combination A to factor combination B is a change in a technique or process of production. This implies no change in the production function which defines the input-output set. A change in technology on the other hand, does explicit ly imply a change in one or more of the parameters of the production function, and is represented by the shift in the isoquant (defining the same level of output Qo to the position shown by Q1

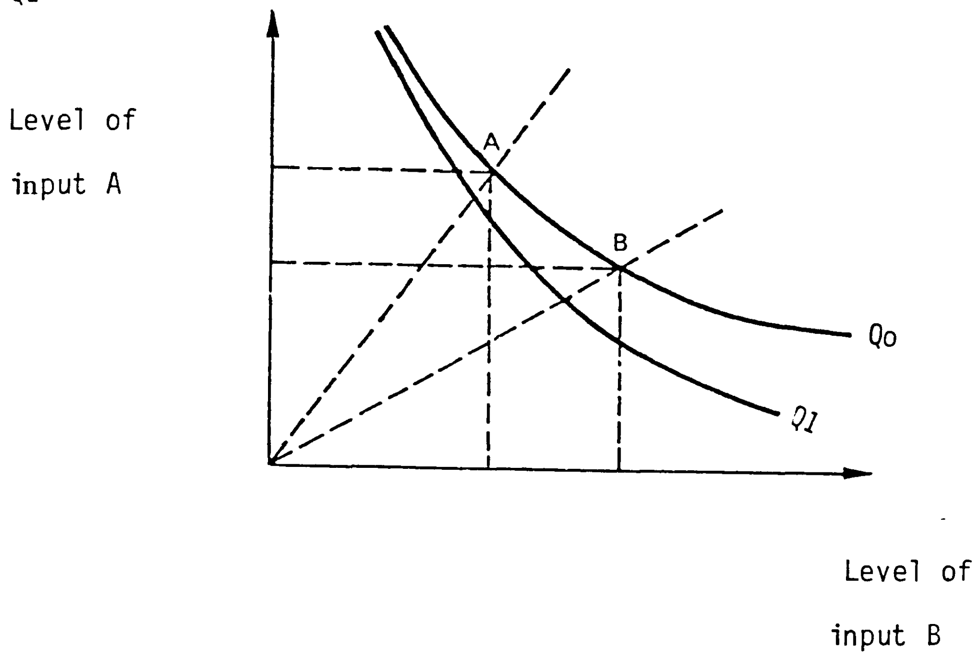


Figure 3.1 Change in Technique and Change in Technology

3.3 Methodological and Data Problems in Technological Change Studies

3.3.1 The Need for Micro Level Research

Study of technological change is not an abstract science that can be usefully studied in isolation from the real situations and circumstances at national, regional and farm level. A necessary first step in any study in this field must be to obtain information about the important input-output variables and relationships which affect the rate of technological change. In most cases, depending on the nature of the study, they include variables such as physical output and inputs such as land, labour, seed, fertilizer, livestock, machinery. These data on which the analysis is based must be as accurate and relevant as economically possible. Accuracy relates to the degree of conformity between the data and the real factors the data are supposed to describe. However, the experience of many previous studies shows that the high degree of accuracy of the input-output data that are required in this area is not easily achieved at macro-level.

The time series input-output variables used are estimates based on official government statistics which are often highly unsatisfactory for firm conclusions on the effect and rate of technological change. The work by Solow (1962) and Lave (1962) in US agriculture, Tuschiya (1975), Hayami (1965 and 1975), Hayami-Yamda (1968) in Japanese agriculture and Hayami and Ruttan (1985)in an inter-country study for DC and LDC are the best examples to demonstrate problems of data based on official statistical estimates and secondary information. The seriousness of the problem varies from country to country and according to the periods under consideration. The data used from LDCs tend to have critical defects when compared to data from DCs. For example, in the pioneering inter-country study of DC and LDC agriculture of Hayami and Ruttan (1985), which is mainly based on FAO statistics and other publications, some of the estimation for yields of wheat and maize crops of 80 countries in the lists are reported to be based on eye estimates rather than some kind of measurement (Yarkovich, 1975). Certain variables were, in fact, difficult to get. In many studies, labour was based on the economically active male labour force, rather than the actual labour used. The value of such data as an instrument of technological change research indicates the limitations of the existing statistics and the constraints of a macro-level study.

Despite data limitations several of these studies have been very important in influencing policy choice.

In the past, practical researchers in this field of study have attempted to obtain such data as they thought available and of some accuracy, and then exploit it as best they could. Empirical economists, particularly, seem to have adopted the attitude that having some data is better than no data at all. Their task was to learn as much as possible about the rate of the contribution of technological change from the statistical data available to hand. They recognised that the availability of quality economic statistics remained the major answer to the problems. The quality and the availability of economic data for studying technological change presents a continuing challenge for economists. However, now it is the time for this problem to cause us to modify our expectations and our approach. A micro-level approach may be the answer to the problems at macro-level but we do not have sufficient extensive time series micro data sets to open up new possibilities for analysis of the role of technology. This necessitates the need for a strong empirical, fact-accumulating tradition in technological change research. The major appeal of the micro approach is that it provides a link between the farm, the region and the industry as a whole, since it permits the consideration of the role of technological change at the national or regional level or the individual farm.

3.3.2 The Micro Level Approach of Studying and Measuring the Effect of Technological Change

Given the practical problems of data generation in traditional agriculture and the weakness of the aggregate approach of measuring technological change at macro level, one valid alternative approach is to design appropriate methods of data generation within a micro economic framework and then carry out the production function analysis on micro level aggregated and disaggregated data.

Theoretically, several research designs exist which can be considered when studying technological changes in production and productivity (Cairncross et al, 1980). The alternative study methods postulated in the past are set out in Table 30, according to the characteristic of each method.

The strongest evidence of change due to a new technology which could satisfy the academic criteria will be obtained from the ideal type (with-without and before and after) and long term study methods (ideal type plus the control eventually receiving a new technology, plus restudy of both the control under new technology and the project area some years later). However, it is clear that these approaches are very rarely possible in social science research in DCs let alone in LDC. Given the shortage of funds and staff in many poor countries to generate data necessary for this method, the realistic alternative approaches which have some practical importance in traditional agriculture are the Case Study method, the Comparative Cross Section method and the Comparative Time Series method.

Table 3.0 Possible Research Design and Methodology of Studying the Micro Level Impact of New Technology

Methods	Area of study	Type of study Base Line	 Subsequent
1. Case Study	New technology area/farms		After-with new technology
	Control old technology area farms	-	-
2. Comparative cross section	New technology area farms		After -with new technology
	Control old technology area/farms	-	After-without new technology
3. Comparative time series	New technology area farms	Before-without new technology	After-with new technology
	Control old technology area/farms	-	-
4. Comparative cross section and comparative time series	New technology area farms	Before-with old technology	After-with new technology
	Control old technology area/farms	Without new technology	Without new technology

In the discussion which follows, therefore, as the basis of assessment of this area, the significance of these alternative approaches will be considered.

3.3.2 Commonly Used Methods

3.3.2.1 Case Study Approach

A case study approach is one simple method which is used to research the nature and the extent of change brought about by technological change. It consists of a detailed examination usually of a relatively small number of farms where new technology is adopted. In this method the data may be collected from the sample farms on a ' after' basis with the objective of making a comparison between adopters and non-adopters of technological innovations. Normally the farms are picked to be 'representative' rather than selected by random means. Various different types of farms recognised in the study area are represented in the group studied.

The argument often raised against this approach is that it does not ensure that the overall results obtained are representative of the changes brought about in the area of technological changes.

However, despite this weakness, it is helpful, particularly when one wants to make an early assessment of the package programme and as a preparatory study for overall evaluation using more complex methods.

3.3.2.2 Comparative Cross-Section method (With and Without)

The main focus of this method is to study a sample of farms that have adopted the particular technology and compare them point by point with a sample of farms that still employ traditional methods. It regards the differences between adopters and non-adopters as being due to the impact of new technology. However, a number of considerations are critical to the validity of the method. To attribute the differences to new technology it is necessary that both groups of farms studied are essentially homogenous with respect to all their main features. The use of either new or traditional technology must be the sole characteristics for differentiating a farm in one group from its counterpart in the other group of the survey. Clearly, this is an impossible ideal to achieve at field level. It is impossible to construct a survey by purely random sampling among the components of the sub-populations of modern and traditional farms and control the differences associated with the groups. For example, in stratifying the population and then sampling from groups, which are similar with respect to farm size and labour force, it is impossible to eliminate the change one is trying to measure.

This then, is the essential weakness of the comparative cross-section study as a practical method of data generation for measuring the effects of technological change in traditional agriculture. In general the actual difference obtained by this type of study between farms adopting new technology and non-adopters reveals nothing about the effects of technological change upon the farm. It merely shows only the difference between the two groups of farms.

3.3.2.3 Alternative Approaches: Comparative Time Series Method (Also Called Historical Method or Before and After Approach)

The dilemma in the measurement of the impact of technological change in traditional agriculture noted in the case of the two approaches mentioned above, can be overcome by observing the situation prior to the arrival of the new technological packages and again after the new techniques have been adopted. This gives rise to a kind of 'before and after' study. It is relevant where technological innovation is widely spread throughout the package area, and is generally concerned with charting the course of technology, and its contribution to productivity growth. It is an approach most appropriate to the study of an actual process of change because it can measure the shifts in the value of the variables of interest as opposed to merely examining a series of differences between the adopters and non-adopters as in the case of the comparative cross-section method. It focuses only on actual changes that have been induced by the technology under study, which can be observed and measured. The method does not involve any assumptions about what traditional farmers might or might not do. In relative terms this method is a practical and efficient method of generating data on the effect of change before and after the introduction of technologies.

In the past this method was rarely used in the area of smallholder agriculture. It requires statistically valid input-output data by survey schedules or cost-account records, before the adoption of new technology and then on an annual or periodic basis afterwards. Observation in prior or latter periods is rarely done in many areas where attempts have been made to increase productivities through the introduction of technological packages. Over time things other than the subjects of study can influence change. Even if some data is successfully generated in line with the objectives, sometimes the lack of consistency between the periods poses serious problems in measurement. More importantly, as demonstrated from the Ethiopian farm management survey experience, the complexities of the information collected and the lack of computer services at the survey stage and in later periods hinders the researchers during the processing and analysis of the data. In most cases it is difficult to process data and therefore the bulk of the questionnaire remains without any analysis or report.

Although one could argue that the comparative time series method, properly conducted, holds out the greatest hope of providing the kind of information required and the appropriate form to assess the impact of technological change, its uses are limited due to data availability. In most areas where a technological package is introduced, data is not collected as part of an evaluation system.

Besides the problems related to the availability of data, the method has other weaknesses which require consideration.

1. All too often, agricultural output has been measured in terms of total value of farm products produced or in terms of value added (Hayami and Ruttan, 1985). The difficulties caused by inclusion of prices and the existence of bias are hard to understand. Price fluctuations over time periods render the estimate inaccurate. To avoid distortions caused by the inclusion of prices, some attempts can be made to confine the measurement of technological change to purely technical relationships in physical inputs. Even when dealing with physical inputs, one cannot ignore the fact that the quality of inputs changes over time. These changes in quality include capital inputs and improvement in the quality of the labour force. As Griliches (1963) concluded, qualities of labour and capital are heterogenous and cannot simply be added without biasing

the estimates of the parameters in the production function. The quality of labour is particularly associated with managerial ability, which is important for the modern type of farms that require skills, but less important in traditional agriculture.

2. Variation in climate, the incidence of pests and diseases and other similar exogenous factors distort any effect of the technology, although this may not be serious if the period under consideration happens to be "normal" years. The effects of the new technology cannot be isolated from the effects of other related factors.
3. Changes in management, production intensity, type of farming and the country's political and economic environment, all cause similar variations in production that can cover any possible effects of the impact of new technology.

In this study from the outset the difficulties of measuring and quantifying these variables in the real world are recognised. We are aware that to diagnose accurately and then measure sources and rate of technological change for alternative policies, more detailed and much longer studies with bigger samples related to some of the variables pointed out as the weakness of the method are required. However, many of the problems raised as weaknesses are difficult to measure accurately, even if they are followed over periods of years. The existence of these formidable problems is another reason for the lack of interest by economists in studying technological change at micro level on the basis of the dynamic approach. For example, in the Ethiopian context it is hardly possible to isolate the impact of technology from the effects of management and various government policy changes over the last decade. As is common with many of the studies of technological change which are based on time series analysis, there is insufficient data to work with. Therefore, in using the comparative time series method as a means of measuring the impact of new technology, we have tried to be realistic by combining both the academic ideals and pragmatic approach of measurement problems. An attempt has been made to derive the maximum benefit by making the best out of the variables that it was possible to quantify and to measure directly or indirectly while still accepting the need for further research to cope with unresolved problems.

3.3.3. Economic and Empirical Models

Since the pioneering work of Solow, (1957) the production function concept has been used for studying the role of technological change in agriculture (e.g. Lave, 1962; Griliches, 1963; Mollett, 1964; Brown, 1966; Salter, 1969; Hayami, 1965 and 1975; Hayami and Ruttan, 1971 and 1985; Sidhu, 1974; Nagyyen, 1979). Most of these studies represent a valuable contribution towards an understanding of the basic factors which are involved in measuring technological change in agriculture. In this study, the production function method has also been employed to measure the effect of technological change in the Ethiopian highlands. The approach adopted here involves a direct estimate and a comparison of the total change in output which is brought about by shifts in the parameters that define the function itself and by changes in the volumes of inputs.

The production function analysis is carried out under the assumption that the same functional relationship applies to all farms. It is regarded that the data collected for each farm are observations of the same production function. There are two necessary and sufficient conditions which must exist for this assumption to be realistic. The specification of the variables shall be both complete and correct (Heady and Dillon, 1961). If these conditions are not satisfied, specification errors may arise. The first condition may be violated by the existence of unobserved variables, since it is very difficult to measure all inputs that are relevant in the production process. The second condition refers to the homogenization of aggregative output and the aggregation of inputs.

Thus the way input and output variables have been defined and measured is crucial for the applicability of an empirically estimated production function. However, the cost of complete and perfect specification of variables is prohibitive (ie. it exceeds any benefits from insights gained and/or better uses of the resources). It is, therefore, necessary to strike a balance between the theoretical ideal and the empirically feasible specification of variables (Yotopoulos, 1967).

3.3.4 Specification of the variables

3.3.4.1 Dependent variable

The dependent variable considered is the 'crop output' which is defined as the gross farm income of the cross-section of the farm in the sample for the period of investigation. A value was preferred due to the diversity of crops cultivated and the different uses to which farm products were put - which would limit the aggregation on a physical basis. The concept of gross farm income includes all farm crops output during the period 1967/70, 1974/76 and 1979/80, valued at 1974/76 constant producer prices for the respective products.

3.3.4.2 Independent variables

The independent variables considered could be broadly classified into the conventional variables such as land, labour, working capital and period dummies.

a) Land (X_2) - Cultivated land and not the physical area per household enters the production function in physical units as hectares. In principle, the land should be represented by a vector of non-homogenous hectares, in order to recognise the qualitative difference that exists between the land grades. Such complete specification was not feasible due to lack of information. In this study, the difficulty in specifying land by grade and inherent fertility, therefore, necessitated its treatment as one variable.

b) Labour (X_3) - Different categories of labour were explicitly recognised in the data collection and processing phases. They have been aggregated into homogenous man-hours to express the relationship of the productivity of women and children to that of adult man as realistically as possible. Labour entered the production functions as a flow concept rather than a stocks concept and is quantified as the actual man-hours involved during the three periods of study. The importance of family labour, hired labour and exchange labour are separately evaluated during the data processing stage, but are considered here aggregatively as total labour.

c) Working Capital (X_4) - Here the expenditure on variable inputs used in the production process are included. Fertilizers and improved seeds are the major inputs that have to be purchased from markets. They are valued at prices that farmers paid which were less than the cost due to government subsidy. The costs to the farmer rather than the costs to society have been used because it is the former that influences the farmer's decision about how much of these inputs he will use.

Period dummies (D_1). Our input and output data are based on the survey for the period between 1967/70 and 1979/80. Therefore a small sample in the baseline and fairly large samples in later periods. Furthermore, during these periods, there have been extreme policy changes in the economy. There was agrarian reform and civil war between 1977 and 1979/80. The abnormal conditions prevailing during these years may have caused a shift of the production function downwards, due to uncertainty, various controls, and other factors. Their variation during the three periods is difficult to measure quantitatively. To capture shifts between the periods and the variables which it is not possible to measure, a period dummy has been used with the value of 1 for period II and 0 for other periods.

Finally, climatic influence among the variables has been considered. The data in the baseline and the second period includes climatic factors. By taking two years average of annual output the climatic effects that appear in the resultshave been lessened considerably. Furthermore, as one can see in Appendix E.1 the three periods do not indicate a high variation.

Table 3.1 gives a summary of the mean input-output variables that are employed in the regression analysis.

Table 3.1 A Summary of the Mean Input-Output variables

	Periods		
Variables	I	II	III
Gross farm income (Y_1)	1035.95	2198.56	977.59
Land (X_2)	4.05	4.43	2.0
Labour (X_3)	1953.00	3101.00	1339.00
Working Capital (X_4)	125.83	393.65	94.86
D	0	1	0

Source: Computed from the survey data.

3.3.5 Selection of functional forms

Given the existence of the production function, one has then to choose the appropriate algebraic forms for it. Three decision rules appear to be relevant in choosing from the numerous alternative forms (Yotopoulos, 1967). The first refers to the logic, or the basic mechanics of the production process. However, little is known about the logic of the production process, especially in connection with entrepreneural decision-making processes (Heady and Dillon, 1961). To overcome this problem partially, testing various functional forms for statistical adequacy is sometimes suggested. The second decision rule that applies in choosing from alternative functional forms is theoretical fruitfulness. Given the body of established economical theory, the explicit relationship chosen should offer possibilities of providing a unified explanation of a wide range of empirical phenomena (Yotopoulos, 1962). Thirdly, the computational manageability of the function is also an important factor.

In studies such as this, which deal with a more complex mix of factors than a simple biological response, it is difficult to establish empirically that a functional form can adequately describe the logic and the mechanics of the production process. Therefore, an empirical approach is necessary to specify the functional form of the equation. Yet research has established a strong presumption that a number of functions are competent initial approximations of the "true forms" (Head y and Dillon, 1961). Amongst these functions a comfortable choice of a specific algebraic form can be made on the basis of its theoretic specifications and computational manageability.

In this study, whilst selecting a functional form of the equation, linear, semi-log and Cobb-Douglas functions were tried, using combinations of the variables specified earlier. A more general production function of the transcendental logarithmic (translog) has also been tried. However, for most of the analysis a Cobb-Douglas function is the only functional form that performed well. For example, in testing the translog functions it was found that models involving more than three variables are too complicated and unreliable to make a reasonable judgement and interpretation. The baseline data, in fact, did not respond at all to the translog functional form. Therefore, after rigorous testing of the functions in relation to the data, a purely technological function of the multiplicative Cobb-Douglas type has been selected.

3.3.6 The model and production relationships

The functional form of the Cobb-Douglas function in general is the form:-

$$Y_t = F(X_{1t}, X_{2t}, \ldots, X_{nt})$$

Where Y_t is aggregate crop output in period t produced from the inputs X_{1t}, X_{2t}, X_{3t}, ..., X_{nt} in period t. The function is estimated in the form of an unrestricted CD production function. It can be expressed in the following form:-

Where, $Y_t = \beta_1 X_{2t}^{\beta 2} X_{3t}^{\beta 3} X_{4t}^{\beta 4} U_t \qquad t=2,\ldots,4$

β_1 = constant term

X_2 = cultivated area, hectares

X_3 = labour, man hours

X_4 = working capital, Birr

To perform actual empirical analysis, the function has to be made operational and this is accomplished by logorithmic transformation the result being:-

$$LnY_t = Ln\beta_1 + \beta_2 lnX_{2t} + \beta_3 LnX_{3t} + \beta_4 lnX_{4t} + U_t$$

Where, B = coefficients

U_t = error term

To account for the shift in the production function, dummy variables have been incorporated into the econometric model and will be demonstrated in the course of analysis.

Finally it may be worthwhile to briefly state some properties of the Cobb-Douglas production function which form the basis of the ensuing discussion. The production coefficients of the Cobb-Douglas function are interpreted as the elasticities of production, and are constant over the entire range of inputs. The production elasticities indicate for each input the expected percentage increase (or decrease) in the gross value of output if the amount of that input increased (or decreased) by one per cent, other inputs held constant. The function is homogenous of degree one defined by the sum of elasticities.

3.4. Empirical Analysis of the Micro Level Impact of New Technology on Agricultural Production and Productivity

In this section an attempt will be made to analyse the nature of change in the production function in the Ethiopian highlands. There are two central objectives here:-

1. To attempt to see if there is a shift in the production functions because of the introduction of new technology.
2. To attempt to explain possible productivity difference in the Policy periods. In this exercise, appropriate Cobb-Douglas regressions are run to estimate elasticities, using separate and pooled data pertaining to both the pre- and post-technological change periods.

However, before proceeding further, it seems worth mentioning again that the study deals with an aggregate production function with all crops growing in the case areas due to lack of disaggregate data, particularly in the base year.[1]

Aggregate production functions provide, at best, a rather crude index of technological growth. The main weakness, in common with many analytical techniques, is the problem of aggregation of input-output. Quite apart from any economic limitation, the factor being measured-technological change-is lumped with other non-technical factors in many studies (Solow, 1957). It comprises all growth not directly attributed to capital and labour input. In studies at micro level however, this problem has been minimised by introducing technological variables embodied in improved seeds and fertiliser. Despite this weakness, aggregate production functions do provide policy makers with useful, if imperfect, information about the total economic benefits derived from technological change.

3.5 Shift From Old to New

The regression statistics obtained in comparative cross-section analysis(based in 1974/76 and 1979/80 data)for the traditional and new farm technology groups are summarized in Table 3.3. In R1 and R2 which do not include the technology dummy D_j, about 0.90 and 0.91 respectively of the variation in output is explained by the independent variables. The Cobb-Douglas production function model given by the equation in Table 3.2 fits the data well in a statistical sense. In addition, the output elasticities with respect to all the relevant inputs have the expected signs and have values which are both plausible and comparable to the results of other studies in the Ethiopian highlands (Cornia, 1985).

The pooled regression R.3 in Table 3.3 was estimated assuming all slope coefficients as well as the intercept remain unchanged, irrespective of the technological strata. The input coefficients in R.3 of Table 3.3 vary substantially from the corresponding coefficients in R.1 and R.2. They were indeed operating on different production functions in the post-technological period.

The analysis suggested by Chow(1960) was applied to test whether the differences between the two regressions are due to different slope coefficients or due to change in the intercept. The test procedure is as follows:

Table 3.2 **Model to test for equality of the estimated production function between the old and new technology farms**

Restricted Model:

Test 1:- with intercept dummies

$$LnY=\beta_1+\alpha_{11}D_1+\beta_2 lnX_2+\beta_3 lnX_3+\beta_4 lnX_4+U$$

Test 2:- with slope dummies

$$LnY=\beta_1+(\beta_2+\alpha_{21}D_1)lnX_2+(\beta_3+\alpha_{31}D_1)lnX_3 +(\beta_4+\alpha_{41}D_1)lnx_4+U$$

Test 3:- with both intercept and slope dummies

$$LnY=\beta_1+\alpha_{11}D_1+(\beta_2+\alpha_{21}D_1)lnX_2+(\beta_3+\alpha_{31}D_1)lnX_3 +(\beta_4+\alpha_{41}D_1)lnX_4+U$$

Unresticted model:

Test 1:- old technology farms

$$LnY_{old}=\beta_1+\beta_2 lnX_2+\beta_3 lnX_3+\beta_4 lnX_4+U$$

Test 2:- new technology farms

$$LnY_{new}=\beta_1+\beta_2 lnX_2+\beta_3 lnX_3+\beta_4 lnX_4+U$$

Table 3.3 Cobb-Douglas production function estimates for Ethiopian highland farming systems traditional v new technology

Input	Technology		Overall			
Variable	Old (R.1)	New (R.2)	Pooled (R.3)	Pooled (R.4)	Pooled (R.5)	Pooled (R.6)
Intercept	2.04984	1.47966	1.54400	1.69052	2.04984	1.72618
	(11.800)***	(10.666)***	(14.719)***	(16.201)***	(12.507)***	(15.801)***
LnX_2	0.89560	0.51225	0.54739	0.68292	0.89560	0.76205
	(9.437)***	(6.667)***	(14.719)***	(11.352)***	(9.997)***	(10.201)***
LnX_3	0.11385	0.22388	0.17163	0.18536	0.11385	0.19711
	(2.078)**	(5.669)***	(5.088)***	(5.750)***	(2.201)**	(4.764)***
LnX_4	*0.91500*	*0.31935*	*0.35313*	*0.20587*	0.09150	0.14911
	(1.342)	(4.933)***	(9.394)***	(4.380)***	(1.156)	(2.431)***
AD_1				0.08673	-0.57017	-
				(4.830)***	(-2.621)	-
$D_1 \cdot LnX_2$					-0.38355	-0.13255
					(-3.206)**	(-1.822)*
$D_1 \cdot LnX_3$					0.11007	-0.01163
					(1.672)*	(-0.343)
$D_1 \cdot LnX_4$					0.22785	0.09718
					(2.457)**	(1.226)
R^2	0.90	0.91	0.90	0.91	0.91	0.91
F. Ratio	224.17	474.49	640.69	536256	319.38493	361.4512
RSS	0.67739	1.16845	2.15335	2.08632	2.05149	2.13916
DF	3:69	3:142	3:214	4:214	7:211	6:212
Return to scale	1.00945	1.05548	1.07245			
Sample	73	146	219	219	219	219

* significantly greater than zero at 10% level
** " " " " " 5% "
*** " " " " " 1% "
T values in parenthisis

1. Estimate the unrestricted model and collect its residual sum of squares (RSS-d.f=n-k).
2. Estimate the restricted model and collect its residual sum of squares (RSS*-d.f=n-k).
3. Calculate the F.ratio and then accept or reject the null-hypothesis (Ho)

$$F = \frac{(RSS^* - RSS)/k-k^*}{RSS/(n-k)}$$

Where, RSS*=residual sum of squares from the restricted regression:
RSS=residual sum of squares from unrestricted regrssions
k-k*=the number of restrictions imposed in the restricted model
n-k=degrees of freedom in the unrestricted equations

To apply this test, regression R.4 was estimated by pooling data for old and new technological group and introducing a technological dummy (D_j). The dummy variable has the value of 1 for all the new technology group elsewhere. The dummy variable allows for a difference in the increase between the two regressions of interest.

Following the above formula postulated by Chow (1960) and using the relevant values obtained from the equation in tab 3.3, the F. statistics for both intercept and slope parameters (R.5) tests, for example, can be calculated as :

$$F = \frac{2.05149-1.84584/8}{1.84584/211} = 2.9385$$

The tabulated value of F(Ft) with 8 and 211 degrees of freedom at the 5% significance level is 1.94. Since Fc>F8,211,0.05, the null hypothesis is rejected with 95% confidence interval. Thus alternative hypothesis that the production functions differ quite significantly between the old and new technology is accepted. The F tests based on unrestricted regression R.1, R.2, and restricted regressions R.4, R.5, R.6 are set in table 3.4.

The F1 test is highly significant and indicates that the production functions differ substantially in terms of intercept. Therefore the F2 value is also significantly different from zero at 1% level. Thus, the hypothesis regarding that of the equality of the slope coefficients in the two underlying production functions can be rejected.

Table 3.4. Test for equality of intercepts, slopes, and both intercepts and slopes.

Hypothesis	Computed and theoretical F. value			
	DF	F calculated	F table 1%	5%
Differential intercept test (F_1)	(5, 214)	5.58	3.02	2.21
Differential slope test (F_2)	(7, 212)	4.81	2.64	2.01
Both intercept and slope (F_3)	(8, 211)	2.94	2.51	1.94

Furthermore, the F_3 value is highly significant which confirms the hypothesis that there is a strong overall difference between the two production functions.

These results, therefore, imply that the introduction of new crop technological packages has shifted the production function upward. The extent of the upward shift, which can be estimated from the coefficients of the dummy variable in R.4, appears to be about 7%.

Another feature of the results in Table 3.3, is that for all regressions, the sum of the coefficients for the conventional inputs (ie. X_2, X_3, X_4)is approximately equal to one. In fact, in no case was this return to scale parameters significantly different from one at the 10% probability level. The data, therefore, supports the hypothesis that there are constant returns to scale for both old and new technological strata in 1974/76 and 1979/80 periods.

3.6 Shift from Base Period to Post-Technological Periods II and III

Table 3.6 presents the regression estimates of the Cobb-Douglas function before and after technological change. The production function model in equation of Table 3.5 was estimated for each of the three production periods. As in the previous sections, two pooled regressions were estimated. The first was computed after pooling all data for the three periods. The second pooled regression included two year dummy variables to allow for change in the intercept from period to period.

Overall, the first three columns in Table 3.6 suggest the Cobb-Douglas model fits the data well in a statistical sense and gives plausible and reasonable coefficients for all inputs in the periods in post-technological change. However, the base line regression indicated low $\bar{R}^2$ of 0.59 as compared to 0.81 and 0.79 in period II and III. This is probably due to the small size of the sample.

The two hypothesis concerning constant slope coefficients (partial elasticities) and constant intercept terms were investigaed using the Chow test as discussed above. In this case, with three rather than two production functions, it was necessary to estimate the second pooled regression R.1.5 with two dummy variables.

To test the hypothesis of equality between sets of regression coefficients in the production functions for the period I, period II and period III the three separate regressions in R.1.1, R.1.2 and R.1.3 were compared with pooled regression R.1.4.

Table 3.5 **Model to test for equality of the estimated production function between the base period and post-technological change**

Restricted Model:

Test 1:- with intercept dummies

$$LnY=\beta_1+\alpha_{11}D_1+\alpha_{12}D_2 +B_2 lnX_2+\beta_3 lnX_3+\beta_4 lnX_4+U$$

Test 2:- with slope dummies

$$LnY=\beta_1+(\beta_2+\alpha_{21}D_1+\alpha_{22}D_2)lnX_2 +(\beta_3+\alpha_{31}D_1+\alpha_{32}D_2)lnX_3+(\beta_4+\alpha_{41}D_1+\alpha_{42}D_2)lnx_4$$

Test 3:- with both intercept and slope dummies

$$LnY= \beta_1+(\alpha_{11}D_1+\alpha_{12}D_2+\beta_2\alpha_{21}D_1+\alpha_{12}D_2)lnX_2 +(\beta_3+\alpha_{31}D_1+\alpha\ _{32}D_2)lnX_3+(\beta_4+\alpha_{41}D_1+\alpha_{42}D_{42})lnX_4+U$$

Unrestricted Model:

The period is divided into three sub-periods of after and before technological change. ie. base period 1967/70, post technological change periods 1974/76 and 1979/80.

1967/70: $LnY=\beta_1+\beta_2 lnX_2+\beta_3 lnX_3+\beta_4 lnX_4+U$

1974/76: $LnY=\beta_1+\beta_2 lnX_2+\beta_3 lnX_3+\beta_4 lnX_4+U$

1979/80: $LnY=\beta_1+\beta_2 lnX_2+\beta_3 lnX_3+\beta_4 lnX_4+U$

Table 3.6 **Cobb-Douglas production function estimates for Ethiopian highland farming systems 1967/70, 1974/76 and 1979/80**

	Periods			Overall			
	I	II	III				
Input variable	1967/70 (R.1.1)	1974/76 (R.1.2)	1979/80 (R.1.3)	Pooled (R.1.4)	Pooled (R.1.5)	Pooled (R.1.6)	Pooled (R.1.7)
Intercept	1.2242	1.52191	1.80964	1.04367	1.25457	1.2247	1.51048
	(3.886)***	(7.626)***	(12.850)***	(7.566)***	(8.256)***	(3.943)***	(9.409)***
LnX_2	0.47543	0.32509	0.58800	0.21745	0.44142	0.47543	0.28892
	(4.550)***	(4.639)***	(9.089)***	(3.228)***	(6.710)***	(4.457)*	(2.192)**
LnX_3	0.24417	0.19880	0.14600	0.24383	0.16496	0.24417	3.37669
	(3.686)***	(3.053)***	(3.282)***	(5.210)***	(3.269)***	(4.135)***	(0.040)
LnX_4	0.30058	0.39372	0.32700	0.53487	0.41068	0.30058	0.59149
	(2.646)**	(6.094)***	(7.150)***	(11.061)***	(9.007)***	(3.406)***	(4.670)**
A_1D_1					0.24695	2.93820	
					(7.692)***	(4.249)***	
A_2D_2					0.21807	2.89611	
					(7.257)***	(4.403)***	
$D_1 \cdot LnX_2$						0.48211	0.06459
						(2.507)**	(0.404)
$D_2 \cdot LnX_2$						0.66921	0.25994
						(3.841)***	(1.741)*
$D_1 \cdot LnX_3$						-0.75294	0.16222
						(-3.291)***	(1.945)**
$D_2 \cdot LnX_3$						-0.72279	0.17617
						(-3.342)***	(2.313)**
$D_2 \cdot LnX_4$						0.24907	0.16255
						(1.703)*	(1.085)
$D_2 \cdot LnX_4$						0.33798	0.24055
						(2.466)**	(1.725)*
$\bar{R}^2$	0.59	0.81	0.87	0.79	0.83	0.84	0.83
F Ratio	80.64	125.07	297.59	307.41	247.15	122.59	137.20
RSS	0.22512	0.8080	1.0803	5.3496	4.1881	3.8097	4.1325
D.F.	3:26	3:86	3:125	3:245	5:243	11:237	9:239
Return to scale	1.02	0.92	1.061				
Sample	30	90	129	249	249	249	249

* significantly greater than zero at 10% level
** " " " " " 5% "
*** " " " " " 1% "

T - values in parenthesis

Table 3.7. Tests for Equality of Intercepts, Slopes and Both Intercepts and Slopes Before and After Technological Change.

Hypothesis	Degrees of freedom	Computed F	Critical values at given level of significance	
			0.05	0.01
Differential intercept test (F1)	(6,243)	39.75	2.60	3.78
Differential slope test (F2)	(10,239)	22.83	1.83	2.32
Both intercept and slope (F3)	(12,237)	15.85	1.83	3.78

The computed F_1 test is highly significant. Thus, the hypothesis of equality between the sets of coefficients in the three periods is rejected, indicating that the production function for the technological period has been unstable over the three year period.

It is, however, necessary to go a step further. The analysis of Chow (1960) test comparing the separate regressions (R.1.1, R.1.2, and R.1.3) with the overall pooled regression (R.1.5) yielded an F_2 value which was highly significant. Therefore, the hypothesis of equality between slope and coefficients allowing the intercepts in period regressions to vary is also rejected. Furthermore, the F_3 value is highly significant which confirms the hypothesis that there is a strong overall difference between the two production functions. The results therefore imply that the introduction of new technology has shifted the production function upward.

The relatively large and highly significant coefficients for the dummy variables on regression R.1.5 add strength to the above conclusion. On the basis of the value of these coefficients of the dummy variables (which can be used to estimate the extent of the shift in the production function) in the 1974/76 period, the area under technological innovation was operating on a production surface which was 21% above the function of traditional technologies in the base year. The production surfaces for period III was 19% more than period II.

3.7 Technological Change Over Time and Changes in Input Factors

One approach to examine the nature of the time dependent interrelationship discussed above is to test the effect of the year dummy variables (D_1 and D_2) on the input factors. For this purpose, the Table 3.5 equation version with both year and slope dummies, ie.-

$$
\begin{aligned}
LnY = \beta + \alpha_{11}D_1 + \alpha_{12}D_2 \\
+(\beta_2 + \alpha_{21}D_1 + \alpha_{22}D_2)\ln X_2 \\
+(\beta_3 + \alpha_{31}D_1 + \alpha_{32}D_2)\ln X_3 \\
+(\beta_4 + \alpha_{41}D_1 + \alpha_{42}D_2)\ln X_4 + u
\end{aligned}
$$

was fitted to the pooled data for each of the three periods. The results are shown in Tables column R.1.6.

Improvements in farm technology especially such change as the introduction of new technological packages, can be expected to affect the productivity of land and other factor inputs. In Table 3.6, the coefficients of both the interaction term (D_1. $\ln X_2$) between period I and period II regressions and (D_2. $\ln X_2$) between period I and period III regressions, are all positive and highly significant in a statistical sense. These results imply that the new technological packages introduced after 1967/69 have raised the productivity of land appreciably.

The introduction of new inputs already mentioned, has also enabled the farmers to improve the productivity efficiency of variable inputs in both post-technological change periods. The coefficient D_1.

LnX4 and D2. LnX4 are positive and statistically significant indicating an upward shift in the function between the periods.

Improvements in the productivity of labour surprisingly is not as expected. The coefficients for both the introduced term (D1. LnX3) and (D2. LnX3), are all negative and highly significant. The result of the labour inputs suggests that since the introduction of new inputs in the Ethiopian highland farming systems, labour productivity has shifted downwards.

The above analysis was repeated using the data for the base line and post-technological change periods. In all instances, the data supported the view that the production surface was shifted upwards as one moved from the base years to 1974/76 and 1979/80. This suggests that when the high-yielding varieties and associated package inputs were introduced to replace the old technology, the potential gain for increased productivity was very substantial.

3.8 Shifts in the Production Function and Non-technological Variables

The upward shifts in the production function in the study area which have been attributed to technological change may be contended that it is due other factors such as change in weather and economic and institutional policies which provide incentives to the producers. Such incentives may be influenced by wide range of production oriented policies such as prices, markets, and a secure tenure system. However, as we argue in the discussions that follow there is no reasonable grounds to suggest that change in these factors between the base period and periods II and III has contributed to any significant upward shifts in the production function.

With regard to shifts as a result of weather changes in the study areas, an analysis of the table in appendix E.1 shows that the years under study have normal weather patterns which are similar in three periods. Any upward shifts due to changes in the weather pattern has no statistical justification.

A glance at changes in policy between periods I, II, and III, however, shows some changes in the country's economic and institutional policies that would have important consequences for smallholder agriculture. As we have noted in detail in chapter I, periods II and III encompass post revolutionary years when a number of radical changes in political, economic and social policies were proclaimed. With the proclamation of the land nationalization decree of march 1975, the government initiated a far-reaching land reform programme. Land which was under individual ownership was nationalized and private ownership of land was abolished allowing only a 'possesory' form of tenancy. Furthermore the hiring wage labour by farmers, which was common in period I, was prohibited on small farmers land. This is further followed by re-organization of farmers by coercion into state controlled institutions such as Peasant Associations, Service co-operatives and Producers co-operative(collective farms).

Land tenure reforms in feudal societies, are essential to the mobilization of labour resources and the generation of productivity growth. Owner cultivator with a secured land tenure system is said to achieve a more efficient allocation of resources and make a greater contribution to national economic growth than landlord/tenant relationship(Hayami and Ruttan,1985:389). Experiences from Ethiopian land reform, however, did not provide, this degree of support for generalization in terms of productivity changes. During periods II and III, although land reform had been carried out, it didnot allow the individual ownership and security of tenure that was important for the small farmers sense of self-esteem, freedom, desire for self improvement and long term investment on his land. The reform was carried out as a result of distrust of the small-holder, resulting in the establishment of state farms, producer co-operative collective farms and other enterprises guided and controlled by state agencies. The political leadership has sought to retain control over the organization of agricultural production and the decision making process of small farmers. Little effort is made to encourage farmers through incentives to work hard, take independent decisions regarding his farm and employ resource necessary for efficient agriculture. As noted by the world Bank (1983:36) and Cohen(1984:52), the main concern in periods II and III of Policy makers were to consolidate the political power structure through institutional building and to safeguard supplies for the army, militia and urban consumers rather than encouraging smallholder production through policy incentives.

As a result of this policy the farming institutions became a burden on development in periods II and III rather than an efficient source of increase in productivity(World Bank, 1983:11, Cohen, 1984:52). Following the imposition of the above Policy the small-holder sector has made little productivity progress and production has in fact declined since agrarian reform(Table 3.8). Given the coercive nature of the reform , the disruptions of the revolutionary period and the marketing problems to be discussed later the small-holder has responded by reducing the level of production and paying more attention to his own food needs(World Bank, 1983:13). A pronounced shift has therefore taken place in the cropping pattern. The major change has been a drastic reduction in the area harvested for all crops from 6,5 to 5,4 and 5,8 million has between the 1971/72, 1975/76 and 1979/80 periods of study. This is most notable for cereals falling from 5,2 to 4,4 and 4,8 million hectars(Table 3.8). In fact, the slow growth of smallholder output and reduced marketing that followed the change in land tenure and shift in the cropping pattern, forced the policy makers to rely heavily on state farms and imports to provide food stuffs for urban consumers, the military and other institutions(World Bank, 1983:19).

The other important change in policy between the base period and periods II and III that has an important effect in productivity of agriculture was the price policy. The Price policy in period I was governed by a market mechanism with little intervention by the state. However, in periods II and III the government, as noted in chapter I, fixed the price of all agricultural products at an official low level at which peasants are obliged to sell their produce. Free market prices are of-course higher, but a number of control mechanisms have been put in force to ensure the peasants only sell at prices set by the government. One method is that the peasants are required to deliver, through their Peasant Associations, a fixed quota of agricultural produce to the state Agricultural Marketing Corporation(AMC) which pays at the official rates. A second method is that the consumers can only buy grain from their local urban institutions(Kebbelles) and not directly from the peasants. The Kebbelles in the smaller towns purchase their stocks from peasants at the official rates, in others they obtain them through the Agricultural Marketing Corporation(Rahamato,1984:66). These prices were set for all cereals, cash crops such as coffee, chat and oil seeds at such low levels (with no change is allowed in period II and III), while prices of major farm inputs like fertilizers, pesticides and consumer goods have escalated(Rahamato, 1984:66; Cohen, 1984:45;

Table 3.8 Changes in Area and Production of Major Crops Before and After Agrarian reform

	Cereals	Pulses	oil seeds	Total
Areas(1,000 has)				
1971/73	5200	800	500	6500
1975/76	4411	640	364	5415
1976/77	4215	666	229	5111
1979/80	4807	768	252	5827
1981/82	4377	751	285	5413
% change				-16.72
Production(1,000 tons)				
1972	6093	1382	298	7773
1974	5545	1350	331	7226
1979	4214	612	169	4995
1980	4404	626	191	5221
1981	4379	632	171	5182
% change				-33.33

Source: 1. World Bank(1983). Ethiopia: the Agricultural sector- An interim Report,Volume I: Main Report, January,p.13.
2. IBID, Volume II: Annexes 1-12, PP.100-101.

Table 3.9 Agricultural Marketing Corporation Prices of selected Agricultural Commodities(Birr per 100 kgs)

	1974/75a	1979/80b	1980/81b	1981/82b	% increase 1974/75 to 1981/82
Crops Purchase Price:					
Teff	40.60	42.46	40	40	-1.47
Wheat	31.20	27.31	35	35	+12.17
Barley	24.24	27.31	32	32	+32.01
Sorghum	26.11	28.22	27	27	+3.40
Maize	21.11	27.11	21	21	0
Inputs selling Price					
DAP	44.00	65.00	85(75)d	116(95)d	163.64
Urea	40.00	65.00	85(75)d	84(70)d	110.00

Source: a. FAO (1984). Ethiopia: Data Book on Land Use and Agriculture in Ethiopia, Volume 1, P.268.
b. World Bank (1983). Ethiopia: Review of Farmers incentives and Agricultural Marketing and Distribution Efficiency, P.104.
c. IBID, P.99
d. The value in the brackets is differential prices for producer co-operatives and State farms

World Bank, 1983:49). Infact, as argued in many parts of this thesis the government price policy has been designed to benefit the urban population at the cost of smallholder farmers.

This combination of low farm gate prices and high prices of farm inputs and consumer goods(Table 3.9) implies that the Ethiopian agriculture has been adversely affected because farmers incentive to produce more and to adopt yield increasing innovations is greatly diminished, leading to reduction in production in period II and III at national level. For example, the World Bank(1983:49) points Out the deteriorating smallholder price incentive pattern as one reason for decline in smallholder production.

In period II and III, further to the above important factors that has affected productivity, production efficiency has been affected by the disruption of the internal economy and marketing systems. War, revolution, internal disorder, the expulsion of land lords, all combined with price and land reform policy have also seriously affected agricultural production (World Bank, 1983:11).

In general, as noted by Bengtssson (1983:188); Cohen(1984:52) and World Bank(1983:36) much of the Policy shifts in period II and III were given over to political considerations rather than economic measures that would improve the productivity of the agricultural sector. Except for the maintenance of fertilizer, improved seeds and other associated packages that would raise productivity, Policy incentives that would improve the efficiency of the farmers received little attention (Bengtsson,1983:188). Therefore, it is reasonable to conclude from the above evidences that, with exception of the technological packages, Policy changes were ineffective in improving productivity. The upward shifts in the production function by 21% and 19% respectively in periods II and III, are therefore, attributed to the use of technological packages.

However, the potential gains from the introduction of new technology were much less in period III. The result of the data sets in period III indicate a substantially small shift when compared to period II. These relatively smaller shifts in period III may be accounted for by exogenous factors such as deteroration in seed quality, uncertainty due to the revolution, strong government restriction in the agricultural sector and unavilability of inputs that was more acute in period III than II(Nichola,1985:30; World Bank, 1983:35). Empirical assessment of the downward shift effect of non-technological variables within the production function framework has not been dealt due to data problems. Further research is therefore required to study the effects of these factors in the agriculture of the study areas.

their relative influence seems impossible and requires further research.

3.8 Summary and Conclusions

An attempt has been made here to give some empirical content to the change in production technology from the introduction of technological packages in the Ethiopian highlands. The methodology and the model used are simple and represent an application of comparative time series methods and the standard neo-classical theory of production. Empirical evidence is based on farm level primary and secondary data for the years 1967/70, 1974/76 and 1979/80.

The results presented in this study indicate that the introduction of technological innovation has led to the adoption of new technology which has appreciably raised the productivity of traditional agriculture. The introduction of yield increasing innovations, such as improved seeds and fertilizers, has generated a series of new technological strata each more productive than the base years.

The production functions for technological periods were established at three different points in time. In all cases, the results indicate an upward shift in the production function, establishing conclusively the important role of new technology in agricultural expansion. Estimates of production function parameters, indicated the substantial contribution of the new technology to the expansion factor output in the case study areas. The estimates derived on the basis of the estimated coefficients of a dummy variable which is interpreted to represent percentage upward shifts, shows that the production functions of 1974/76 and 1979/80 are higher by 21% and 19% respectively above the production surface of the base period.

3.9 NOTES

1. Attempts have been made to disaggregate the technological variable into fertiliser and seeds used for post-technological periods. However, there was a problem in refining regressions due to the well-known disadvantage of a conventional Cobb-Douglas logarithmic function. It was not possible to include zero value levels of the farmers who do not use fertiliser and do not grow certain crops since the log of zero is unexplained. The usual solution to this problem is to add some low constant value across all observations of the problem, thereby, in theory, leaving the marginal estimates not importantly affected.

Several values of constants were used in separate runs, but it was found that the estimted elasticity coefficients were extremely sensitive to the choice of the constant value.

Lacking an objective criteria for the selection of an added constant value, an alternative procedure was employed by which an aggregate value of the two inputs was used to estimate response elasticities for the purchased inputs.

CHAPTER IV

TECHNOLOGY AND RELATIVE PRODUCTIVITY

4.1 INTRODUCTION

In previous chapters we have investigated the nature and impact of technological transformation that has occurred or is underway by exploring the farm level impact of new technology. The analysis conducted in a historical context provided convincing evidence that agricultural production has increased since the technological change. In this chapter the specific purpose is to compare the relative performance of small and large farms.

The efficiency comparison amongst clearly differentiated group of farms has assumed an important place in the literature on agricultural development. In the main, the analysis has been confined to Indian data and to a comparison of small and large farms.

The interest in relative efficiency arose out of the observation that for Indian farms yield and labour intensity are inversely related to farm size. This result, of course, has obvious policy implication for formulating agricultural development strategy. In Ethiopia these questions are indeed important policy issues. Previous studies of the package projects, particularly of CADU, showed that small farmers are economic men who make rational decisions and small holder agriculture can be an engine of growth for the economy as a whole (Tecle, 1975; Hunter, 1974). The FMS survey collected from traditional farming systems in 1972/73 in the Ethiopian highlands also indicated that small farms are more productive than large farms. The analysis carried out by Cornea in 1985 showed that output per unit of farm sizes rises under traditional technology. He argued that higher productive efficiency on small farms is associated with higher use of available labour input for more intensive land improvement programmes.

However, in spite of evidence presented by some research and by experience of the potential of small farm development, on many occasions Ethiopian policy makers in their policy guidelines assumed that small farmers are economically and technically inefficient. They have always believed that economics of scale based on pooling land, manpower and implements into commercial or state and collective big farms would lead to substantial output.

During the early 1970's, for example, emphasis was laid on rapid development of commercial agriculture. Commercial agriculture was considered the only means to get the relatively quick increase needed in agricultural export (IEG, 1968; Goering, 1972). Furthermore, it was assumed that production from larger commercial farms and new land would be the source of most of the growth in agriculture. As a result of these policies, based largely on political considerations, budget allocations for investment concentrated on commercial farming. For several years, also, agricultural mechanisation was subsidised to a considerable extent through the tax exemption of fuel for all agricultural uses in commercial sectors, and through the duty free import of machinery, spare parts and cheap credit at 7% (Ellis 1972; Goering, 1972; Wetterhall, 1974). However, the tax exemption on agricultural fuel was abolished under pressure from the Aid donor countries in May 1973.

In post 1980 too, according to many authors, the government pursued an agricultural development policy based on large scale mechanised farms (UN, 1981; Cohen, 1984; Abate, 1984; Fassil, 1984). Consequently, although the debate about small farm and collectives has continued in Ethiopia, it has to be accepted as a policy directive by high level officials as well as the field extension agents. The idea is frequently reiterated to the peasants in peasant association meetings and in speeches on public national holidays (Cohen, 1984; Dejene, 1985).

The results of the above policies are clear. Many of the studies on the extension services and distribution of inputs indicate that small farmers accounted for significantly small proportions of the farming populations (Kifle, 1972; Tecle, 1975; World Bank, 1982; Cohen, 1984; Dejene, 1985). Furthermore, a recent FAO mission concluded that only 8% of the agricultural sector budget allocation goes to the 90% of the farming inputs involved in small farm productions. The remainder is allocated to large scale mechanised farms such as settlement schemes, producer co-operatives and state farms (FAO, 1982). In this study the weakness of such a policy will be spelled out by examining the farm-size productivity relationship using the data from the post-technological change period. Before proceeding with the empirical verification of the relationships, the theoretical and methodological framework are presented and the nature of the hypothesis being tested is discussed.

4.2. Theoretical and methodological issues

4.2.1. Theoretical Debates

The important relationship between the size of land holdings and agricultural productivity in developing countries has been debated intensively. The modern version of the controversy on the size effect stated with the publication in the 1950s of the results of the Indian farm management studies which showed that there was an inverse relationship between farm size and land productivity. Although there is an extensive debate on the causes of the inverse relationship, subsequent empirical investigations under traditional technologies leaves little doubt for many authors about the validity and generality of this phenomenon. It has been observed in many developing countries with widely different natural and climatic conditions, types of soil, agrarian structures and cropping patterns. For example, empirical investigations by Sen (1962, 1964); Kurso (1964); Saini (1979); Griffens (1974); Berrys and Cline (1976); Hussain (1977); Cornia (1985) endorse an inverse relationship which supports the theory, farmers in smallholdings are more productive in their use of land than those on large farms.

Various explanations are put forward for the observed inverse relationships. Sen (1962, 1964) rationalised the observed inverse relationship by arguing that family labour on small farms has zero opportunity cost so that they employ labour up to the point of zero marginal productivity of labour, thereby maximizing gross output rather than profit. Large farms, on the contrary, are run on capitalstic lines following equi-marginal principles. Since they have to pay hired labour they employ labour upto the point where wage rate equals marginal product. Hence, small farms use more labour than large farms and a attain a higher level of production.

Bhattacharya and Saini (1974) extended the above explanation for inverse relationship in terms of differential intensity of cultivation on small farms and large farms. It was argued that larger inputs of labour were expanded on small farms because they cultivated land more intensively (e.g they raised more than one crop in a crop season on the same piece of land) than their larger counter parts, and that this might have resulted in observed higher production.

Khurso (1964) explained inverse relationship between farm size and land productivity in terms of land fertility and level of tenancy. He observed that as farm size increased the proportion of 'bad and indifferent' land to total cultivated land increased which in turn accounted for the decrease in output per acre on large farms. Furthermore, Khurso (1964) also reported that large farms leased in more land than small farms. On the presumption that inputs applied on own land are higher and better than on leased in land, he argued, therefore, that per acre production on large farms was likely to decline.

Recent studies in many developing countries by Berry and Cline (1979) and Cornia(1985),however, tend to generalize the explaniation for diseconomies of scale in peasant agriculture in terms of dual labour market postulated by Sen at the start of farm size productivity debate. They confirmed further that higher productive efficiency of small farms was associated with higher use of family labour inputs per unit of farmland than large farms in better land prepearation, frequent weeding, line transplanting (for rice), execution of infrastructural work of irrigation and water control and improved soil conservation measures.

The general conclusions that small farms normally generate higher land productivity has a number of important policy implications, regarding agricultural development strategies, particurlarly in a labour surplus economy where land is scarce.

1. Agricultural strategies focussing on small farms start with a major advantage, that is, the demonstrated capacity to achieve high productivity from what is usually the most scarce resource, land (this applies in particular in Asia), largely through the greater application of the abundant resource . labour. One such strategy has as its central feature, the redistribution of land from large farms including state farms, commercial farms and co-operatives into small farms.
2. Where little land is currently found on large farms, where it is not possible for political reasons to redistribute land, or where large farms are unusually productive, a possible strategy is to improve the access of small farms to credit and new technology, investing in an infrastructure that helps to raise the productivity and so forth.

Clearly both strategies are expected to lead to more equal distribution of income than strategies favouring large farms or state, commercial and co-operative farms. They can also be efficient policies, in the sense of leading to high total output. In general they are attractive policy instruments for raising production and for improving rural employment and equality of income distribution.

Previous investigations, before the introduction of technological changes in the area of small holder agriculture leading to the above policy implications, were made mainly with the data from the mid 1950s and 1960s. Unless these relationships are also shown to hold for post technological change data, the effect of technology on interfarm income disparities may also have changed in favour of large farmers. For instance, if new data reveal that the relationship between farm size and productivity is positive, new technology could widen income disparity between small and large farms.

The few studies that did use post-technological data produced ambiguous results. Briefly, the study by Cummings, Herdt, Robert and Ray (1968), Bhattacharya and Saini (1972), Srivatava and Heady et al (1973), Hearth (1983) found no evidence of such change. Rao (1975), Khan and Maki (1979), Saini (1976) and Dasgupta (1977), however, confirms positive relationships in post technological change. The change in output-farm size relationships was attributed to a shift to the use of tractors and other mechanical innovations and government subsidies for modern inputs and better credit and agricultural extension services that disproportionately benefited large farms (Khan and Maki, 1979). Some other authors, Rao and Chotigeat (1981) argued without firm conclusions that large size land holdings are not less productive in all circumstances, as may generally be believed. They argued that if hired labour is employed in preference to family labour, and if more non traditional capital as opposed to traditional capital is used, large sized holdings and higher productivity could go together.

In another interesting study, Rudra (1968a, 1968b) added a further dimension to the size-productivity controversy. In the analysis of Indian FMS data at a further disaggregated level, he presented results which clearly con tradicted earlier findings of an inverse relationship between farm size and production per acre. While the result did not find any consistent pattern of relationship between farm size and yield per acre, he accused FMS of making on over-generalisation of its findings. In particular, he questioned the very aggregation procedure followed in the FMS, which, in his opinion, caused a spurious inverse relationship between farm size and land productivity. In a recent article Chattopadhyay and Rudra (1977) argued that inverse relationship might indeed have operated in certain regions and during certain times, but not necessarily in all areas at all times.

It should be noted, however, that although the theoretical and empirical aspects of this problem have been intensively debated, no question has been seriously raised as to the validity of the methodology and analytical tools on which the above conclusions are made.

4.2.2. Methodological Issues

There are important methodological shortcomings that may cast doubt on some of the results and policy implications that derived from previous investigations.

The first methodological problem in farm size-productivity studies reviewed above, is the lack of evidence as to whether the result is robust with respect to other functional forms. A very common practice in this area of study is to select arbitrarily a mathematical functional form to test the hypothesis, and then stop at that. Indeed, this approach has been clearly visible in the series of studies which have used linear functional forms in the early phase of the debate (Khurso, 1964; Bhattacha Berry's and Cline, 1979) and Cobb-Douglas form in latter periods (Srivatava et al, 1973; Saini, 1979; Hussain, 1977; Dasgupta, 1977; Yotopoulos and Nugent, 1976; Khan and Maki, 1979; Cornia, 1985). Here obvi ously the basic assumption of the selection of this two functional forms is that the fitted model by this function can adequately represent the relations in the phenomen understudy. This procedure gave rise to a whole range of important problems. It is of paramount importance to have a sound basis for the functional forms adopted. However, justification for the functional form adopted is very rarely offered. In many of the studies, one either uses the functional forms because it is used by many other research workers, or one depends only on expediency. Thus, many have resorted to the linear form without pointing out the existence of non-linear or discrete relationship between the two variables. This gives rise to a problem which, according to this author, is of an obvious nature and yet has not attracted the attention of many researchers who participated in the debate. The problem consists of theoretical results depending on such properties of the functional form assumed for reasons of convenience which do not in any way reflect any aspects of the phenomenon under study and are irrelevant to them. Quite often model makers do not express any hesitation in making use of those properties having given little thought to the difference in results that would follow if some other functional forms were used. Of course it would not matter if the results obtained by using different functional forms were not different. In this case the procedure for using any one of them would be justified on pragmatic grounds. However, quite often the results following from the use of different functional forms indicate totally contrary propositions; and to accept one that follows from the functional form assumed arbitrarily seems to lack any justification (Heady and Dillon, 1961).

The second major weakness in many of the previous studies is the nature of the division between small and large farms and the omission of important variables which reflect some aspects of the phenomenon under study. A common method used to assess the differences in production technology between "small" and "large" farms in less developed countries is to divide the sample arbitrarily into two groups (see, for example, Lau and Yotopulos, 1971; Singh and Patel, 1973; Yotopulos and Nugen, 1976) or into many groups (Hussain, 1977), on the basis of some measure of farm size, and estimate a separate production function for each group. Others attempt to discover, without classification the relationship between size and productivity by resorting to aggregated and pooled data, or non-aggregated and/or non-pooled data of a farm to verify returns to scale (see, Srivastava and Heady et al, 1973; Cornia, 1985; Hearth, 1983, Saini, 1979). Typically, the method used by this type of researcher consisted of estimating equation Y=a+bx or $Yi=\hat{a}X_i^{\beta}$ where Yi stands for output or output per hectare of farm or group of farms, Xi the size (in hectares) of the farm or group of farms (Srivastava and Heady, 1973; Yotopolos and Nugent, 1976; Hussain, 1977; Hearth, 1983; Cornia, 1985). An estimated b coefficient less than unity (if Y is output) or negative (if Y is output per hectare) confirmed the inverse relationship. These different classifications and testing procedures are made on the relative efficiencies which in turn may lead to policy decisions. The weakness of this approach lies in the arbitary nature of the division and testing procedures which introduce bias through omissions of important variables. Because X in the equation is expressed in absolute terms, the sample used in testing the hypothesis cannot extend beyond a fairly homogenous group of farms. Obviously, a farm size of 3 hectares does not mean the same thing in coffee producing areas of Ethiopia as it does in cereal dominated farming systems. In the latter, it can be classified as a small farm, but in the former, it is clearly large. Farm size is therefore a relative concept, and its measurement in absolute terms can be quite misleading, especially in a large and heterogenous sample.

Furthermore, the estimation of the relationship between only two variables, namely the size of farm and the land productivity, which are extensively used by many researchers is likely to be meaningless because other factors exist which bear upon the productivity of the land. Some authors, (Berry and Cline, 1979) have tried to secure their analysis against those objections by including in the regression model variables like the percentage of irrigated area, an index of land quality and an index of cropping intensity, but the relationship of the important inputs, like labour and technological variables with farm size, is not given much attention.

4.2.3 Hypothesis

From the above results it follows that the argument that the inverse relationship is likely to disappear with technological change involving the introduction of chemical fertilisers, labour saving machinery and modern irrigation equipment, has been far from established in fact. There always has been some controversy regarding its validity in agriculture.

None of the previous studies were able to answer the question satisfactorily. This necessitates the need, in many developing countries, for testing in the form of hypothesis in order to answer some of the issues which were not given enough attention or which remained unresolved in the debate. Furthermore, there is a need to start the debate about farm size and productivity in the African situation. In this study a hypothesis has been proposed, in the context of Ethiopia, that the inverse relationship is true only in a traditional technology and its breakdown with technological change.

In Ethiopia, no studies have been carried out on the basis of FMS in post-technological change. However, as has been argued in the introduction, Ethiopian agriculture has undergone some transformation since 1967. New technologies introduced in Chilalo and MPP areas and on large farms, particularly before the Agrarian reform, have been relatively favoured by government policies regarding the purchase of material, machines and credit and extension services. Therefore there is some theoretical basis for expecting the inverse relationship to be weakened or even replaced by a positive relationship between yields and farm size, with technological change in the area of Ethiopia.

4.3. The Data and Analytical Framework

4.3.1. The Data and Variables

The farm management survey taken during the periods 1974/76 and the 1979/80 period provide the data for post-technological change studies. The data was collected from Farming Systens A and B.

Two dependent variables are defined which directly or indirectly represent the productivity of land to test the main hypothesis that is Y_1 is the gross value of output per cultivated hectare and Y_2 is the farm business income per cultivated hectare. Y_1 is the measure of the physical productivity while Y_2 is the measure of profitability obtained by deducting all production costs actually incurred from gross output value expressed at 1974/76 constant farm gate price.

Three regressors which are also important in peasant agriculture farm size (X_2), human labour (X_3) and (X_4) working capital discussed in Chapter III are employed in the study.

4.3.2. The Model and Analytical Techniques

Many attempts have been made in the past to estimate input-output relationships in peasant agriculture using various types of production functions (Srivastava and Heady, 1973; Rao and Chotigeat, 1981; Hearth, 1983; Cornea, 1985). As indicated above, these estimates have been used to evaluate productivity, production elasticity and returns to scale. Any function usually imposes certain restrictions on the input-output relationship and hence dictates the nature of the results. The Cobb-Douglas function, one of the most commonly used functions, for example, assumes unitary elasticity of substitution that does not vary over the range of the function. In this study, Semi-log, Cobb-Douglas and transcendental logarithm (or known as "translog" for short) functions have been tried. The translog function was favoured as the basic functional form of the model, because the others failed to satisfy the methodological approach followed in this study.

The properties of the translog function are discussed in Berndt and Christensen (1973). The usual form of the function is:

$$(1)\ \ LnY = Ln\beta o+\sum_{i=1}^{n}\beta_i Lnx_i+\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_{ij}Ln\chi_i Ln\ \chi_j+E_i$$

Where Y is output and the X is input, the Greek letters are parameters to be estimated. In this model, the output elasticity with respect to X1 is given by:

$$(2)\ \ \eta_i=\frac{\ln Y}{\ln X_i}=\beta_i+\sum_{j=1}^{n}\alpha_{ij}\ln\chi_j,$$ the co-operating inputs

The single measure of elasticity (η_i) at different values of the X_j, indicates the nature and magnitude of the relationship between output and selected input.

The empirical application of translog is now fairly straightforward. First, the model is specified in actual variables and the variables are defined. Secondly, the parameters of the model are estimated using OLS. On the basis of the general function (1) the translog function for Ethiopian highland farms, for example, can be specified in the actual variables as:

$$(3)\ \ LnY_1=A+\beta_2\ln\chi_2+\beta_3\ln\chi_3+\beta_4\ln\chi_4+\frac{1}{2}\sum_{i=2}^{4}\sum_{j=2}^{4}\alpha_{ij}\ LnX_i\ln X_j$$

$$=\ A+\beta_2\ln\chi_2+\beta_3\ln\chi_3+\beta_4\ln\chi_4+\frac{1}{2}\sum_{i=2}^{4}(\alpha_{i2}\ln\chi_i\ln\chi_2+\alpha_{i3}\ln\chi_i Ln\chi_3+\alpha_{i4}\ln\chi_i\ln x_4)$$

$$=A+\beta_2\ln\chi_2+\beta_3\ln\chi_3+\beta_4\ln\chi_4+$$
$$\frac{1}{2}(\alpha_{22}\ln\chi_2\ln\chi_2+\alpha_{32}\ln\chi_3\ln\chi_2+\alpha_{42}\ln\chi\ln\chi_2$$
$$+\alpha_{23}\ln\chi_2\ln\chi_3+\alpha_{24}\ln\chi_2\ln\chi_4+\alpha_{34}\ln x_3\ln x_4+\alpha_{42}\ln x_4\ln x_2$$
$$+\alpha_{33}\ln\chi_3\ln\chi_3+\alpha_{44}\ln\chi_4\ln\chi_4)$$
$$=A+\beta_2\ln\chi_2+\beta_3\ln\chi_3+\beta_4\ln\chi_4+$$
$$\frac{1}{2}(\alpha_{22}(\ln\chi_2)^2+\alpha_{33}(\ln\chi_3)^2+\alpha_{44}(\ln\chi_4)^2$$
$$+\alpha_{32}\ln\chi_2\ln\chi_3+\alpha 24\ln\chi_2\ln\chi_4+\alpha_{34}\ln\chi_3\ln\chi_4+\alpha_{43}\ln x_4\ln x_3)$$

Given that $\alpha_{ij}=\alpha_{ji}$ it follows that $\alpha_{32}=\alpha_{23};\alpha_{24}=\alpha_{42}$

Therefore, $\ln Y_1=A+\beta_2\ln\chi_2+\beta_3\ln\chi_3+\beta_4\ln\chi_4+$

$$\frac{1}{2}(\alpha_{22}(\ln\chi_2)^2+\alpha_{33}(\ln\chi_3)^2+\alpha_{44}(\ln\chi_4)^2)$$
$$+2\alpha_{23}\ln\chi_2\ln\chi_3+2\alpha_{24}\ln\chi_2\ln\chi_4+2\alpha_{34}\ln\chi_3\ln\chi_4$$

The main advantage in using the translog function is that it does not impose prior constraints on returns to scale and factor substitution as in Cobb-Douglas.

The translog function differs from the Cobb-Douglas function in the addition of squared and crossed product terms. These additional terms allow for quite general specification of the production function, which are important when examining the elasticity of substitution. If all the coefficients of the interaction terms are not significantly different from zero, the function reduces to Cobb-Douglas form.

However, the translog function has some disadvantages too. The main disadvantages are that the estimates of marginal products and the elasticity of substitution require the calculation of the function of the input variables, which adds additional work burdens. Moreover, it has been observed also the tranlog function is potentially subject to serious multicollinarity problems, probably because it includes more regressions in the functions than other functional forms (Sheh, et .al, 1977). However, this problem could be minimized by dropping variables which could create the problem, if there are sufficient variables which may be used to estimate the elasticities.

4.3.3. Stability of the Production Function

The main interest in this chapter on the production function analysis is the farm-size issue in post-technological change periods 1974/76 and 1979/80. There now follows an examination to see if production functions vary between different periods and whether there is statistical justification to pool the data for the two periods to obtain a sufficient number of observations. The relevant null-hypothesis in this respect is: there are identical production function in the post-technological periods for year 1974/76 and 1979/80, implying that there is no difference between each periods with respect to productivity. To test this hypothesis two types of regression are needed to be estimated: one is restricted regression assuming no period effects and the other an unrestricted equation allowing for period effect (Table 4.1). For convenience of analysis, a testable null-hypothesis is further postulated as follows:

1. There is no difference in intercepts between the periods.
2. There is no difference in slopes between the periods.
3. There is no difference in both intecepts and slopes between the periods.

The appropriate test applicable for the stability of production functions as we noted in the previous chapter is the use of Chow test (1960). Here the Chow test evaluates whether the model fitted separately to each period explains significantly, more variation in the dependent variable than when run for the entire combined sample.

Using the last procedure discussed in the previous chapter unrestricted regression has been estimated using year dummy for both intercept and slope parameters and the results presented in Table 4.2 The value of F estimated was calculated as follows. For instance, let us assume that we want to test the null-hypothesis:

Ho: No dummies

Hi: With dummies

For this the relevant equation is as follows:

Table 4.1. An equation of the restricted and unrestricted translog production function

---

Restricted model

(1) With intercept dummy

$$\begin{aligned} LnY = {} & \delta_0 D + \beta_2 \ln\chi_2 + \beta_3 \ln\chi_3 + \beta_4 \ln\chi_4 \\ & + \alpha_{23} \ln\chi_2 \ln\chi_3 + \alpha_{24} \ln\chi_2 \ln\chi_4 + \alpha_{34} \ln\chi_3 \ln\chi_4 \\ & + \alpha_{22} (\ln\chi_2)^2 + \alpha_{33} (\ln\chi_3)^2 + \alpha_{44} (\ln\chi_4)^2 \end{aligned}$$

(2) With slope dummy

$$\begin{aligned} LnY = {} & \beta_1 + \beta_2 \ln\chi_2 + \beta_3 \ln\chi_3 + \beta_4 \ln\chi_4 \\ & + \alpha_{23} \ln\chi_2 \ln\chi_3 + \alpha_{24} \ln\chi_2 \ln\chi_4 + \alpha_{34} \ln\chi_3 \ln^{3V}{}_4 \\ & + \alpha_{22} (\ln\chi_2)^2 + \alpha_{44} (\ln\chi_4)^2 \;\; \alpha_{33} (\ln\chi_3)^2 \\ & + \delta_2 \ln\chi_2 D_1 + \delta_3 \ln\chi_3 D_1 + \delta_4 \ln\chi_4 D_1 + \delta_{23} \ln\chi_2 \ln\chi_3 D + \delta_{24} \ln\chi_2 \ln\chi_4 D \\ & + \delta_{34} \ln\chi_3 \ln\chi_4 D + \delta_{22} (\ln\chi_2)^2 + \delta_{44} (\ln\chi_4)^2 D + \delta_{33} (\ln\chi_3)^2 D + \end{aligned}$$

(3) With both intercept and slope dummy

$$
\begin{aligned}
\alpha nY = {} & \beta_1+\delta_0 D+\beta_2 \ln\chi_2+\beta_3 \ln\chi_3+\beta_4 \ln\chi_4 \\
& + \alpha_{23}\ln\chi_2 \ln\chi_3+\alpha_{24}\ln\chi_2 \ln\chi_4+\alpha_{34}\ln\chi_3 \ln\chi_4 \\
& + \alpha_{22}(\ln\chi_2)^2+\alpha_{44}(\ln\chi_4)^2 \\
& + \delta_2 \ln\chi_2 D_1+\delta_3 \ln\chi_3 D_1+\delta_4 \ln\chi_4 D_1 \\
& + \delta_{23}\ln\chi_2 \ln\chi_3 D_1+\delta_4 \ln\chi_2 \ln\chi_4+ \delta_{34}\ln\chi_3 \ln\chi_4 \mathbf{D} \\
& + \delta_{22}(\ln\chi_2)^2\mathbf{D}+ \delta_{33}(\ln\chi_3)^2\mathbf{D} +\delta_{44}(\ln\chi_4)^2\mathbf{D}
\end{aligned}
$$

Unrestricted model

The period is divided into two sub-periods of post technological change, ie., 1974/76 and 1979/80.

1974/76:

$$
\begin{aligned}
LnY = {} & \beta_1+\beta_2 \ln\chi_2+\beta_3 \ln\chi_3+\beta_4 \ln\chi_4 \\
& +\alpha_{23}\ln\chi_2 \ln\chi_3+\alpha_{24}\ln\chi_2 \ln\chi_4 \\
& +\alpha_{34}(\ln\chi_3 \ln\chi_4+\alpha_{22}(\ln\chi_2)^2+\alpha_{44}(\ln\chi_4)^2 + \alpha_{33}(\ln\chi\ )^2
\end{aligned}
$$

1979/80:

$$
\begin{aligned}
LnY = {} & \beta_1 + \beta_2 \ln\chi_2 + \beta_3 \ln\chi_3 + \beta_4 \ln\chi_4 \\
& + \alpha_{23}\ln\chi_2 \ln\chi_3 + \alpha_{24}\ln\chi_2 \ln\chi_4 \\
& + \alpha_{34} \ln\chi_3 \ln\chi_4 + \alpha_{22}(\ln\chi_2)^2 + \alpha_{44}(\ln\chi_4)^2 +\alpha_{33}(\ln\chi_3)^2
\end{aligned}
$$

Table 4.1 Estimates of Translog production functions for unretricted model in the Ethiopian highland farming systems

	Periods	
	1974/76	1979/80
Intercept	6.74167	4.53429
	(1.431)	(3.205)***
LnX2	5.13887	4.48667
	(1.710)*	(4.496)***
LnX3	-1.1698	0.11003
	(-0.421)	(0.135)
LnX4	-3.2323	-3.20956
	(-1.772)*	(-3.606)***
LnX2LnX3	-1.24248	-0.3788
	(-1.474)	(-1.617)*
LnX2LnX4	-0.47974	-1.80322
	(-0.713)	(-1.617)*
LnX3LnX4	1.44468	0.46874
	(2.606)**	(1.824)*
$(LnX2)^2$	0.60765	1.25965
	(0.927)	(3.710)***
$(LnX3)^2$	-0.17529	-0.13901
	(0.379)	(-0.897)
$(LnX4)^2$	-0.26799	0.71390
	(-0.952)	(3.633)***
$\bar{R}2$	0.80	0.89
RSS	0.81165	0.9744
D.F	9:80	9:119
F.ratio	39.71629	109.70986
Sample	90	129

*** coefficients are significant at 1% level
** coefficients are significant at 5% level
* coefficients are significant at 10% level
Figures in the parenthesis are t-values.

Table 4.2 Estimates of Translog production functions for retricted model in the Ethiopian highland farming systems

	Poold	only intercept dummy	only slope dummy	with intercept and slope dummy
Intercept	3.89971	3.83253	4.27539	4.430516
	(3.696)***	(3.701)***	(2.984)***	(3.075)***
LnX2	3.12151	3.2875	4.44102	4.587554
	(3.679)***	(3.941)***	(4.636)***	(4.736)***
LnX3	-0.28326	-0.22468	0.25600	0.21092
	(0.499)	(-0.404)	(0.303)	(0.250)
LnX4	-1.74099	-1.70539	-3.13880	-3.27125
	(-2.650)**	(-2.646)**	(-3.651)***	(-3.762)***
LnX2LnX3	-0.382087	-0.46990	-0.70513	-0.39545
	(1.960)*	(-2.429)**	(-2.230)**	(-1.665)*
LnX2LnX4	-0.905785	-0.83225	-1.24777	1.42084
	(-2.371)**	(-2.216)**	(2.071)**	(2.269)**
LnX3LnX4	0.452672	0.43038	0.46648	0.48325
	(2.248)**	(2.178)**	(1.805)*	(1.867)*
$(LnX2)^2$	0.62443	0.60418	-0.37098	1.29979
	(2.451)**	(2.421)**	(-0.578)	(3.785)***
$(LnX3)^2$	-0.05293	-0.06118	-0.16406	-0.23900
	(0.522)	(-0.614)	(-1.028)	(-1.950)*
$(LnX4)^2$	-1.74097	0.25418	0.69269	-0.95010
	(-2.650)**	(1.589)*	(3.475)***	(-2.484)**
D1		0.06271	-	0.350944
		(3.029)***	-	(1.0131)
LnX2.D1			-0.01348	-0.02818
			(-0.194)	(-0.397)
LnX3.D1			1.05677	2.25944
			(0.037)	(0.639)
LnX4.D1			-6.9691	-9.34866
			(0.115)	(-0.154)
LnX2LnX3.D1			-0.70513	-0.69447
			(-2.230)	(-2.195)**
LnX2LnX4.D1			1.247765	1.42083
			(2.031)**	(2.269)**
LnX3LnX4.D1			0.951652	0.92302
			(2.235)**	(2.163)**
$(LnX2)^2$.D1			1.27621	-0.56053
			(3.712)***	(-0.839)
$(LnX3)^2$.D1			-0.164065	-0.16601
			(-1.028)	(-1.002)
$(LnX4)^2$.D1			0.69269	-0.95010
			(3.475)***	(-2.484)**
$\bar{R}2$	0.90	0.90	0.91	0.91
RSS	2.04439	1.85802	1.79258	1.78338
D.F	9:209	10:208	18:200	19:199
F.ratio	219.90297	206.57158	121.55781	115.22951
Sample	219	219	219	219

*** coefficients are significant at 1% level
** coefficients are significant at 5% level
* coefficients are significant at 10% level
Figures in the parenthesis are t-values.

Using the relevant values obtained from the above equation F-Statistics can be calculated as:

$$F = \frac{RSS-RSS/11}{RSS/208} = \frac{(1.85802-1.78605)/11}{1.78605/208} = \frac{0.00654}{0.00856} = 0.76$$

The tabulated value of F(Ft) with 11 and 208 degrees of freedom at the 5 % significance level is 1.79. Since $F_c \leq F_{11,208,0.05}$, the above null-hypothesis is accepted with 95% confidence interval. Thus the alternative hypothesis that the production functions differ quite significantly between the periods is rejected.

Following this, we shall attempt to examine whether the observed difference in production function arises due to variation slope parameters and both intercept and slope parameters. The relevant partially restricted regressions is given in table 4.2 respectively for intercept and slope tests. It should be emphasized here that unrestricted regressions for both tests is the same as used earlier. The value of F-statistic is calculated using the same procedures as above and the results are given in table 4.3. It is clear from the table that in both cases $F_c < F_t$ at 5% significance level, implying that both intercept and slope parameters are not different for different periods. These results show that estimation of production function using pooled data are justifiable on statistical grounds since there is equality between the estimates of the two-period regressions.

Table 4.3 **Tests of equality of intercepts, slopes and both intercepts and slopes**

Hypothesis	Degrees of freedom	Computed F	Critical values at given level of significance(F_t) 0.05	0.01
Only intercepts difference	(11,208)	0.76	1.79	2.24
Only slope difference	(19,200)	0.04	1.57	1.88
Both intercepts and slope difference	(20,199)	0.01	1.57	1.88

4. 4 Empirical analysis and results

The answer to farm size and productivity issues can better be answered through an appropriate approach to farm classification and model formulation that would enable studies of complex interaction of many factor inputs.

In this study, attempt has been made to test the functional form used first. This is followed by calculation of elasticities with the minimum, maximum, and average value of the co-operating inputs to verify whether productivity is increasing, constant or decreasing as farm size increases or decreases.

In selecting the functional forms, R1 of the Cobb-Douglas has been compared to that of R3 of the translog functions in Table 4.4. As can be seen from the table the translog function has five additional terms which are significant at conventional levels. Furthermore, when compared to the Cobb-Douglas, the translog model (R3) shows a reduction in residual variance that is statistically significant at the 0.01

level. This is evidence that the Cobb-Douglas function is not appropriate and the translog function is better for studying the complex relationship between gross value of output and inputs.

The relationship between farm size and gross value of output is given in table 4.4. This table shows that the average size of holding (X_2) is significantly related to the gross value of output per cultivated hectares. Similarly, farm size is also significantly related to the farm business income. The coefficients of the translog model indicate that the relationships are much more complex than is reflected by the simple models. It is also clear that there is no systematic relationship between the inputs and outputs. In cases where relationship can be systematically explained by the separate effect of one input, farm size alone is not significant. But farm size and other inputs significantly explain variation in productivity in association with other inputs. Thus, for example the negative sign for land observed in multiplicative terms, while important, should not be taken to reflect the total relationship between productivity and farm size. The sign of the squared terms is mathematically consistent with the sign of individual terms.

The total relationship can be understood more clearly by examining output and farm business income elasticities with respect to the different inputs used. Thus the elasticities were computed at minimum, average and maximum values of co-operating inputs from the sample data using equations in Table 4.5.

Table 4.4. Estimates of Cobb-Douglas and Translog production functions for Ethiopian highland farming systems

	Cobb Douglas LnY1	Cobb Douglas LnY2	Translog LnY1	Translog LnY2
	R1	R2	R3	R4
Intercept	1.54303	1.54303	4.33980	4.54460
	(15.447)***	(13.116)***	(5.113)***	(4.740)***
$\ln X_2$	0.52389	0.60666	3.23170	3.43640
	(9.864)***	(9.670)***	(4.073)***	(3.832)***
$\ln X_3$	0.16539	0.19315	-0.55320	-0.63511
	(5.148)***	(6.712)***	(-1.8445**	(-1.875)**
$\ln X_4$	0.36483	0.2834	-1.77270	-1.90056
	(10.246)***	(6.712)***	(-2.993)***	(-2.0085)***
$\ln X_2 \ln X_3$	-	-	-0.42573	-0.49378
	-	-	(-2.427)***	(-2.495)***
$\ln X_2 \ln X_4$	-	-	-0.88370	-0.84745
	-	-	(2.549)***	(-2.165)***
$\ln X_3 \ln X_4$	-	-	0.42191	0.48443
	-	-	(2.441)***	(2.252)***
$(\ln X_2)$	-	-	0.57761	0.58565
	-	-	(2.509)***	(2.252)***
$(\ln X_3)^2$	-	-	-	-
$(\ln X_4)^2$	-	-	0.28546	0.24587
	-	-	(1.905)**	(1.453)
$\bar{R}^2$	0.90	0.89	0.91	0.89
RSS	1.95425	2.71100	1.83982	2.33537
D.F.	3:215	3:215	8:210	8:210
F. Ratio	685.24	509.14	169.65	210.99
Sample	219	219	219	219

***Coefficients are significant at 1% level
** Coefficients are significant at 5% level
* Coefficients are significant at 10% level
Figures in parenthesis are t-values.

Table 4.5. Output and farm business elasticities equation with respect to co-operating inputs.

Y_1 W.r.t.$X_2=\beta_2+2\alpha_{22}\ln X_2+\alpha_{23}\ln X_3+\alpha_{24}\ln X_4$

Y_1 W.r.t.$X_3=\beta_3+2\alpha_{22}\ln X_3+\alpha_{34}\ln X_4$

Y_1 W.r.t.$X_4=\beta_4+2\alpha_{44}\ln X_4+\alpha_{24}\ln X_4+\alpha_{34}\ln X_4$

Y_2 W.r.t.$X_2=\beta_2+2\alpha_{22}\ln X_2+\alpha_{23}\ln X_3+\alpha_{24}\ln X_4$

Y_2 W.r.t.$X_3=\beta_3+ .\alpha_{23}\ln X_2+\alpha_{34}\ln X_4$

Y_2 W.r.t.$X_4=\beta_4+2\alpha_{44}\ln X_4+\alpha_{24}\ln X_4+\alpha_{34}\ln X_4$

Only those inputs with significant interactions were used in the computation of the elasticity. The signs of the elasticity measure depend on the signs of the estimated coefficients and the values of the co-operating inputs. An analysis of these signs will show the role of the co-operating inputs in the overall relationship. The elasticities so computed for land, which are the more important variables in the farm size productivity debate are given in Table 4.6.

Table 4.6 Translog function output and farm business elasticities

	with minimum values of co-operating input	with average values of co-operating input	with maximum values of co-operating input
Y_1 w.r.t. X_2	0.9591	0.5028	0.0817
Y_1 w.r.t. X_3	-0.3609	0.1460	0.2372
Y_1 w.r.t. X_4	0.1297	0.3915	2.4035
Y_2 w.r.t. X_2	0.9620	0.5121	0.8490
Y_2 w.r.t. X_3	1.2687	1.4357	1.1735
Y_2 w.r.t. X_4	1.9306	2.2139	1.7766

The elasticity of gross value of output to farm size is positive, but diminishes with increase in the value of co-operating inputs, labour and Capital variables. This implies that the gross value of output per cultivated hectares increases at a diminishing rate with average size of holding when more and more co-operating inputs are used. At maximum value of both the co-operating inputs, large average size of holdings generate lower extra gross value of output per extra hectare of cultivated land. Thus as more and more labour is used on farms above average the negative effect of labour swamps the positive effects of the land variable.

However, it should be noted that this relationship may be reversed. The sign of the coefficients suggest that land (X_2) has a consistent positive effect, capital variables (X_4) both positive and negative effect and labour (X_3) has consistent negative effects on elasticity measures. The net effect depends on the individual effects acting in conjunction with one another. Thus large extra units of farm size, some extra units of capital and small extra unit of labour acting in opposition to one another will ensure a consistent positive relation between farm size and productivity with large holdings.

Analysis of the elasticity of farm business income to farm size also shows a positive relationship. The elasticity of Y_2 with respect to X_2 first diminishes and then increases as both co-operating inputs are increased and decreased. This effect is the net result of positive effect of land and negative effects of labour and capital. As extra unit of labour and capital are increased and decreased beyond the average co-operating inputs the large positive effect of land dominates the small negotive of the two co-operating inputs, ensuring higher elasticity of farm business income both at maximum and minimum values of co-operating inputs.

A further analysis of elasticity of output and farm business income with respect to labour and capital, also gave some interesting results. The elasticity of gross value of output with respect to labour is negative with minimum co-operating inputs but slightly increased as the co-operating input is increased. The elasticity with respect to capital variables is positive and increases with the increase the co-operating input of land and labour. This suggests that the gross value of output per units of capital used increases at an increasing rate when more and more co-operating inputsare used. The elasticity of farm business income with respect to both labour and capital is positive. However, the elasticity decreases with maximum and minimum co-operating inputs, implying that farm profitability per cultivated hectares decreases at an increasing rate with an average size holding when more and less of the two variables are used.

4.6 Conclusions

This isastudy of productivity in agriculture in the post-technological change period by farm size for 219 farms in the highland farming systems of Ethiopia. It is based on three years average data, which should have a better predictive value than those obtained from a single cross section. It would not be appropriate to draw any definite conclusions for Ethiopia as a whole by studying only 219 farms in one agro-ecological zone. So the results of this study should be taken as conclusive for the highland farming systems and as indicative for other parts of Ethiopia.

The main findings of the study suggests that land has a positive effect, labour negative effect and capital both negative and positive effects on the elasticity of the gross value of output per unit of land. Although, this shows the weakening of the inverse relationship, it is the large extra increase in farm size, some units in the capital and small increase in the unit of labour acting in opposition to one another that can ensure consistent positive effect between land size and productivity with large holdings.

A further analysis carried out to examine farm size and farm business income relationship confirms the positive relationship between land size and profitabity.

The overall results of this study suggest the weakening of inverse relationship with the introduction of new technologies. As noted in this and previous discussions, government policies have favoured large scale production. Studies on agricultural extension services indicate that large size farm groups have greater access to information on fertilizers and improved seeds. Perhaps most important is the fact that large farms have enjoyed more favourably access to institutional credit from ARDU and MPP in the form of HYV, fertilizers and etc. Consequently, they have benefitted by higher adoption of new inputs and were able to produce on a superior production function, resulting in a relatively higher production.

We speculate that these considerations constitute the most important factors explaining the greater observed efficiency of large size holdings. It was not possible to test the influence of these factors, given the data set, but such testing constitutes an important direction for future research.

PART II EX-ANTE ANALYSIS

CHAPTER V

MODEL DEVELOPMENT AND CONSTRAINTS IN THE HOUSEHOLD PRODUCTION SYSTEMS

5.1 INTRODUCTION

This chapter discusses the basic structure of the farm household model in the Ethiopian highlands. The chapter starts with the description of the farm household resource flow system and algebraic formulation of the linear programming model. This is followed by formulation of the activities and constraints of the farming systems and estimation of the input-output coefficients which constitutes the model.

5.2. Representative Farming Systems

Attention in selecting and defining representative farming systems is usually focussed on soil type, rainfall, topogaphy and farm size as the principle factors (Byerlee et al, 1980). It has been suggested that other factors be incorporated in order to capture changing social or economic relationships. Serious questions have been raised as to whether variables other than physical and climatic factors be considered in defining a representative farm in particular. Upton (1973) for instance, stresses the role of managerial ability in farm performance. Factors such as type of tenure, age and family circumstances of the farmer are also important factors suggested as being important by others (EL Adeemay and J MacArthur, 1969). It is difficult to select representative farming systems on a number of these factors but to attempt to classify these systems into a homogenous recommendation domain on the basis of many variables requires the use of a number of representative farm groups which adds a considerable extra amount of work. This problem is particularly serious where simulation of a number of alternative technologies and policies are involved. Some, in fact have used only a typical farm approach in modelling the farming systems (Low, 1974; Kinsey 1979). Thornton (1972) argued that typical farm data within a fairly homogenous area in terms of climate and geography could be a basis for policy recommendation to a higher percentage of the population. Spencer (1977) stressed the stratification of the study area into relatively homogenous agro-ecological and resource regions. Collinson (1981) further suggested grouping into a relatively homogenous population on the basis of present farming systems. This approach of groupings has three justifications:-

1. The existing farming systems in a particular zone is a manifestation of a weighted interaction of natural, economic and historic factors influencing farmers decisions.
2. The existing farming systems of each zone is the starting point for development - the base into which productivity improvements have to be grafted.
3. Farmers with the same farming systems have the same priorities and resource endowments and thus the same researchable problems and development opportunities. (Collinson, 1981:434).

In this study as noted in Chapter II, the highland area of the country where the sample of households were selected, was stratified into agro-ecological zones and resource regions reflecting the different physical and climatic factors. From the agro-ecological zones of the Ethiopian highlands, two representative farming systems, namely, the Central Highlands and Eastern Highlands, were used for building the model that follows. These two farming systems have great agricultural potential, but the way this potential is exploited will have a profound consequence for agricultural development in Ethiopia.

5. 3 Structure of the Basic Model

5.3.1 Resource Flow of Traditional Household Farming System

To model the farm household system, it is necessary to specify the basic subsectors of households' activities and their relationship and interactions in the real system. Figure 5.1 represents the components and linkages of the farm household system in the Ethiopian highlands.

Small farm systems in Ethiopia are surprisingly complex. The bio-physical and socio-economic conditions which interact in the system are beyond the control of the farm household. Given that farmers are members of government sponsored peasant associations, the prevailing economic policy of the government influences the availability of resources, use of inputs and market situations to a great extent. Government policy also limits the freedom of the farm family in the use of inputs. At present for example, membership of a peasant association implies access to land for individual and communal cultivation, within the size of the smallholder's family and the total land area and mix of land qualities available to a smallholder in one year are not necessarily allocated to the same person again in subsequent years.

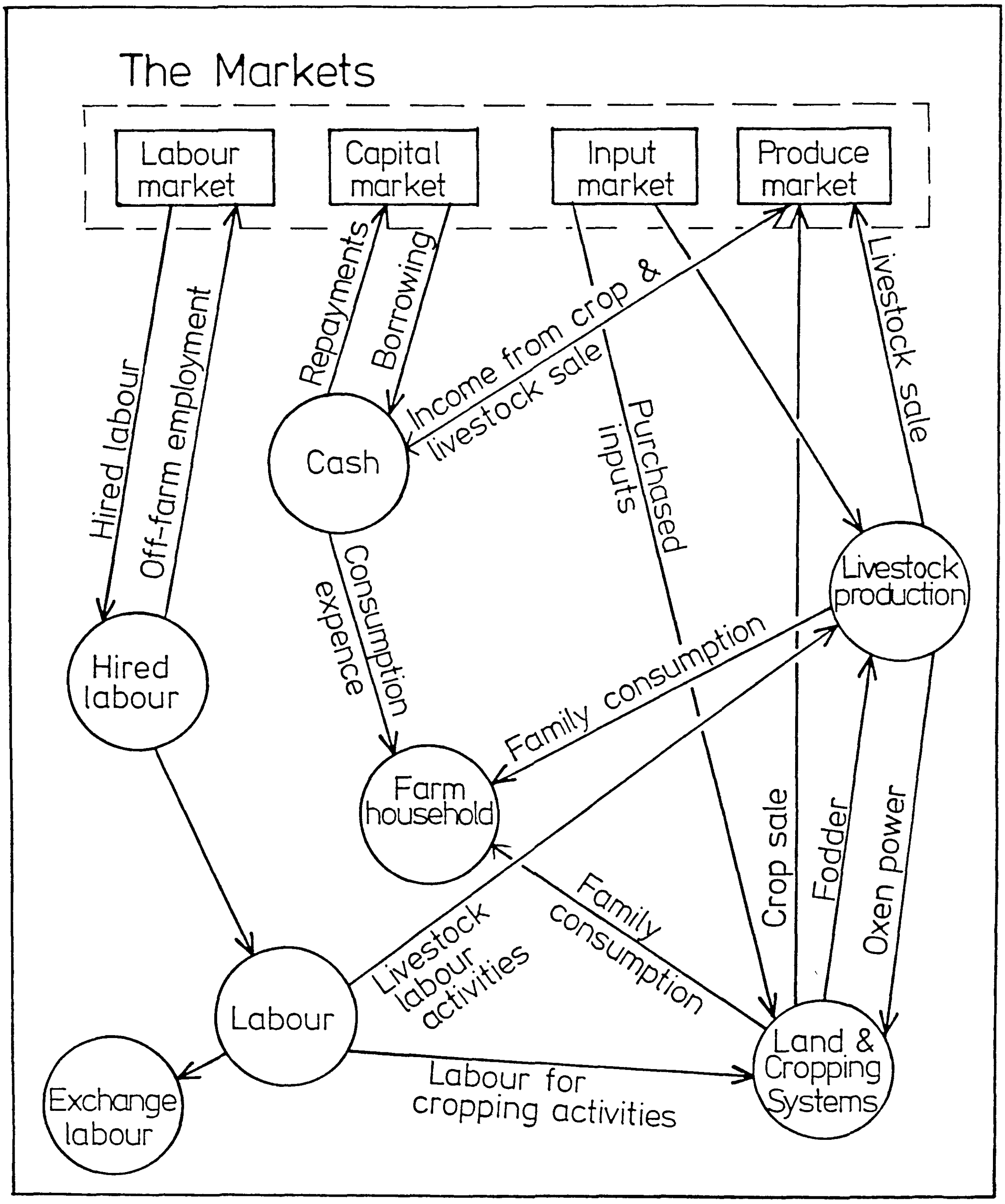


Figure 5.1 Resource flows in small holder farming systems in Ethiopia

Table 5.1 Outline of the farm household system

Resource	Crop production per ha	Crop consumption Kg	Crop sale Kg	Labour hire Birr	Loan Birr
Land	+aij[a]	0[b]	0	0	0
Family labour					
Ploughing	+aij	0	0	0	0
Planting	+aij	0	0	0	0
Weeding	+aij	0	0	-aij	0
Harvesting	+aij	0	0	-aij	0
Threshing	+aij	0	0	-aij	0
Hired Labour					
Weeding	+aij	0	0	+aij	0
Harvesting	+aij	0	0	+aij	0
Threshing	+aij	0	0		
Oxen time					
Ploughing	+aij	0	0	0	0
Planting	+aij	0	0	0	0
Threshing	+aij	0	0	0	0
Operating capital	+aij	0	0	+aij	-aij
Borrowing	0	0	0	0	aij
Yield					
Teff	-aij	+aij	+aij	0	0
Wheat	-aij	+aij	+aij	0	0
Barley	-aij	+aij	+aij	0	0
Maize	-aij	+aij	+aij	0	0
Sorghum	-aij	+aij	+aij	0	0
Horse bean	-aij	+aij	+aij	0	0
Peas	-aij	+aij	+aij	0	0
Chick pea	-aij	+aij	+aij	0	0
Flax	-aij	+aij	+aij	0	0
Consumption minimum					
Teff	0	+aij	0	0	0
Wheat	0	+aij	0	0	0
Barley	0	+aij	0	0	0
Maize	0	+aij	0	0	0
Sorghum	0	+aij	0	0	0
Horse bean	0	+aij	0	0	0
Peas	0	+aij	0	0	0
Chick peas	0	+aij	0	0	0
Flax	0	+aij	0	0	0

[a] aij represents input-output coefficients

+aij/-aij indicates that the input/output coefficient in the particular sub matrix are positive or negative.

b indicates all aij are zero

Although the small farmers are allocated individual holdings, the land tenure system does not secure their holdings. Therefore, any attempt to build a model which simulates the farm household system must recognise that the incorporation of more detail and realism results in a bigger, more complex model. However, this is often very cumbersome and difficult to manipulate. As a result, many authors suggest that the model and its data requirements should be kept as simple as possible (Barlow, et al, 1983).

One of the aims of this thesis as discussed in Chapter I is to study the means and possibilities of raising farm income and resource productivity. The linear programming (LP) approach is used in modelling the farming system. LP has been used widely to model and study the household farming systems in less developed countries. The technique is described in detail in numerous publications (Clayton, 1963; Heyer, 1972; Low, 1974; Kinsey, 1979; Barlow, 1983). However, a brief background of the technique in relation to the analytical model used in this study is appropriate.

5.3.2 Algebraic Formulation of the LP model

Linear programming is a mathematical technique which can be used to maximize or minimize some function within a given technology and subject to some constraints. In such a context, the objective function is usually in the form:

$$Z = \sum_{j=1}^{n} Cj\ Xj$$

Where, Z represents the objective function to be maximized

Cj is the vector price or other weights of the objective function

Xj is the vector of activity levels to be determined (Crop poduction and others)

The fixed conditions present on the farm are usually stated in the form of linear restrictions such as:

$$\sum_{j=1}^{n} a_{ij} Xj \leq b_i \quad (i= 1,2 \ \ldots n)$$

Where, the Xj is as previously defined, and b_i represents the total amount of resource available or other constraints. Aij represent the input-output coefficients.

Another restriction in the decision variables takes the form of:

$$X_j \geq 0 \text{ for all } j\text{'s } (j = 1,2, \ldots n)$$

which specifies that only non-negative levels of each decision variable may be examined. Linear programming then provides a means to find the levels of the decision variables that would maximize the objective function subject to the resource conditions on the farm and the non-negativity requirement (Barnard and Nix, 1979).

The mathematical framework of a linear programming matrix requires a number of important assumptions to be made about the nature of the process being presented. These assumptions include additivity, divisibility, finiteness and linearity (Hardaker, 1971; Barnard and Nix, 1979). In this study it is assumed the input-output values, resource supplies and the prices of inputs and outputs are known with certainty. Although for many purposes this assumption may be a useful simplification of reality, Upton (1974) have contended that risk consideration is an important decision making variable and that some method of incorporating risk factors within a linear programming framework is therefore desirable.

A number of approaches have been developed to account for risk in the linear programming model of the farm-firm but there is no clear guidance as to which of these approaches is the most desirable. In the formulation of the linear programming models in this study, the risk factor is only implicitly specified by incorporating restrictions to ensure the production of food grain to meet minimum family consumption needs. In addition to being easily included in the model, the specifiction is relatively undemanding in its data requirements about yield and price distributions.

The structure of a linear programming model is determined by three related components (Bernard and Nix, 1979). The components are: the objective function, the activities in the model and the constraints on restrictions in the model. The next section describes each of these components for the linear programming model which is used to represent the planning environments of the representative farm in the area.

Hardaker (1971) has stressed that the validity of the results obtained from linear programming exercises depends on the reliability of the data employed and on the skill with which the real circumstances of the farm are represented in the rather rigid mathematical framework of a linear programming matrix. Table 5.1 shows the broad activities of the matrix used in this study. This matrix is essentially an attempt to quantify many of the relationships in Figure 5.1. In the formulation of the model and specifying the household system in the matrix in this study, every effort was made to reflect as realistically as possible the actual farming systems in the study areas. A detailed survey of a sample of farms in the study area provided most of the data used for quantifying resources and other restrictions, activities and input-output relationships. In some cases these were validated using other secondary sources.

In this study, there are ten types of models considered. Model 1 depicts a farm production situation where existing methods are exclusively used and the rest shows sets of alternative new technologies and policies. The table for the basic model is presented in tables 5.2 and 5.3.

Each column of the tableau defines an activity with its respective input-output coefficient. Each row represents restrictions. A negative coefficient signifies an addition to the resource, while a positive coefficient indicates a demand on the resource.

5.3.3 The Objective Function

Once the system is specified in a linear programming framework, it is necessary to identify the goal it attempts to achieve. It is recognised widely that small farmers typically have a multiplicity of economic and non-economic goals (Clayton, 1983, Barlow et al, 1983). As a result a variety of objectives have been specified for the smallholder in traditional agriculture. Schultz (1964) and Hopper (1965) believe that peasant farmers are profit maximizers. De Wilde (1967) contends that, for many Africans, security is a more important consideration than the possibility of increasing income. Norman (1973) found that although small farmers in the Zaria area in Northern Nigeria used inputs in a manner consistent with profit maximizing

Table 5.2 Linar Programming Matrix of The Basic Model In Farming System A

Row	Constraints			CROP PRODUCTION								LABOUR HIRING			CROP SALE								LOANS	CONSUMPTION							
	Activities			A1 Wheat Has	A2 Barley Has	A3 Teff Has	A4 Maize Has	A5 Sorgum Has	A6 Bean Has	A7 Pea Has	A8 Flax Has	A9 Weed. Birr	A10 Harv. Birr	A11 Thresh. Birr	A12 Wheat Kgs	A13 Barley Kgs	A14 Teff Kgs	A15 Maize Kgs	A16 Sorgum Kgs	A17 Chick Kgs	A18 Lent. Kgs	A19 Flax Kgs	A20 Borrow Birr	A21 Wheat Kgs	A22 Barley Kgs	A23 Teff Kgs	A24 maize Kgs	A25 Sorg Kgs	A26 Beans Kgs	A27 Peas Kgs	A28 Flax Kgs
				-147	-47	-81	-13	-4	-73	-61	-15	-0.50	-0.50	-0.50	+0.52	+0.34	+0.59	+0.33	+0.35	+0.36	+0.52	+0.56	-0.10	0	0	0	0	0	0	0	0
1	Cropland	Has	1.90 GE	1	1	1	1	1	1	1	1																				
	Family labour																														
2	Ploughing	Hrs	735 GE	166	119	170	109	123	109	83	77																				
3	Planting	Hrs	472 GE	71	36	47	34	39	31	29	27																				
4	Weeding	Hrs	469 GE	188	172	283	119	140	82	77	20	-1																			
5	Harvesting	Hrs	316 GE	155	130	277	260	155	183	132	148		-1																		
6	Threshing	Hrs	620 GE	86	66	83	60	55	47	32	38			-1																	
	Oxen Labour																														
7	Ploughing	Hrs	980 GE	332	238	340	218	246	218	166	144																				
8	Planting	Hrs	630 GE	149	58	87	60	68	47	50	42																				
9	Threshing	Hrs	397 GE	186	177	262	120	110	90	80	89																				
	Hired Labour																														
10	Weeding	Hrs	0 GE									1																			
11	Harvesting	Hrs	0 GE										1																		
12	Threshing	Hrs	0 GE											1																	
	Yield																														
13	Wheat	Kgs	0 GE	-1520											1																
14	Barley	Kgs	0 GE		-1730											1								1							
15	Teff	Kgs	0 GE			-1070											1								1						
16	Maize	Kgs	0 GE				-1320											1								1					
17	Sorgum	Kgs	0 GE					-965											1								1				
18	Beans	Kgs	0 GE						-1020											1								1			
19	Peas	Kgs	0 GE							-831											1								1		
20	Flax	Kgs	0 GE								-510											1								1	
	Credit Maximum																														1
21	Capital	Birr	200 GE	147	47	81	13	4	73	61	15	0.50	0.50	0.50																	
22	Borrowing	Birr	0 GE																				-1								
	Consumption Minimum																						1								
23	Wheat	Kgs	199 EQ																												
24	Barley	Kgs	260 EQ																					1							
25	Teff	Kgs	207 EQ																						1						
26	Maize	Kgs	133 EQ																							1					
27	Sorgum	Kgs	81 EQ																								1				
28	Beans	Kgs	200 EQ																									1			
29	Peas	Kgs	38 EQ																										1		
30	Flax	Kgs	3 EQ																											1	
																															1

Table 5.3 Linar Programming Matrix of The Basic Model In Farming System B

Row	Constraints			Activities	CROP PRODUCTION								LABOUR HIRING			CROP SALES								LOANS	CONSUMPTION							
					A1 Wheat Has	A2 Barley Has	A3 Teff Has	A4 Beans Has	A5 Peas Has	A6 Chick Has	A7 Lentil Has	A8 Flax Has	A9 Weed. Birr	A10 Harv. Birr	A11 Thresh. Birr	A12 Wheat Kgs	A13 Barley Kgs	A14 Teff Kgs	A15 Beans Kgs	A16 Peas Kgs	A17 Beans Kgs	A18 Peas Kgs	A19 Flax Kgs	A20 Borrow Birr	A21 Wheat Kgs	A22 Barley Kgs	A23 Teff Kgs	A24 Beans Kgs	A25 Peas Kgs	A26 Chick Kgs	A27 Lent Kgs	A28 Flax Kgs
					-128	-37	-107	-49	-57	-24	-8	-16	-0.50	-0.50	-0.50	+0.52	+0.34	+0.59	+0.33	+0.35	+0.36	+0.52	+0.56	-0.10	0	0	0	0	0	0	0	0
1	Cropland	Has	2.10	GE	1	1	1	1	1	1	1	1																				
	Family labour																															
2	Ploughing	Hrs	686	GE	180	162	169	138	100	94	72	60																				
3	Planting	Hrs	441	GE	55	40	48	34	25	37	19	23																				
4	Weeding	Hrs	474	GE	190	265	287	94	58	53	24	45	-1																			
5	Harvesting	Hrs	544	GE	248	190	338	120	132	154	125	130		-1																		
6	Threshing	Hrs	576	GE	93	61	87	44	62	43	30	27			-1																	
	Oxen Labour																															
7	Ploughing	Hrs	980	GE	360	232	238	276	200	188	78	120																				
8	Planting	Hrs	630	GE	94	66	70	45	36	53	30	35																				
9	Threshing	Hrs	397	GE	177	148	196	155	167	170	154	159																				
	Hired Labour																															
10	Weeding	Hrs	0	GE									1																			
11	Harvesting	Hrs	130	GE										1																		
12	Threshing	Hrs	0	GE											1																	
	Yield																															
13	Wheat	Kgs	0	GE	-795											1									1							
14	Barley	Kgs	0	GE		-828											1									1						
15	Teff	Kgs	0	GE			-1124											1									1					
16	Beans	Kgs	0	GE				-1160											1									1				
17	Peas	Kgs	0	GE					-966											1									1			
18	Chickpeas	Kgs	0	GE						-643											1									1		
19	Lentiles	Kgs	0	GE							-572											1									1	
20	Flax	Kgs	0	GE								-474											1									1
	Credit Maximum																															
21	Capital	Birr	285	GE	128	37	107	49	57	25	8	16	0.50	0.50	0.50									-1								
22	Borrowing	Birr	0	GE																				1								
	Consumption Minimum																															
23	Wheat	Kgs	210	EQ																					1							
24	Barley	Kgs	312	EQ																						1						
25	Teff	Kgs	387	EQ																							1					
26	Beans	Kgs	231	EQ																								1				
27	Peas	Kgs	51	EQ																									1			
28	Chickpeas	Kgs	40	EQ																										1		
29	Lentiles	Kgs	38	EQ																											1	
30	Flax	Kgs	4	EQ																												1

obectives, they adopted intercropping and other practices indicative of an insurance or risk minimizing strategy. He concluded that both security and profit maximization were relevant goals to farmers in that area. Upton (1974) further suggested that the objectives of the smallholder may include maximization of the flow of consumption, growth maximization and this objective is likely to vary in time according to the farmer's age and needs and the external factors. Clayton (1983) also argued that smallholder families have multiple objectives such as security of the family food supply, income to purchase a required level of material needs and a certain degree of security reflecting farmers' circumstances and psychology observanse of socio-cultural customs and obligations, and a need for a satisfactory amount of leisure. Heyer (1971) has stressed the difficulty of deciding what it is that subsistence farmers aim for. She contends that the objective function is ambiguous and suggests ensuring an adequate food supply in drought years, producing a suitably varied diet, maximizing the number of people fed, maximizing the market value of output as possible alternatives that could be considered. This complexity in ascertaining the objectives of smallholders makes the definition of a meaningful and operational objective function a difficult problem in application of linear programming of smallholder agriculture.

In this study, it is assumed that farmers in the study area are risk averse and seek first security (through the production of grain for family consumption) as well as the maximization of net income. Upton (1974) has indicated that there are two alternative approaches to incorporating more than one objective in a single linear programming model. One approach is to combine the various objectives into a single decision criterion such as expected utility maximization. The other approach (known as the "lexicographic approach") is to employ a hierarchy of objectives treating all but one as constraint. The lexicographic approach has been widely used in studies on African farmers (Ogunfowora, 1972; Low, 1974) and is the approach adopted in this study.

The security objective of producing food for the family is specified in the matrix as constraints to force the production of necessary amounts of each crop produced for meeting minimum family consumption levels. Farmers were allowed to sell crops only after fulfilling the minimum constraints. These required amounts were derived from the results of a consumption study undertaken in the study area which we shall discuss later.

5.3.4 Formulation of the Model Structure

The model depicts a traditional farm production situation of one year covering the period between April 1979 to March 1980. In setting up the model structure the study commenced by outlining the resources available and classifying them into whatever categories are appropriate. Different activities and the requirements of each for the resources were then defined. This involved the preparation of a schedule of resource requirements for every enterprise (activity) included. Next consideration was given to resource constraints.

5.3.5 Formulation of the Activity Set

Five groups of activities have been specified in the model. These were crop production, consumption, marketing, labour hiring and borrowing activities.

5.3.5.1 Crop Production Activities

Modelling of the crop production activities requires a knowledge of the types of crops grown in the family sytem. To this end, the importance of the crop in terms of the production of total cultivated hectares in the two farming systems, from the survey and other secondary sources, were taken into consideration. Table 5.4 on average barley/wheat and teff/barley cultivation dominated the cropping pattern in the farming systems A and B respectively. In farming system A, barley and wheat covered 29% and 20% of the cultivated land. The other cereal crops occupied 32% and pulses and oil crops only 19% of the cultivated land. In the case of farming system B, the pattern of the importance of the crops is somewhat different. Here, teff cultivated area is the highest (50%).

Table 5.4. Distribution of different crops among farmers in Arssi and Shoa administrative regions (%)

Crop	Ethiopian highland regions	
	Arssi Region[a]	Shoa Region[b]
Cereals		
Wheat	20.30	7.10
Barley	28.80	23.30
Teff	12.30	50.10
Maize	16.30	0.05
Sorghum	3.10	0.03
Pulses		
Horsebeans	8.40	10.11
Chickpeas	0.30	3.15
Peas	3.40	3.10
Lentils	1.00	0.90
Oil Crops		
Noug	2.20	1.00
Flax	2.80	0.80
Others	0.50	0.30

Source: MOA Crop Sampling Survey (1979) Agricultural Sample Survey, Area production and yields of major crops by adminisitrative regions, 1974-80, Addis Ababa.

(a) Farming System A in Arssi regions
(b) Farming System B in Shoa regions.

Table 5.5 **Summary of average land utilization and proportion of sample farmers cultivating a crop, Ethiopian highlands**

	Farming Systems			
	A		B	
Crop	has	%	has	%
Cereals				
Wheat	0.54	28.42	0.20	9.52
Barley	0.70	36.85	0.40	19.05
Teff	0.21	11.05	0.90	42.86
Maize	0.12	6.31	-	-
Sorghum	0.05	2.68	-	-
Pulses				
Horsebeans	0.17	8.95	0.27	12.86
Chickpeas	-	-	0.11	5.24
Peas	0.08	4.21	0.13	6.19
Lentils	-	-	0.04	1.90
Oil Crops				
Flax	0.03	1.58	0.05	2.38
Total	1.91	100	2.10	100

Source: Computed from the Survey Data.

Other crops, barley, wheat, horsebeans, peas, chickpeas, and lentils are also grown in the area (Table 5.5). Maize, sorghum and flax are also grown but their contribution in the farming system is small.

Land use pattern of sampled farmers cultivating the various crops are also summarized in Table 5.5. Barley accounted for 38% of the total cultivated land in farming System A and the remaining land was allocated to wheat, teff, maize, sorghum, horsebeans and other crops in the proportion indicated in Table 5.5. In farming System B, teff cultivated areas occupied 43%, followed by barley, horsebeans, wheat, peas, chickpeas, flax and lentils.

Tables 5.4 and 5.5 indicated that barley, wheat, teff, horsebeans, maize, sorghum, peas, lentils and flax are the crops which are in the farmers' production programmes; these are therefore taken into account in the model and are shown as crop production activity in Table 5.2 and 5.3 in column A_1 to A_8.

5.3.5.2 Food Consumption Activities

Ethiopian farm families are heavily dependent on home production for their consumption. Total quantities and estimated values of grain consumption by the sample farmers are not available, but a socio-economic survey conducted in the study region found that in the area teff, wheat, barley, maize, sorghum, horsebeans, peas, chickpeas, lentils and flax are consumed by farm households. It is assumed that each household farm should maintain its customary consumption habits through retained farm produced commodities for consumption requirement. Therefore, in the consumption activities all grain crops consumed by farmers in the study area are included in the model. The grain consumption activities are shown in Table 5.2 and 5.3, Columns A_{21} to A_{28}.

5.3.5.3 Capital Borrowing Activities

The model permits borrowing when the initial working capital (Cash for the previous year) is not enought to meet production expenditure. It is assumed that the borrowed capital is short term and used only for cash operating costs including hired labour. Capital borrowing activities are shown in Table 5.2 and 5.3 and columns A_{20}. Loans are assumed available from formal loan programmes by ARDU and MMP at 10% annual interest rate. The activity unit is one Birr

5.3.5.4 Labour Hiring Activities

There are three main sources of labour - family labour, exchange labour and hired labour. Exchange labour is excluded from the model since the equalization of the exchange received has to be met by the family labour within the period. Thus, they cancel out. Farmers hire labour in particular periods when the household labour is inadequate to perform agricultural operations. The total amount of hired laboour needed, depends on the amount of crop labour required in relation to the amount of family labour from the households.

Men and women are hired mainly during weeding and harvesting periods. They are assumed to be paid the same rate since no sex difference has been reported. The price used is the wage rates per man hour prevailing in the study area during the study periods.

In the model, hired labour and family labour are assumed to be near perfect substitutes. The labour hiring activities have a negative coefficient in the family labour rows, indicating that an increase of one unit of hired labour relaxes the labour constraints by one unit. The wage rate of hired labour is positive in the operating capital row, meaning that an increase of hired labour by one unit will decrease operating capital by its wage rate. Thus the extent to which hired labour can be used to relax the family labour constraint is determined by the operating capital available to the farm firm. The average farm in the study area is assumed a net buyer of labour. Hence, the selling of family labour in the form of off-farm work is not permitted on the model.

5.3.5.5 Crop Selling Activities

In the formulation of the model all crop produce are permitted to be sold. It is assumed that the minimum family grain consumption requirements will be satisfied before any selling activities are undertaken. Table 5.2 and 5.3 columns A_{12} to A_{19} indicate the crop selling acitivies. The activity unit is one kilogramme (1Kg). The prices used are those prevailing in the local market during the survey period and after.

5.3.5.6 Resource Constraints

Farming in the study area is carried out under a number of constraints and restrictions. These restrictions, which include availability of land, family labour, hired labour, oxen power, operating capital, yield (output) and consumption requirements and non-negativity of activity levels are outlined as rows in Table 5.2 and 5.3. They are described below.

Land

Two soil types prevail on sample farms. Sandy loam designated as red soil and clay loam designated as black soil. However, there is no clear evidence in the collected data of any published secondary materials in the area to prove that certain crops are grown on particular soil types. As a result, the model permits all crops to be cultivated in both red and black soils and therefore, there is only one land constraints in the model. The amount of land available for cultivation by the representative farming systems was about 1.90 and 2.10 hectares. The row unit is hectares.

Family labour

Family labour is the most essential resource next to land. All labour of farm household persons who perform farm activities was included. The type of activities performed in crop production were mainly ploughing, planting, weeding harvesting and threshing.

In the model used, the family labour constraint is specified on the basis of these operational activities. There is one family labour constraint for each labour period. The row unit is in man hours.

Animal power

Oxen labour provides the main source of animal power in the study areas. They are used for ploughing, planting and threshing operations. In the model one constraint for each of the operations is specified

Hired labour

Setting the appropriate value for hired labour is different from designing the constraint level for other types of family resources. Land, family labour and available capital are determined by what is known about the farm under study. The amount of hired labour available and the rate at which it will be hired are determined outside the farm and requires information not available from survey data of the type collected in this study. Therefore, it is necessary to make assumptions based on what is considered realistic for the area being studied. Existing government policy in the Ethiopian highlands prohibits hired labour, hence it is to be expected that labour available for hiring will be extremely limited in critical periods, especially during weeding and harvesting. Previous experience of the author indicates that 300 man hours per year hired to a single farm seems to be a realistic assumptiom. The model allows farmers to hire up to this level during weeding, harvesting and threshing periods. It is assumed that both sexes are available for labour hire.

Working Capital

Major problems in the specification of operating capital constraints in a linear programming matrix is the difficulty in obtaining relevant data on the amount of operating capital available for the farming activities. Theoretically, working capital is available to the sample farmers from seasonal carryover and from institutional and other traditional sources.

In the study area money is borrowed from friends and neighbours at very high interest rates, sometimes reaching 100% per annum. ARDU and EPID also supply in the form of credit, improved wheat and teff seeds and fertilizer. However, in this study due to lack of sufficient data, we have used reported cash at hand and production expenses of the individual households as a proxy for the amount of operating capital. The amount of funds available for cash expenses on the representative farming sytems was set equal to the amount estimated to have been spent on seeds, fertilizer, hired labour for the 1979/80 crop year.

Borrowed capital is limited to farm operating expenses related to improved seeds and fertilizer given by ARDU/EPID at a 10% institutional interest rate.

Consumption Constraints

Consumption constraints are incorporated into the model to force the production of minimum amounts of crops for family consumption. The required amounts were derived from the results of secondary consumption study undertaken in the study areas. The amounts are defined and discussed under consumption activities.

Other restrictions

Separate inventory rows are specified in the model for the output (yield) of wheat, barley, teff, maize, sorghum, horsebeans, peas, chickpeas, lentils and flax.

Non-negative restrictions

None of the activities included in the model can be operated at negative levels.

5.3.6 Estimation of Coefficients

Technical coefficients are estimated for all activities. The coefficients are based on averages from field observation of the representative farming system.

The Family Labour and Oxen Input

The family labour utilized in production was computed using the weights presented in Chapter II. The requirement was estimated for each crop for ploughing, planting, weeding, harvesting and threshing operations.

The average oxen labour input was calculated on the assumption that the farmers plough with one pair of oxen. Theoretically, the oxen labour input for cultivation should be more or less equal to double human labour but in the case of threshing this can surpass the human labour. Farmers sometimes use 1 or more oxen for this type of work.

Seed and fertilizer input

In general, farmers in the study area save seeds from the previous years harvest for planting in the next season. However, where this is not possible, the usual source of seed would be the market place or other farmers. With the exception of wheat and teff crops, all farmers plant local varieties and often the seed contains many weeds. Improved seeds of wheat and teff and their fertilizers packages are purchased on credit from ARDU and EPID.

The survey data produced the amounts of seed and fertilizer used for each farm by crop. Per hectare seed and fertilizer was then computed for each farm. The average amount of seed and fertilizer per hectare used in the model is given in Table 5.6.

Table 5.6. Average seed and fertilizer input in the Ethiopian highlands (Kg/ha).

	Farming Systems			
	A		B	
Crop	Seed	Fertilizer	Seed	Fertilizer
Wheat	136	85	95	79
Barley	146	-	115	-
Teff	36	66	48	87
Maize	40	-	-	-
Sorghum	10	-	-	-
Beans	203	-	137	-
Peas	118	-	110	-
Chickpeas	-	-	65	-
Lentils	-		13	
Flax	29		37	-

Source: Computed from the Survey Data.

Output Coefficients

To estimate the yield of crop per hectare in the study area in each crop, the yield data on the farm growing the crop were aggregated and then the average yield was computed by dividing by the number of observations.

Consumption Coefficients

In Ethiopia consumption surveys have been undertaken in the study areas on many occasions in the past, but not for all the sample farms in 1979/80. For example, 1974/76 much consumption data was collected but abandoned by the author because of its heavy demand on time during processing and validation of the data. At the very least, a minimum of 5 months may be required for processing the weekly data. Other surveys which are published have been collected by HSIU (1974), CADU (1972, 1973, 1976), IAR (1979), ILCA (1983), Mela (1985).

In this study, to arrive to the total consumption of the representative households, the average data of the IAR and ILCA & Mela surveys have been used (Table 5.7). Selection of the two are due to familiarity with the procedure of the survey and conviction that the data collected was of a better standard than that collected by CSO in Ethiopia. In the course of analysis, others have been tested also to validate the model with the reality of the farming systems.

5.3.7 Output Price Coefficients

Crop prices used in the models and parameters are based on three years average producer prices collected for the purpose of project evaluation by ARDU for 1979/80 - 1982/83. Therefore, the

Table 5.7 Amount of crop consumed by the farmers in the Ethiopian highlands

	Farming Systems	
Crop	A	B
Wheat	199	210
Barley	260	312a
Teff	207	387
Maize	183	-
Sorghum	81	-
Horsebeans	200	231a
Peas	38	51
Chickpeas	-	40b
Lentiles		38
Flax	3	4

Source: 1. IAR (1979) Unpublished initial Farm Management Survey
2. ILCA unpublished consumption data
a. Mela (1985) opcit, p.82
b. Leithmann-Fruh,G.A (1983) opcit.

Table 5.8 Average crop price in the Ethiopian highlands 1979/80 - 1982/83

Crop	Price per kilogram
Wheat	0.52
Barley	0.34
Teff	0.59
Maize	0.33
Sorghum	0.35
Beans	0.36
Peas	0.52
Chickpeas	0.37
Lentils	0.63
Flax	0.58

Source: ARDU (1982) Cost of production of major crops and grain selling prices. Planning, Evaluation and Budget section. Assela. ARDU. Publication No. 20, p. 22.

5.3.8. Estimation of Resource Constraints

Land

To estimate the cultivated land in the survey areas in the period of investigation, sufficient secondary sources were available which could validate the accuracy of the present survey estimation. In farming system A, Bengstsson (1980) and ARDU (1980) found 2.2 and 1.99 hectares respectively. ILCA (1983), the Ethiopian Science and Technology Commission (1979) and Awole (1983) survey suggested 2.50, 2.56 and 1.93 hectares in farming system B. The survey of the present sample farm also suggests a similar pattern of 1.90 and 2.1 hectares for farming system A and B respectively. The availability of land for farming in the area, therefore, shows little variation between the two farming systems. However, analysis of the distribution of farms indicate some variation among farmers. The variation among farm households was attributed to agrarian reform criteria. Families large in number and with an influential political position in the community were able to receive more land than the average farms. The total land available for cultivation varies between 0.50 hectares and 6 hectares.

In the model, therefore, the average crop area of the sample farm is taken to be 1.90 and 2.1 hectares in the two farming systems.

Labour availability

The importance of labour availability in peasant agriculture has been stressed in the agrarian development literature (Collinson 1972; Upton 1973; Clayton, 1983). It has been noted by Clayton (1963) that farm plans in general should relate labour needs to its availability. If labour needs exceed the labour available, a farm may prove unworkable. Whereas, if labour requirements fall short of that available , it may mean lost opportunities for increased income (Clayton, 1963). It is however, pertinent to classify labour, in terms of labour supply period and to express different types of labour with common denominators if direct comparisons of its availability are to be made.

Labour supply

Labour supply for the farm is characterized by seasonal requirements. The first task in such a situation is the question of how to divide the year with appropriate planning periods. In the early days of linear programming, it was common to divide the year into 12 calendar months, but it is now generally accepted that this is not necessarily the most satisfactory method of division (Nix, 1979). It must be admitted that any division of the farming year is not without its problems, for farm jobs cannot always be neatly allocated to separate seasonal periods. One job tends to overlap another, some tasks spreading over several months and others lasting only a few days. Nevertheless broad seasonal division are generally reasonably easy to specify if the divisions are fairly broad, as can be seen in a later discussion.

In this study, the seasonality of the field work required a classification of the working periods for labour on the basis of seasonal operations , crop activities, namely: ploughing, planting, weeding, harvesting and threshing. The farm labour is comprised of family labour for each household. Therefore, the capacity of labour supply depends on the availabile days for field work, family structure and religious practices of the household members, to work on the fields.

To determine the working periods of the model, statistical analysis of the sample data provides the frequency distribution of sample farms by the week in which a certain activity starts and finishes. The first week of the year is assu med to start on January 1st, with 52 weeks in the total year. The week in which the majority of the farmers started and finished a particular operation are taken as the starting and finishing week in the model.

Experience of previous studies (Sisay, 1980; IAR, 1979) suggests that the seasonal operational periods shown in Table 5.9 provides a suitable basis on which with a little modification, most farm circumstances in the Ethiopian highlands can be modelled.

One important feature of the table is the approach used to solve overlapping problems of labour periods. This approach of taking the data when the majority of the farmers starts and finishes operations allows some element of flexibility in plannng labour, particularly when information is available on an operations basis.

Table 5.9 Starting and finishing week of farm operations by the majority of sample farmers in the Ethiopian highlands

Period	Seasonal farm operation	Starting week	Finishing week	Approx. dates	Work days observed
I	Ploughing	5	22	Feb - May 31	120
II	Planting	23	32	June 1 - Aug 11	72
III	Weeding	33	42	Aug 12 - Oct 20	70
IV	Harvesting	43	48	Oct 21 - Nov 30	41
IV	Threshing	49	3	Dec 1 - Jan 30	62
					365

Source: Compiled from the survey data.

So far the question of introducing the necessary flexibility into labour requirements in the model have been discussed, but of course, the supply of labour on a farm at any time of year depends on the total number of days to each working period. In theory, the total working days observed in each period is 365. However, in the Ethiopian context it should be emphasized that the total number of days in each working period is not the total number of field days. The productivity of Ethiopian farmers as observed by many studies, CADU (1973); HSIU (1974); IAR (1979) is severely limited by the number of religious holidays to be observed. Almost all the farmers interviewed were Coptic Christians. The sample farmers designated certain days of each month as holidays for particular saints. For example the 5th, 12th 19th, 21st and 23rd of the calendar date of each month are set aside as religious holidays for Trinity, St. Michael, St. Gabriel, St. Mary and St. George respecively. On these days, and on Saturday afternoon and Sundays, they do not work. One member of the farm household - often the housewife - attends the local market once a week. Furthermore, during ploughing, planting and weeding periods, rainy days disrupt the field work.

Another point regarding religious holidays concerns annual feast days, such as St. John (early September), Christmas (early January), Epiphany (mid January), St. Michael (mid January), Good Friday (late April), Easter Monday (early May) and Assumption Day (late August). On these feast days, farmers also abstain from major farm activities such as ploughing, cutting crops and weeding work.

In addition to the observance of holidays dedicated to the saints, there are some other social activities which take up the farmers time. A funeral service is among the social activities that were noted during the study period. An average of 8 man-days were estimated for social activities (ESTC, 1979; HSIU, 1974).

In this study consideration was given to above non-working days in calculation of the actual days for farm work. These non-working days were deducted from the total number of days available in each working period. Table 5.10 shows the number of days available for field work.

Table 5.10 The number of days available for field work in the Ethiopian highlands

Period for work	Farm operation	Total Number of days	Non working days	Number of days actual field
I	Ploughing	120	50	70
II	Planting	72	27	45
III	Weeding	70	36	34
IV	Harvesting	41	18	23
V	Threshing	62	17	45
		365	148	216

To arrive at labour available available for crop production, a farm family has been further classified into four categories: adult man, adult woman, school children (who would be available for part-time work) and other children as noted in Chapter III. Table 5.11 shows a typical family structure of the sample farmers in the survey area.

Table 5.11. Average family structure

	Farming Systems	
	A	B
Size of family	5.4	4.9
Total number of dependents	4.4	3.9
Numbe of adult male dependents	0.5	0.4
Number of adult female dependents	1.1	1.0
School children	0.84	1.0
Number of other children	1.96	1.50

Source: Compiled from the survey data

As noted in chapter II, children below 15 years herd livestock and are therefore not available for field work. Also, the children who attend school are unavailable for field work except occasionally. Therefore, the typical family in the survey could be described as having a full-time adult male performing all activities and an adult female weeding, harvesting and threshing. Thus, the labour supply depends predominantly on the farmer, his wife and occasionally other adult males in the family.

The average daily working time of men and women varies since a large proportion of female members' time is spent on household activities such as cleaning animal stalls, fetching water and firewood, caring for small children and preparing food. The wife joins the field work late in the mornings and departs earlier in the afternoon than her husband. Research in the area indicates that the daily average time worked by a man is about 7 hours and about 4 hours by women (ILCA, 1983).

During season labour peaks the sample farmers in B engaged in labour hiring , despite prohibition by law. On average, 130 man hours are available for harvesting. Table 5.12 shows the adult labour available by sample farms for each period. The potential labour available by sample farms are shown in Table 5.13

Table 5.12 Adult labour available by sample farms for each period

		Farming Systems							
		A				B			
Period	Operation	Adult Male	Adult Female	Adult School children	Total	Adult Male	Adult Female	Adult School children	Total
I	Ploughing	1.5	-	-	1.5	1.4	-	-	1.4
II	Planting	1.5	-	-	1.5	1.4	-	-	1.4
III	Weeding	1.5	1.1	-	2.8	1.4	1.0	0.2	2.4
IV	Harvesting	1.5	1.1	-	2.6	1.4	1.0	0.7	3.1
V	Threshing	1.5	1.1	-	2.6	1.4	1.0	-	2.4

Table 5.13 Potential labour and adult man-hours available in the study area.

		Farming Systems							
		A				B			
Period	Operation	Adult Male	Adult Female	Adult School children & others	Total	Adult Male	Adult Female	Adult School children &(others)	Total
I	Ploughing	735	-	-	735	686	-	-	686
II	Planting	472	-	-	472	441	-	-	441
III	Weeding	357	112	-	469	333	102	39	474
IV	Harvesting	241	75	-	316	225	69	120(130)	544
V	Threshing	472	148	-	620	441	135	-	576
	Total	2127	305	-	2612	2010	273	159	2721

In the model therefore, it is assumed that a total of 2612 and 2721 hours of labour is available for typical households in farm sytems A and B respectively. This estimated labour capacity observed for the study area is reasonably close to an earlier study by Sisay (1980:84), which had estimated 2440 man hours for the study areas.

Oxen Labour Supply

Oxen labour forms the main sources of the animal power in the two farming systems. The average sample farmer owned a pair of oxen.

No data was available on actual observations of the oxen labour supply. To estimate the working capacity of a pair of oxen, the number of working days available in each crop for ploughing, planting and threshing that require the services of oxen, has been doubled. This was then multiplied by the number of hours spent by an average sample farmer in each working day.

Threshing required more oxen and the use of other stock. It was assumed that it is possible for the farmer to get the service of additional oxen on an exchange basis or use other cattle for this purpose. Again, no allowance is made for illness or for mortality in the estimates due to lack of data.

Capital Assets

In peasant agriculture, the amount of capital and the proportion of income invested are usually low (Upton 1973; Clayton 1983). In the study areas the farm households' main capital assets consists of land, livestock, farm tools and equipment, household furniture, housing and cash. The average cash money reported by the sample farmers were 50 and 61 Birr in farming systems A and B respectively. Owing to the political climate discussed in Chapter II, land cannot be considered as an individual asset since farmers only have using rights.

The study area is well known for the cereals it produces. (HSIU, 1974; ILCA, 1983; Bengtsson, 1983). Livestock cannot compete favourably with cereals for the use of land. However, the few livestock (Table 5.14) that are found in the area are kept as a supplementary enterprise except the draft animal, oxen and donkeys.

Table 5.14 Average number and values of livestock owned by sample farmers, Ethiopian highlands

	Farming Systems			
	A		B	
Livestock	Number	Value (Birr)	Number	Value (Birr)
Oxen	2.70	831.60	2.10	646.80
Cows	3.00	687.00	0.70	160.30
Other cattle	3.70	995.30	2.00	538.10
Sheep	3.70	173.90	3.00	141.00
Goats	0.30	9.30	0.20	6.20
Poultry	4.00	16.00	3.00	12.00
Horses	0.80	87.20	0.09	9.81
Donkeys	1.20	82.80	0.90	69.00
Mules	0.10	17.50	0.03	5.25
Total		2900.60		1581.36

Sources: Compiled from the survey data. Price used is based on ILCA FMS Survey (ILCA 1983: 20).

Reliable data on other capital assets are also lacking. Therefore, the model does not take the capital assets into consideration. Instead, the average available cash at hand and expenditure by the sample farmer is used as the operating capital capacity of the farm household in the model.

5.9 Some limitations of the Model

The description that has just been presented does not exhaust the list of activities and restrictions that could possible be included in a linear programming model of smallholder agriculture. For example, livestock activities or off-farm activities could be added in the basic model. The number of activities depends on the objective of the study and availability of data. The emphasis of the study is on crop production. Even here, it is important to note that the size and complexity of planning model may have an important influence on its usefulness. Large and complex models are costly to develop in terms of both time and money. It is not always certain that the benefits to be derived from using a more sophisticated model in terms of greater precision of the planning decisions derived from it, are sufficient to justify the costs. Also, as one tries to build more realism into the model by increasing the number of activities and restrictions, (eg. labour activities by week) one risks making the model so complicated that it is impossible to trace the logical connections between a change in an instrument variable and resulting change in production. If it is known from survey experience that labour is constraining only at peak periods (as is the case in Ethiopia) there is no reason to use with a big matrix.

Hardaker (1971) has advised that planning models should be kept simple in the first place but if the results prove to be unsatisfactory in practical terms, more refinements can then be considered. This advice and the nature of the data available to the author dictated the philosophy underlying the approach to model formulation in this study.

This chapter has presented a detailed description of the components of the LP models to be employed in this study. The basic models of the farming systems were completed. The results of the various applications of the model are discussed in the Chapters that follow.

CHAPTER VI

EXISTING TECHNOLOGY AND PRODUCTION POSSBILITIES

6.1 INTRODUCTION

This chapter is devoted to exploring production possibilities under existing farming systems in the Ethiopian highlands. First, theoretical arguments for output increasing strategy in traditional agriculture are pointed out. Secondly, the features of the optimum solution, farm factor and product allocation, including a comparison of the programmed farms and actual farm performance are examined. Thirdly, the constraints which inhibit agricultural production are identified. Fourthly, the effects of relaxing some of the identified constraints on farm and resource productivity are assessed

6.2. Output Increasing Strategy in Traditional Agriculture

The ability of agriculture to contribute directly to economic growth and to the welfare of farm families is dependent on the level of farm income and the resultant surpluses in the agricultural sector. The level of farm income, besides being the principal determinant of welfare of farm families, thus emerges as one of the important factors that condition economic growth.

Other things being equal, the level of farm incomes is determined largely by the efficiency with which farmers are able to utilize the resources at their command by allocating them amongst alternative production activities. If farmers are inefficient in the use of their scarce resources, there certainly exists an unexploited potential for increasing farm income and generating surpluses which can serve as an inexpensive source of economic growth. If, on the other hand, they are extremely efficient in the allocation of their resources among alternative production activities, additional contribution from agriculture can come only through the introduction of new technologies. Resource use efficiency on farms in traditional agriculture thus becomes an important issue in determining the existing opportunities in agriculture for economic growth and welfare of the farm families.

The present chapter is an exploration into resource use efficiency of farmers in the Ethiopian highlands and attempts to determine the potential increases in farm income through a re-allocation of the factors of production presently at the disposal of farmers. Insufficent knowledge about resource use efficiency in Ethiopian agriculture presently exists.

Schultz(1964) advanced the hypothesis that the agricultural sector in many developing countries is relatively efficient in using factors of production at its disposal. However, in other studies carried out in LDC to test this hypothesis, these remain controversial. A number of empirical studies of input and enterprise combinations support the views that farmers could increase their output if they would combine resources somewhat differently (Desai, 1961; Amerosinghe, 1974; Jaime, 1983).

Others support the view that farmers allocate different farm inputs (land, labour, animal power, fertilizer etc.) to alternative products in such a way that their marginal productivity is approximately equal in each case. (Hopper, 1965, Chenuareddy, 1967; Yotopoulos, 1967; Yotopoulos and Nugent, 1976). No studies of this nature have been undertaken in Ethiopia.

In the face of conflicting views and evidence, and given that this is a crucial policy issue, there is clearly the need for further exploration into resource use efficiency in LDC. In this study the hypothesis that it is possible to increase farm income through reallocation of existing resources is postulated in the context of Ethiopia. As argued in Chapter I, Ethiopian agriculture is undergoing a transformation and it is poised to break through the vicious circles constraining traditional agriculture through recent introduction of new technological packages. In such a changing economy, maladjustment in resource allocation may be found. In fact, the investigation in previous studies in the Arssi region of Ethiopia indicates inefficiency of the resource use on the average farm. These inefficiencies arise mainly because of lags in adjusting to the changing resource structure and their new allocative opportunities which do not fit into the experience of farmers (Sisay, 1980).

Before proceeding to the analysis of resource allocation, the factors of the optimum solutions will be examined first. This will give an insight into the resource use pattern in the study areas.

6.3. The Basic Model and Production Possibilities

6.3.1. Features of the Optimal Solutions

Since peasant farms are diversifed, first of all it is important to know how closely the model solution reflects the actual observed cropping pattern before examining efficiency of resource use in the farming systems. The earliest version of the model had no minimum consumption restraints in the matrix. The solution to the model showed all land devoted to barley and wheat in farming Systems A and teff and peas in B, with an income of 1141.39 and 1081.10 Birr respectively. Other crops which were actually grown by the sample farm households were excluded from the solution. This first result reflected the behaviour of commercial farmers producing crops for market and was, therefore, unrealistic for small farmers who grow all the crops for home consumption. The above procedure provides results which are inconsistent with actual observations. However, in extending the analysis by introducing minimum household consumption for each crop, as discussed in previous chapters on the objective function of peasant farmers, the programming model gives the solutions that are consistent with current farming practices in so far as the number of farm enterprises in the model are concerned. A barley, teff and wheat dominated farming system, with other minor crops, emerges in the optimal plan.

The most striking features of the solution is the selection for sale of all important crops for which urban dwellers have a strong commercial demand. This is due to the fact that the others require large quantities of resources upon a relatively low net income per hectare.

Linear programming, however, is an exercise in normative economics, indicating those activities which the entrepreneur ought to undertake in order to maximize his income, given specified constraints (Clayton, 1965; Barlow et al, 1983). The fact that other crops are not produced for sale in the solution means that they are not competitive enough in the income maximizing plans. Thus, with the present level of technology and relative farm prices and yields, the potential income of farmers will increase if they grow barley/wheat and teff/peas for sale and other crops for consumption requirements only.

Economic models are recognised as a simplification of the real world. Yet they are expected to capture the significant operating characteristics of the sector under study and thus are often subjected to a "realism" test. This realism test of assumption is a formal validation which is an important aspect of farm analysis based on survey data (Webster, 1972). A model can not be expected to meet all tests of realism, but the analyst does have considerable freedom in the construction of a model to ensure that the relevant tests are met. Two important tests seem to validate the results of the models in this study. The fact that the number of enterprises obtained in the solutions conforms to the existing number of enterprises per typical farm household is worth noting. Also, the actual cultivated areas and the average net revenues per farming system do not differ much from the maximum values of net revenues obtained from the intitial solutions (Table 6.1). From the point of view of validating the models it is therefore reassuring to see the correspondence between the existing and the model results.

6.3.2 Comparison Between Programmed and Actual Farms.

In previous studies it has been noted that blame for economic underdevelopment and poor performance in the agricultural sectors of LDC's is sometimes laid at the door of small farmers. In Ethiopia, however, the evidence does not substantiate the usual criticisms. It has been argued in Chapter I and III that Ethiopian peasants are responsive to economic stimuli and many of the failures in the agricultural sector lie at the door of policy makers. How far progress can be made in the direction of development through re-allocation of the existing resources, is an issue that requires investigation. To answer this issue, a comparison will be made of performance of the actual farm and normative models in terms of farm income and the farming system disclosed in the programmed model. The difference between the two plans will then be used to indicate the level of allocative efficiency in the study areas.

The two farm objective functions considered as defined earlier are: 1)when the farmer is assumed to only maximize net return and 2) when the farmer is assumed to maximize net return after fulfilling some minimum household consumption. The solution to the model under the first objective of sole maximization of farm income showed that all land is devoted only to barley and wheat in farming systems A and teff and peas in B, with an income increase of 135 and 291 percent respectively. This result indicate that there is a considerable gap between actual and optimal farm plans on the average farms in the study areas. Farmers can increase their income and resource productivity if they allocate their resources optimally, even with the given level of resources and state of technology. This findings of the prevalence of inefficience of resource use is contrary to the Schultzian notion of economic efficiency, which implies that no production factors remain unemployed(Schultz,1964).

However, this analysis assumes that the farm is a pure firm. In reality as observed, they include farm business and household activtes in combination. As discussed in the previous section, this result may depict the goal of a more commercially minded farmer who has access to adequate level of capital. In Ethiopia, given that the farmers grows the crops mainly for consumption purposes, the above result, therefore, is not realistic in depicting the farmers production behaviour. In this regard an extension of the analysis by introducing minimum household consumption under farmers dual objective function of household consumption insurance and net income maximization shows an interesting insights.

In Table 6.2 the net revenue obtained in the normative farm plans and the actual survey data are given. In the model, as noted previously, the farm household follows a cash maximizing strategy subject to th production of minimum farm household consumption. The cash surplus generated by the model is about 523.70 Birr and 308.47 Birr respectively in the two farm solutions. In comparison to the existing level the optimal solutions show that the financial advantage of generating the programmed plan is about 7.87% and 11.47% increase in farming System A and B respectively, Which shows that few opportunities exist for simple resource re-allocation.

Table 6.1 Comparison of actual and optimal activity levels, optimal resource use, net farm income under existing technology.

Activity Units	Farming Systems and Activity levels			
	A		B	
	Actual	Optimum	Actual	Optimum
Crop Production (ha)				
Wheat	0.54	0.59	0.19	0.25
Barley	0.70	0.68	0.49	0.38
Teff	0.21	0.19	0.90	1.03
Maize	0.12	0.10	-	-
Sorghum	0.05	0.08	-	-
Horsebeans	0.17	0.20	0.27	0.20
Field peas	0.08	0.05	0.13	0.10
Chickpeas	-	-	0.11	0.06
Lentils	-	-	0.04	0.07
Flax	0.03	0.01	0.05	0.01
Crop Sales (Kg)				
Wheat		921.85		
Barley		699.34		-
Teff				774.64
Peas		-		48.66
Net income (Birr)	485.47	523.70	276.75	308.47

Resources	A Used	A Unused	A MVP	B Used	B Unused	B MVP
Land (ha)	1.90	-	12.64	2.10	-	416.90
Family labour (hr)						
Ploughing	259.22	475.78	-	329.69	356.31	-
Planting	89.91	382.49	-	91.56	349.44	-
Weeding	326.82	142.18	-	474.00	-	0.49
Harvesting	316.00	-	4.07	539.49	4.51	-
Threshing	132.10	336.84	-	154.17	280.83	-
Total Labour	1124.05	1336.95		1588.91	991.09	
Oxen Labour						
Ploughing	519.00	461.62	-	517.00	463.01	-
Planting	168.02	461.98	-	139.00	491.00	-
Threshing	324.68	151.32	-	372.88	24.12	-

Table 6.2 Annual farm income at the existing level and the normative plan (Birr).

Farming Systems	Existing level	Optimal solution	Change over existing level	% change
A	485.47	523.70	38.23	7.87
B	276.75	308.47	31.72	11.47

A similar comparison can be made between the farming systems disclosed by the programmed models and those of the surveyed farms. Again the difference is not acute (Table 6.3). In the farming systems over 85% of the crops are of both actual and programmed. Plan A is planted with cereal crops dominated by barley and wheat and at least over 12% with pulses and the rest with other crops. A similar position is found between the actual and programmed model in farming System B. Over 71% of the area is planted with cereals and the rest with pulses. Therefore, owing to the similarity of the cropping pattern, the level of resource allocation and the limited effect of marginal change in product mix, which can be seen in the following discussions, agriculture in the Ethiopian highlands appears to be approaching a state of equilibrium, albeit a low level one. The implication of the finding of this result is of significance to research planners and policy makers in Ethiopia as it sheds light on the possibilities that exist for maximization of returns from smallholder agriculture. It suggests that agricultural development which attempts to increase output on farms, needs to relax existing constraints on the farmers through the introduction of technological change. In the discussion which follows, an attempt will be made to identify the binding constraints in the farming systems.

Table 6.3. Comparison of programmed and actual farming systems for the study areas (% areas).

	Farming Systems			
	A		B	
Crop	Survey data	Programmed model	Survey data	Programmed model
Wheat	28.42	31.05	9.52	11.90
Barley	36.85	35.79	19.05	18.10
Teff	11.05	10.00	42.86	49.05
Maize	6.31	5.26	-	-
Sorghum	2.63	4.21	-	-
H. Beans	8.95	10.13	12.86	9.52
Peas	4.21	2.63	6.19	4.76
Chickpeas	-	-	5.24	2.86
Lentils	-	-	1.90	3.33
Flax	1.58	0.53	2.38	0.48

Source: Computed from Table 6.1

6.3.3 Binding Constraints and Policy Alternatives

One of the advantages of the linear programming procedure is that the dual solution to the primal provides the shadow prices or the marginal value products of resources - which indicates the binding constraints in the farming system (Kinsey, 1979). However, the interpretation of the shadow prices on the disposal activities of LP is not consistent with the exact definition of the marginal value products (Kinsey,1979) . The marginal value product of a resource is defined as the increase in the value of total output that is obtained from the use of an additional unit of the resource with all other inputs held constant. This latter condition is not met in the linear programming coefficients for the activities are defined in fixed ratios one to another. Thus increa se in the use of one input requires and increase in another. Despite this, the shadow prices of the desposal activities are operationally useful because they provide information concerning resources that could best be expanded to increase income. The behaviour of the MVP from LP for futher additions of the resources may be erratic due to corner solutions in LP. That is, the solution holds for a specific range until other resources become limiting, at which point another enterprise becomes optimal.

The marginal value products in LP therefore, indicate the amount by which the total gross margin of the farm would be increased by utilising an additional unit of resources. This represents the gains in income which are possible through the acquisition of scarce resources. The MVP's are zero for excess (slack) resources and are positive for limiting or constraining resourves. A relatively high MVP indicates scarcity of the resource. The more limiting the resource, the higher the MVP. On the basis of this theoretical argument, the scarcity of values of the resource shown in Table 6.1, offer in this regard, an important insight to which alternative policies and technological change could most profitably be directed. Indeed, the systematic elimination of these resource "bottlenecks" can become the basis of an approach to the whole problem of low productivity and technology diffusion. In Ethiopian farming systems production is constrained by land, harvesting and weeding labour. All available land is completely utilized but the shadow price of additional land is low in the case of farming Systems A and somewhat high in the case of B. The MVP's of land are the increase in total cash surplus which would be secured through addition to this resource. Thus for farming System A, additional land would enable an extra surplus to be earned at a rate of 12.64 Birr per hectare and 416.90 Birr per hectare to be earned for B. These marginal value product increases are subject to constraints in the complementary resource labour in peak periods. In System B, weeding labour is found to be scarce having an MVP of 0.49 Birr per hour, with scarcity value equal to its prevailing wage rate of 0.50 Birr per hour paid for farm seasonal labour in the study areas. Of greater significance are the scarcity values for harvesting labour in farming System A (MVP of 4.07) and an MVP of land 416.9 Birr in B. Their magnitude confirms the importance of land in farm B and harvesting labour in A. For the two farming systems, the scarcity values of harvesting labour and land are positive, with a strong tendency for farm income to increase as the two constraints are relaxed (see appendix B, Sensitivity Analysis). From this base it can be argued that had the harvesting constraints that are demonstrated clearly by this model been fully understood by agricultural planners in the early 1970's, the rapid increase in the combine thresher and harvester that ultimately occurred in the mid 70's might have been accelerated.

Table 6.1 suggests other ways in which the dual portion of the optimal solution might provide a basis for developing technology policy and research strategy. Traditionally, the ability to alter harvesting problems and, occasionally, weeding problems in the Ethiopian highlands, relied heavily on family labour, exchange labour and hired labour. However, with the "bottleneck" in respect to hired labour unable to be solved due to the rigid national policy which prohibits the use of hired labour, it is clear where the next series of bottlenecks will arise. In some cases this means that policy makers need to relax the disincentive policy and/or use combine threshers and harvesters. In other cases this means the plant breeders will be called upon to select varieties which can be planted later or harvested earlier, so that an additional crop can be squeezed into the rotation. Widespread introduction and adoption of techniques that alter the traditional planting and harvesting dates of certain key crops would permit farmers to relax existing constraints. In all cases, the model suggests a careful examination of alternatives by which the labour constraints in peak periods could be alleviated.

6.3.4 Production Possibilities Through Relaxing Existing Constraints Land and Labour

The programme results given so far in this chapter have been based on the average level of labour and land resources available from the farm survey discussed in Chapter IV. However, as noted above, these two resources limit the potential of increasing farm income. Any further increases in farm production requires the relaxation of these constraints. In order to assess the policy implications of additional land and labour availability constraints at peak periods, the parameters of these two resources are varied. Parametric programming is used to see the effects of change in these two key variables.

6.3.4.1 Hired labour

Farmers in the study area in particular, and Ethiopian farmers in general, often used hired labour for agricultural production. This used to be common, especially during weeding and harvesting operations, until it was prohibited by the government in 1975 (PMA, 1975). Previous knowledge of the labour market suggests that there was a regular market for seasonal labour to the level of 300 man hours in the study areas during this critical period(HSIU, 1974). Generally, those who wanted labourers did not have difficulty in finding them. It is therefore of interest to examine the effects of hired labour availability in addition to family labour on farm income and resource productivity. These results are summarized in Table 6.4

The effects of hired labour availability and relaxation of existing labour policy consistently increases farm incomes and the amount of land cultivated on the two farming systems. The magnitude of income and farm size increase are respectively 134%, 113% on farming System A and 20% and 8% on farming System B. Resource productivity measured in terms of net return per unit of land and labour also shows consistent increases in farm housholds used hired labour during the two critical periods, as shown in the table. The shadow prices or MVP of land are zero for all farms as a result of increased hired labour availability. This decrease occurs because land is not limited like harvesting and weeding labour are in the production process of crops.

Table 6.4 Changes in farm income and resource productivity when hired casual labour is available during critical periods (Unlimited capital).

	Farming Systems					
	A			B		
	Without hired labour	With hired labour	% change	Without hired labour	With hired labour	% change
Amounts of land cultivated (ha)	1.90	4.04	112.63	2.10	2.26	7.62
Total labour used (hrs)	1124	1569	47.62	1589	1377	-13.34
Net farm income (Birr)	523.70	1227.90	134.47	308.47	370.05	19.96
Net return per ha (Birr)	275.63	303.94				
MVP of land	12.64	0	-	416.90	0	
MVP of weeding labour	0	2.05	-	0.45		
MVP of harvesting labour	4.07	1.57	-	0	2.46	
MVP of oxen ploughing	0	0	-	0	0.58	
MVP of hired harvesting labour	0	1.57	-	0	1.90	

Any further increases in MVP requires more hired labour.

To summarize then, the results suggest then that profitability has been adversely affected by the difficulty in finding labour due to restrictive government policy. If government policy were relaxed, it would be possible for farmers to increase their farm income and productivity, even under existing farming systems.

6.3.4.2 Effects of Simultaneous Changes in Land and Labour Availability

In principle, land is extremely unlikely to be a limiting resource to production on household farms. After 1975, the allotment of land to individual farmers up to a maximum of 10 hectares by the land nationalization decree of March 1975, removed this hindrance (PMA, 1975). It also cleared the path for increasing agricultural productivity, farm income and thereby alleviating rural poverty in Ethiopia. But the productive potential of the small farm sector is not being adequately promoted. The economic promise of the land reform is largely unfulfilled due to government emphasis on state farm and co-operative sectors (Cohen, 1984). As a result of the expansion of the state farms in many areas, resettlement of farm households from other parts of Ethiopia and population increases, the farm size of the sample has been drastically reduced to the current level. In order to assess the policy implications of land availability constraint, the land resource parameters are varied for each farming system. Simultaneously with 0.5 and 1.0 units of additional labour, it must be remembered that a labour unit corresponds to an adult man hour equivalent to a young and healthy adult. The result of the effect of different types of policy instruments, that is, change in land resource and family labour are preserved in Table 6.5.

The initial values of the dependent variables are shown at the top of the table and the effects of each policy instrument are given in terms of values that can be attained with variation of land resources.

Table 6.5 Effects of simultaneous changes in land and family labour on farm income

Level of constraints	Farming System A: Level of resource use (ha)	Net farm income (Birr)	MVP of land (Birr)	MVP of harvesting labour (Birr)	MVP of oxen ploughing labour	Farming System B: Level of resource use	Net farm income	MVP of Land	MVP of harvesting labour	MVP of oxen ploughing labour
Initials	1.90	523.70	12.64	4.07	0	2.10	308.47	416.90	0	0.49
Policy alternatives I										
Farm size + 0.5 units of labour increase										
1.0	1.90	577.21	628.48	0	0	2.10	314.08	556.54	0	0
2.0	2.50	954.30	628.48	0	0	2.50	526.39	373.72	0.54	0
3.0	3.00	1173.83	59.94	3.67	0	3.00	713.25	373.72	0.54	0
4.0	3.20	1182.93	0	4.17	0	4.00	1086.97	373.72	0.54	0
5.0	3.20	1182.93	0	4.17	0	4.13	1137.04	0	3.37	0
6.0	3.20	1182.93	0	4.17	0	4.13	1137.04	0	3.37	0
7.0	3.20	1182.93	0	4.17	0	4.13	1137.04	0	3.37	0
% Change	68.00	126.00	0		0	96.67	262.10			
Policy alternatives II:										
Farm size + 1 units of family labour increase										
1.0	1.90	577.89	643.18	0	0	2.10	314.08	556.54	0	0
2.0	2.50	963.80	643.18	0	0	2.50	536.70	556.54	0	0
3.0	3.00	1278.54	624.48	0	0	3.00	814.97	556.54	0	0
4.0	4.00	1619.59	283.98	0	1.08	4.00	1309.71	371.24	0	0
5.0	4.02	1625.50	0	0	2.28	5.00	1579.95	243.98	0.40	0.74
6.0	4.02	1625.50	0	0	2.28	6.00	1823.93	243.98	0.40	0.74
7.0	4.02	1625.54	0	0	2.28	7.00	2067.91	243.98	0.40	0.74
% Change	112.00	210.00				233.33	558.97			

The results in the table show that the net farm income and the number of hectares cultivated consistently increased as land and labour availability level increases. An additional 0.5 units of family labour will increase farm income and cultivated area by 126% and 68% in farming System A and 262% and 97% in farming System B respectively. Further increases by 1.0 units of family labour will drastically increase farm income and cultivated land by 210% and 112% in A and 233% and 559% in B. Any further increase again requires the relaxation of complementary scarce resources, either through the addition of existing technologies or new technology. In this study, with 0.5 and 1.0 units of additional labour available land ceases to be a limiting factor in production at 4 and 5 hectares in farming Systems A and 4.13 and 7.50 hectares in B. The shadow prices (MVP) indicate that there is a relative shortage of harvesting labour with 0.5 units of additional labour in both farming systems.

In the initial solutions, oxen labour for ploughing has zero MVP but with changes in farm size the MVP of this scarce resource has also increased, implying complementary effects of land as an input during the ploughing period. A glance at the table shows that at the level of 4 to 7 hectares in farming Systems A, the MVP of oxen labour is between 1.08 and 2.28 Birr per hectare with 1 unit of additional labour. Renting or hiring oxen is not common in Ethiopia. Any further solution to the problem is to purchase additional oxen or to use tractors in seedbed preparation.

6.3.5 The optimum farm size

Many studies in peasant agriculture reviewed in chapter IV shows when the size of farm becomes too large, it becomes inefficient due to diseconomies of scale. On the other hand, a too small-sized farms is also inefficient because it fails to provide whole time employment to the farmer and his families for part of the year. We have,thus,to find proper size of the farm that can give the maximum income and also is large enough to occupy the reasonable working time of the farmer and his family.

Theoretically,the size of the farm which ensures minimum cost and maximum profit is the ideal size of farm. This has been termed as optimum size of the farm. In this context our linear Programming solutions of the existing farming systems shows a farm size of 1.9 and 2.1 hectares seem an optimum farm size. With this level of farm size farmers' can handle the labour peak problems at harvesting and weeding periods and at the same generate sufficient income for the family with some surplus for market. More important, this farm size permits more efficient use of resource land, labour and capital under existing farmers circumstances.

6.4 Summary and Conclusion

6.4.1 Summary

This chapter has taken a close look at the potential for agricultural development in the Ethiopian highlands by examining representative farming systems. When the maximizing solutions are compared with actual or benchmark performance however, it appears that few clear opportunities exist for simple resource re-allocation. The findings indicate that an optimum recombination of enterprises would on average lead to an increase in gross margin of only 8% and 11%, an amount that cannot be considered a significant difference.

The models are also used to identify constraints in the farming system. The programme solution shows the improvements in farm income and resource productivity are limited by scarcity of seasonal farm labour during harvesting and weeding periods and land availability. Harvesting labour is found to be scarce, having an MVP of 4.07 Birr per hour, with the scarcity value substantially higher than its prevailing stage rate of 0.50 Birr per hour paid for farm seasonal labour in the study areas. MVP of land is also a relatively high 12.64 Birr and 416.90 Birr per hectare in farming Systems A and B, respectively.

The models are also used for testing the significance of a number of institutional parameters, found to be constraining farm incomes and resource productivity. The programme solution shows that the relaxation or removal of these constraints in all cases yields a high reward. In particular, it is found that the supply of casual labour during the peak periods and the availability of land and additional family labour will substantially increase the net farm income and the number of hectares cultivated in the farming systems. Furthermore the varying effects of resource level changes illustrates the complex nature of resource allocation within the farming system and the complementary relationships which exist between various farm resources.

6.4.2 Conclusion

On the basis of our analysis and findings we can make the assertion that farmers in the Ethiopian highlands are generally efficient in the use of resources at their disposal and there are few, if any, opportunities for economic growth under prevailing technological conditions. These findings would appear to have significant implications for agricultural development. It is now reasonable to assume that not much progress can be made towards the development of agriculture within the confines of existing production functions and existing resources. Agricultural development demands the introduction of new resources, new skills, improved techniques and additional resources in agriculture. The limited experience of technological change in Ethiopia fully justifies the assertion and is a sharp pointer in the right direction.

The next chapter will look at what improved crop technology is now available for the region and examine the potential of this technology for raising income and resource productivity.

CHAPTER VII

TECHNOLOGICAL POTENTIAL AND DEVELOPMENT POSSIBILITIES

7.1 Introduction

The previous chapter examined the opportunities for growth presently available to small farmers in the study areas and it was concluded that they are both few and costly. The finding of the analysis of resource use efficiency under farmers dual objective function of household consumption insurance and net income maximization suggested the low level of inefficiency. It appeared that a central feature of agriculture in the case study area was the low marginal returns to farming under existing technological conditions. This chapter attempts to simulate the potential of raising farm income and resource productivity through the introduction of alternative new technologies.

The chapter begins by identifying proven innovations in the study areas. Part II is concerned with the indentification of constraints and designed alternative technologies to relax the 'bottlenecks' in the farming systems. We then move in Part III to the actual evaluation of the effects of potential alternative technologies on farm income and resource productivity. Optimal solutions obtained from the basic model are compared with a series of LP experiments which have generated a number of technological possibilities . In light of our findings, we devote substantial attention in Part IV to a policy dialogue for the diffusion of the simulated technologies. The criteria of appropriateness in line of the current development objectives are defined and priority ranks of the simulated technolgies are analysed.

The final part V and VI investigate the stability of the established priorities in the model and records the results of the sensitivity analysis. This is followed by policy guidelines in the implementation of the simulated plans.

7.2 Proven Innovations and Future Potential in Ethiopia

The traditional farming methods discussed in Chapter VII are not capable of increasing productivity much beyond farmers subsistence level. For farmers to break out of the low productivity trap, a new and improve technology embodied in the new inputs must be introduced and the existing farming systems need to be modified. Such technology should be one that is consistent with the country's resource base, farmers knowledge level, and the Country's growth stage. This would require the introduction of relatively labour-using and capital-saving technologies.

In the study area there are numerous opportunities open to the highland farmer for increasing the farm income and his or her standard of living. In Chapter I, we described the recent policy guidelines in the Ten Year Development Plan which specifies the opportunities of the improvement of agricultural productivity through the introduction of bio-chemical innovations. Other policy sources, namely the Institute of Agricultural Research have also specified these opportunities. The IAR suggested very substantial possibilities for raising the productivity of the Ethiopian agriculture through the use of more capital in such forms as improved seeds, more fertilizers, plant protection materials (IAR, 1979).

These suggested improvements stem chiefly from Agronomic Research and other policy research which has conducted at selected research stations by IAR and ARDU. The result of this agronomic research at experimental stations is given in Chapter I, Table 1.2. However, it should be emphasized that the performance of such innovation on scientific research plots differ from the performance under field production. Given that scientific research concentrates on one or a limited number of variables in controlled environments, some of the important constraints in farm level production are in fact, avoided in research. Problems of peak labour that are most important in agriculture for example are seldom given attention in experimental research.

In practice, therefore, available experimental data seldom fully reflect the performance of alternative technologies. To obtain accurate information of the potential of new technologies, a number of years of interdisciplinary research using various methods, including on-farm research, farm surveys and direct observations are generally needed.

In Ethiopia the IAR and EPID began to conduct on-farm trials in 1971 because of the expected variations in performance. The main objectives of the pilot project were:

1. To carry out trials in order to test conclusions reached in research stations about cultural operations and new inputs.
2. To introduce tested and feasible innovations into farming systems.

3. To examine how best these innovations might best be adopted in field conditions.
4. To act as demonstration farms (EPID, 1974).

The work on farm experimental trials is mainly concerned with variety and fertilizer trials on leading highland crops: teff, wheat, barley, maize, sorghum and horse beans. At the farm level a large number of one-hectare on-farm experimental field trials have been conducted containing standardized unreplicated comparisons of (1) variety, (2) fertilizer (3) a combination of inputs of high yielding variety and fertilizer (4) agronomic practices (that is time of planting, seed rate, seed treatment and weed control methods).

Table 7.1 MOA 1 ha major crops on-farm experimental trials[1]

Year	Numbers	Year	Numbers
1971/72	392	1977/78	NA
1972/73	296	1978/79	351
1973/74	888	1979/80	440
1974/75	433	1980/81	518
1975/76	143	1981/82	618
1976/77	67		

Source: World Bank, (1981). Ethiopia Second Agricultural Minimum Package Implementation Volume, pp.52-53, Washington.

Table 7.2 **Recommended technologies based on on-farm trials in the study areas[2,3]**

Crop	Recommended varieties	Planting date	Seed rate Kg/ha	Rate and type of fertilizer DAP	Urea	Growth period (days)	Expected Yield at Farm Level (kgs) High yielding variety	Fertilizer	High yielding variety with fertilizer
Wheat	Enkoy, Romany BC, K 6295-4A, K 6290-Bulk, and Dereselgne	End of June to early July	125	70	45	120-135	1745	1848	3200
Barley	Bedi Black, Composite 29, IAR/HI 485, Holker	Mid June and early July	85-100	46	41	1200	1657	1590	2300
Teff	DZ-01-354,DZ-01-99 and DZ-01-196.	Early July to end July.	25-30	60	40	107-126	1195	1323	2200
Maize	Bako Composite, SR52, KCC, KCB, Jimms Bacco	Early May to mid May	25-30	77	75	170	3300	3700	5000
Sorghum	ETS 2752, Alemaya 70, ETS 717, ETS 2113	Mid April to mid May	8-10	100	100	115-125	2514	2600	4000
Horse Beans	20 DK, 38 BK, Kuse 2.27.33, 11 AK	Mid to late June or early July	150	100	-	130-150	2136	2397	2526

Source: Ethiopian Government Ministry of Agriculture, Results of Extension and Project Implementation Department (EPID) trials and demonstration, annual series (Addis Ababa: EPID, 1979/80 - 1983/84).

The reported number of successfully completed on-farm experimental trials are given in Table 7.1. The details of the current recommendations in the study area are given in Table 7.2.

The recommendation by IAR is a blanket recommendation for the highland regions, that is, uniform recommendations, despite considerable variation in soil and other factors within the regions. However, the recommendation offers practical answers to the production of many crops which, if adapted locally and correctly applied within a favourable policy regime, it could bring quite an improvement to smallholder agriculture (IAR, 1979:7).

Collinson (1972) and Norman (1978) argued that the improvement role these promising innovations could play in the transformation process depends upon their feasibility and their acceptibility to the farming community. However, ample evidence gathered by various authors from production response investigations and attitudinal tests in the Ethiopian highlands, indicated that small farmers were strongly motivated for higher income, were technically knowledgeable in relevant fields and thoroughly price conscious Bisrat (1980).

For some time, on the basis of their general understanding, the Ministry of Agriculture attempted to dissemenate the recommended packages through regional, provincial and then district level. The details of the recent guidelines and the technical packages are contained in the "Extension Agents Handbook", which was published by MOA in 1983. The handbook covers the main crops grown in the country, lists of climatic and soil requirements, improved varieties, recommended agronomic practices and fertilizers and a description of common disease and insects for each crop based on on-farm experimental trials (MOA, 1983). The recommendations were made taking into consideration variation on altitude, climate and soil in the main agro-ecological zone discussed in Chapter II.

7.3 Identified Constraints in the Farming Systems and Design of Alternative Technological Packages

In the present study, as demonstrated in Chapter VII, for the average farmer in the study area, land and labour for harvesting and weeding were indentified as constraints to increasing farm income. Therefore, in this particular situation, relaxation of these limitations by improving the productivity of labour - particularly at bottleneck periods - and the productivity of land, seems desirable. Improved technology needs to address these issues in order to increase the productivity of existing farming systems.

In the study areas seasonal labour productivity could be increased directly by using hired labour, chemical technology such as herbicides for weeding and combine harvester-threshers. Such types of technology increase the amounts of land that can be handled by a farming family. Indirectly, labour productivity could be increased also through biological-chemical technologies such as improved seed, inorganic fertilizer or insecticide, which would avoid an increase in labour requirements during the bottleneck period. However, this technology is unlikely to be feasible for most crops due to the relatively short rainy season that allows for little flexibility in planting dates. Bio-chemical technology is likely to result in increased harvesting and threshing workloads. Therefore, it is necessary to ensure that the cost of increased labour input during the labour bottleneck period is more than offset by the increase in returns from its application. Further complications arise if improved technology for a cash crop rather than a food crop is being considered. Farmers would be reluctant to increase labour requirements for cash crops during the labour-bottleneck period, since all others being equal, they would give priority to food crops during that period. It has been suggested in a previous chapter that farmers have a security orientation until food requirements are met.

Land productivity could be increased through introducing land augmenting and land substituting technology. Land drainage, irrigation, deep ploughing, bush clearing, soil conservation measures and other processes are examples of land augmenting technology. They directly increase the productivity of land without directly substituting labour. Indeed this type of technology represents investment directly to land.

The effect of land substituting technology is essentially similar to that of land augmenting technology, the only difference being that the technology is not directly embodied in the land. Examples of this are improved seeds which give higher yields, fertilizers and any new cultural practices which when added to the old practices, increase land productivity more than costs.

Empirical data relating to land augmenting technology are not available for this study, but in examining other considerations it could be seen that there are several technological packages to relax the major constraints in farming systems. Therefore, the design of alternative potential technological packages, from the results of already identified on-farm experimental research, is necessary to study the effect of these technologies and rank the results in terms of their potential success in smallholder farming systems.

The first step in studying the effect of new technology on farm income and resource productivity was to design a number of feasible alternative technological packages for the study areas. The following table shows the alternative potential technologies packages that are designed from the results of 1979/80 to 1983/84 on-farm experimental trials discussed above.

Table 7.3. Alternative potential technological packages for wheat, barley, teff, maize, sorghum, and beans in Ethiopian highland farming systems

Code and Models	Technological Package[1]
1.	Existing technology
2.	Existing technology and high yielding variety
3.	Existing technology and fertilizer
4.	Existing technology with high yielding variety and fertilizer
5.	Existing technology with high yielding variety and herbicide
6.	Existing technology with fertilizer and herbicide
7.	Existing technology with high yielding variety and fertilizer and herbicide
8.	Existing technology with high yielding variety, fertilizer and combine
9.	Existing technology with high yielding variety, fertilizer, combine and herbicide.
10.	Combination of all technologies

[1] All the technological packages consist of improved planting date and seed rate technologies with the exception of Model No. 1

These experiments were designed to generate new technologies such as improved seeds, type and rate of fertilizers, rate and type of herbicide, sowing dates and seed rates. In the design of the package, consideration of the current intention of policy makers and advice of researcher was also taken into account. Their recommendations and expectation were incorporated in the set of technology which were explored with existing traditional oxen technology and farm practices.

The second step was to identify technological possibilities by the modification of the basic matrix of the simulation developed in Chapter VI through alteration. As has been noted before, the basic model already validated in a previous chapter, in an acceptable representation of the Ethiopian highland farming systems which can be used to test the effect of proposed alternative potential technological packages. The effect of technological change can be analysed, maintaining the assumption made for the basic model which is altered by incorporating suggested technological changes in Table 7.3, for which necessary detailed input-output data are given in Appendix C, Tables C1 - C7. For example, the existing production activity of the basic model in farming system A reflects the existing production activity which involves lower levels of improved seed and fertilizer for wheat and teff than recommended, local varieties of other crops and when late planting. If an improved variety with fertilizer is introduced along with an earlier planting date and current seed and fertilizer rate is anticipated, its effectiveness may be studied overwriting the existing input-output coefficients for recommended wheat, barley, teff, maize, sorghum and horse beans production, holding all the other practices in the model constant and then re-run the model. This procedure was repeated for each of the new technological packages in Table 7.3 for both farming systems. This step-wise procedure facilitated the evaluation of benefits accuring to the farming systems from alternative potential technological packages by deteriming the magnitude of increase on farm income and resource productivity for each reiteration.

The third step was to identify technological possibilities by extension of the basic matrix with model 10. Matrix extension here is concerned with the extension of the range of choice in the model without affecting any of specification or quantifications of the basic model, whereas model alteration as noted above involves changes in farmer's decision making environment which has to be specified as a modification to the basic model. In the study area, 8 alternative technologies each are designed of six recommended high yielding varieties(i.e wheat, barley, teff, maize, sorghum and Horse beans) are designed to investigate the profitability of alternative technologies. Therefore, in model 10 alternative technologies 2 to 9 are allowed to complete with existing technologies model1 for one resource supply by extension of the basic model activities row and columns. In terms of the matrix, model 10 is represented by additional extension with 48 crop production, 48 consumption, 48 sales rows and Column of the basic model in farming system A.

Having done this, however, the dissemination of alternative technologies required a ranking of programme outcome and a process of choice between the alternative technologies, choice being influenced by the relative weighting given to national policy priorities which involved a value of judgement by the government. Here, as a policy decision to rank the alternative technological packages for dissemination into the Ethiopian highland farming systems, the increase in farm income has been used as the main criteria.

7.4. Analysis of the Simulation Results

A common feature of LP models is that the results of simulated farm operations are expressed as changes in output, income and input variables as compared with the basic run. In the following analysis, the base run consisted of values of technological and policy variables expected in the absence of changes in alternative technology and policy meaures.

Table 7.4. **Effects of alternative technologies on farm income and resource productivity in farming System A (unlimited credit).**

Model	Alternative technology	Land cultivated	Total family labour used	Total working capital	Net income	% of land cultivated	% of household labour used	Net return per ha	Net return per hr of labour	Net return per unit of capital
		(has)	(hrs)	(Birr)	(Birr)			(Birr)	(Birr)	(Birr)
1.	Existing	1.90	1124	153.29	523.70	100	45.67	275.63	0.46	3.42
2.	With HYV	1.49	1046	100.03	655.00	78.42	42.50	344.73	0.63	6.55
	% change	-21.58	-7.0	-34.57	25.10					
3.	With fertilizer	1.34	1000	182.85	499.51	70.52	40.63	372.77	0.50	2.73
	% change	-0.56	-11.03	19.28	-4.49					
4.	With HYV & fertilizer	0.82	798.24	124.12	577.95	45.79	32.44	664.31	0.72	4.66
	% change	-103.00	-28.29	-19.03	10.35					
5.	With HYV & herbicides	1.49	795	130.00	625.05	78.42	32.30	419.46	0.78	4.80
	% change	-41.00	-29.27	-15.19	19.35					
6.	With fert. & herb.	1.34	776	209.62	472.95	70.52	31.53	352.76	0.61	2.25
	% change	-56.00	-30.96	36.75	-9.73					
7.	With HYV, fert. & herb.	0.87	660	141.00	561.14	45.79	26.82	644.82	0.85	3.98
	% change	-103.00	-41.81	-8.72	7.15					
8.	With HYV, Fert. & combine	1.90	1030	415.62	1999.18	100	41.85	1052.20	1.94	4.81
	% change	0	-8.36	171.14	281.24					
9.	With HYV,Fert. & comb. & herb.	1.90	807	452.07	1962.85	100	32.79	1033.08	2.43	4.34
	% change	0	-28.28	194.91	274.80					
10.	With combination of all technol.	1.90	1050	388.09	2011.25	100	42.66	1068.45	1.93	5.23
	% change	0	-6.58	153.17	287.64					

Table 7.5. **Effects of alternative technologies on farm income and resource productivity in farming System B (unlimited credit)**

Model	Alternative technology	Land cultivated	Total family labour used	Total working capital	Net income	% of land cultivated	% of household labour used	Net return per ha	Net return per hr of labour	Net return per unit of capital
		(has)	(hrs)	(Birr)	(Birr)			(Birr)	(Birr)	(Birr)
1.	Existing	2.10	1589	174.46	308.47	100	61.12	146.89	0.19	1.77
2.	With HYV	2.10	1687	198.18	820.81	100	64.88	390.86	0.48	4.13
	% change	0	6.17	13.76	166.68					
3.	With fertilizer	2.10	1553	249.40	848.87	100	59.72	371.17	0.50	3.12
	% change	0	-2.26	42.96	152.68					
4.	With HYV & fertilizer	2.10	1455	175.00	960.12	100	55.96	457.14	0.66	5.48
	% change	0	-8.43	0	211.21					
5.	With HYV & herbicides	2.10	1253	130.44	783.15		48.19	372.85	0.63	6.02
	% change	0	-18.88	-25.23	153.83					
6.	With fert. & herb.	2.10	1253	290.00	809.02	100	48.19	385.24	0.65	2.79
	% change	0	-21.14	66.23	162.27					
7.	With HYV, fert. & herb.	2.10	1214	195.33	939.73	100	46.69	447.14	0.77	4.82
	% change	0	-23.60	11.96	204.64					
8.	With HYV, Fert. & combine	2.10	1046	465.94	1938.11	100	40.23	922.90	1.85	4.16
	% change	0	-34 17	167.07	528.29					
9.	With HYV,Fert. & comb. & herb.	2.10	654	511.00	1898.38	100	25.23	903.99	2.90	3.71
	% change	0	-58.84	192.90	515.42					
10.	With combination of all technol.	2.10	1537	371.50	2032.86	100	59.11	968.03	1.32	5.47
	% change	0	-3.27	112.94	559.01					

7.4.1 The Effect of Introducing High Yielding Variety, Fertilizer and a Combination of High Yielding Variety and Fertilizer On-Farm Income and Resource Productivity.

7.4.1.1 Resource use and Marginal Value Products

Optimal Cropping Pattern

The optimal solutions to the problem set up as described above are shown in Appendix Tables D1 and D2, alongside the actual cropping pattern observed during the survey. The linear programming cropping pattern for all farming systems was somewhat close to the actual pattern observed for existing technology, though it should be remembered that the study focussed on food crops, the results were obtained by constraining the levels of the crops to consumption requirements. Most striking perhaps, was the closeness of the optimum solution hectarage to the ob、 served hectarage in farming systems B. Only with barley production in both farming systems was there any substantial divergence between LP solution and the observed hectarage.

Farm Income

The above analysis has indicated the effect of alternative technolgies on the level of cropping pattern. These effects are ultimately reflected in net-farm revenue obtained. Table 7.4 and 7.5, Models 2 to 4 shows the simulated net farm income for the two farming systems with unlimited credit. The results indicate a substantial improvement in farm incomes as compared to the actual situations. In contrast the actual situation, the simulation of HYV varieties, fertilizers individually produced an income increase of 167% and 153%

in farming systems B. If improved varieties and fertilizers are introduced, the possibility of a 211% increase was indicated. These income increases are higher than those obtained from the introduction of high yielding variety or fertilizer. Similarly in farming Systems A, the individual effect of HYV varieties and fertilizer into the farming system, appears to be an increase in net income by 25% and a decrease of 4% respectively. The effect of combined HYV varieties and fertilizers produced a 10% increase which was more than the separate individual income effect of HYV varieties or fertilizers.

In overall terms, the results suggest that farm income is most likely to increase with the introduction of high yielding varieties and combination of high yielding varieties and fertilizers. However, farmers would obtain higher incomes if they used a combination of high yielding variety and fertilizer rather than individual technologies. It is interesting also to note that the introduction of fertilizer produced a negative income when compared with existing farming systems in the case of B. This may be due to the selection of horse beans for cropping for sale which is low yielding and low priced.

Marginal Value Products

The implicit resource and constraint values obtained from the solution of linear programming as argued in Chapter VII, are more rewarding in terms of insights into the inner working of production systems. It can be used to identify the critical parameters of constraints to which the activity levels are sensitive, thereby pointing towards possible technologies which can be introduced to relieve specific binding constraints.

Table 7.6 A comparison of Marginal Value Products (MVP's) under existing and alternative technologies.

Farming Systems	Resource	Unit	Marginal Value Products (Birr) — Alternative Technologies 1	2	3	4	5	6	7	8	9	10
A	Land	HA	12.64	0	0	0	0	0	0	1429.30	1408.31	1381.70
	Farming labour											
	Ploughing	HR	0	0	0	0	0	0	0	0	0	0
	Planting	HR	0	0	0	0	0	0	0	0	0	0
	Weeding	HR	0	0	0	0	0	0	0	0	0	0
	Harvesting	HR	4.07	4.67	4.33	4.62	4.53	4.22	4.56	0.11	0.11	0.33
	Threshing	HR	0	0	0	0	0	0	0	0	0	0
	Oxen labour											
	Ploughing	HR	0	0	0	0	0	0	0	0	0	0
	Planting	HR	0	0	0	0	0	0	0	0	0	0
	Threshing	HR	0	0	0	0	0	0	0	0	0	0
	Operating Capital	Birr	0	0	0	0	0	0	0	0	0	0
B	Land	HA	416.90	384.12	634.78	52.18	497.42	613.92	63.12	1429.30	1408.58	1429.30
	Farming labour											
	Ploughing	HR	0	0	0	0	0	0	0	0	0	0
	Planting	HR	0	0	0	0	0	0	0	0	0	0
	Weeding	HR	0.49	0.34	0	0	0	0	0	0	0	0
	Harvesting	HR	0	0.98	0.49	2.98	0.80	0.49	2.89	0	0	0.11
	Threshing	HR	0	0	0	0	0	0	0	0	0	0
	Oxen labour											
	Ploughing	HR	0	0	0	0	0	0	0	0	0	0
	Planting	HR	0	0	0	0	0	0	0	0	0	0
	Threshing	HR	0	0	0	0	0	0	0	0	0	0
	Operating Capital	Birr	0	0	0	0	0	0	0	0	0	0

Table 7.6 and Columns 1 - 4, give the imputed values of the resources employed in the solution. Land is a constraint for farming System B with the shadow price ranging from a low of 52.18 Birr to a high of 634.78 Birr when fertilizer technology is used. This shadow price of additional land is high when compared with existing technology of 416.90 Birr per hectare. The MVP of fertilizer technology implies that for farming system B one additional hectare of land will raise the net revenue by 634.78 Birr. The extent to which this is valid should be seen in the parametric analysis of land. However, the high marginal value product for land under this technology reflects the scarcity of land.

Labour required for harvesting is also scarce in both farming systems, a further reflection of the higher resource demands of each alternative technology. In the case of farming system A, its scarcity value is greater than the market wage rate of casual labour 0.50 Birr per hrs . The results here accentuate even further the importance of labour for harvesting in both farming systems, and land in the case of B. The benefits to be gained by overcoming the constraints imposed by land and labour at peak periods could be significant when high yielding varieties are grown according to research-derived recommendations. These findings, therefore, provide the rational for replicating the set of experiments carried out with the existing technology and for examining several additional technologies to relax labour constraints. In the discusssion which follows, the effect of herbicide and combined technology will be assessed.

7.4.2 The effect of using herbicides and combine threshers

In the previous discussion, the modification of cropping activities to represent the performance of biochemical was shown to be relatively uncomplicated . The biological technology incorporated in the model is based upon the yield performance of high yielding varieties. The procedure for determining the relationship when herbicides and combine threshers and harvesters are introduced is the same as that employed for the high yielding variety and fertilizer model. The structure of the model remains unchanged and it is necessary only to substitute the input-output coefficients appropriate to weeding and harvesting operations for the combination of high yielding variety packages to alter the variable cost entries in the objective function.

Table 7.4 and 7.5, Models 5-8, depict the effect of introducing herbicides and combines. It is obvious from this table which depicts selected aspects of the optimum solution that the introduction of herbicides and combines produces a radical change in production, and its family labour used and hence the net revenue. The programming results show first the general distribution pattern of crops is not too dissimilar. Actual production of wheat and barley is widespread in Zone A and teff and barley in B. Wheat production especially had increased rapidly due to ARDU/MMP and wheat and teff is produced significantly more under optimum plan than the actual plan due to its relatively high yield and price.

Optimal land cultivated is the same as the actual land for farming system B but decreased for farming systems A. The average actual land cultivated is 1.49 ha, 1.34 ha, 0.87 ha, 1.90 ha, 1.64 ha, respectively for family system A and 2.1 for family system B. The decline of cultivated land under farming systems A optimal solutions is due to contsraints in complementary resources of harvesting labour. In these cases the available labour is used and any increase in further production requires the relaxation of these constraints through alternative policy measures. The figure in Table 7.4 and 7.5 illustrates clearly that the introduction of a combination of high yielding varieties, fertilizers, herbicides and harvesting combine, could substantially raise income on both farming systems. The model of farm A, able to raise its income by as much as 217% and farm B by 515%. However, when individual effects of alternative technologies with herbicides and combine were run to see the trend in farm income increases, different income levels were obtained. For example, the combine effect of high yielding varieties and herbicides; fertilizer and herbicides; HYV, fertilizer and herbicides; HYV, fertilizer; herbicides and combines, resulted in an increase in net income by 20%,200%,162%,154%,528% in farming system B (Table 7.4 and 7.5, Model 5-8). These results indicate that farmers may be better of by adopting the combination of improved varieties with fertilizers, herbicides and combines in crop production, rather than other alternative technologies under existing farming systems.

7.4.2.1 Resource Use and Marginal Products

Land

The size of arable land used for crop production in both the existing model and under alternative technologies was 2.1 hectares in farming system B, which was the maximum available. However, with farming system A, the size of cultivated land had decreased in all technological combinations. In the existing solution, the MVP of land was 12.64 Birr per hectare in A and 416.90 birr in farming system B, indicating that land was a limiting factor. Theoretically, since new technologies make land more productive, the MVP of land from existing technologies should show a rise in relation to land availability. However, the MVP of land increases are subject to complimentary resources labour. This is illustrated by the maximum fall of MVP of land in farming systems A to zero and with generally substantial rises for farming system B, with one exception, when HYV fertilizer and herbicide combination are introduced. In these cases most available harvesting labour has been exhausted. Any further increases requires additional labour during harvesting periods either as hired labour or exchange. In summary, the marginal value products vary considerably in farming systems B and reflects substantial differences in productivity and profitability of technologies available to farmers. Thus for farming system B the maximum MVP is 1429.30 when a combination of HYV, fertilizer and combine are adopted.

Labour

Table 7.4 and 7.5 presents the comparison of the actual pattern of family labour used per year with that generated by the model when alternative herbicides and combine technologies are used. The difference in pattern of family labour used between the existing technology and model solution for alternative technology indicates some decline as herbicides and combine harvester and thresher replace family labour during peak weeding and harvesting periods. These results are not very encouraging from the employment point of view because they reduce total employment up to 59 and 28 per cent respectively. This occurs with no significant change in cropping pattern and an increase of farm income to the level of 278 and 528 per cent in the two farming systems.

The effects of alternative technologies on cash surplus of raising family labour availability are also minor. The farmers have relatively ample workers, except during weeding and harvesting peak periods, and thus their marginal value products of labour is generally close to, or even reaches zero. In the few and restricted peak labour use periods, however, the model shows that many additional workers are needed to increase productivity. The MVP of family labour indicates that labour is scarce during weeding and harvesting operations. These solutions vary with each alternative technology and the farming systems in comforming with the differences in solution. Marginal value products for harvesting labour in farming system A, for example, varies from 0.19 to 4.56 Birr per man, indicating that in all cases the scarcity value is greater than the market wage rate of casual labour 0.50 Birr per hour. Of greater significance are the scarcity values of family labour when a combination of HYV and fertilizer are introduced in farming systems B. Their magnitude of 298% increases confirm the importance of this technology if policy makers aim to increase MVP and labour. In both farming systems, the shadow price of labour is the highest when a combination of high yielding variety and fertilizer technologies are introduced, as illustrated in Table 7.6.

7.4.3 The Effects of the Introduction of Combination of New Technology with Existing Resource Levels.

In model 10 optimal programming was devised by allowing improved crop production technologies to compete with existing technologies. All technology designed in Table 7.3 was allowed to compete with existing resources by extending the existing technology matrix with eight packages of wheat, barley, teff, maize, sorghum and H. beans.

Table D1 and D2 and column 10 in Appendix shows the cropping pattern, the effect on quantity of land cultivated, farm income and average productivity of resources of introducing improved technology under these situations.

The effect of introducing improved production technology under unlimited capital levels is to consistently increase income as was shown with the alternative technologies simulated earlier. The magnitude of income increased is 288 and 559 per cent for farming systems A and B. The use of new technology induced increases in the average return to the limiting resources of land, family labour and operating capital. The average return per hectare with the new technology and existing resources combined for the two farming systems are respectively 1068.45 and 968.03 Birr. The return per unit of operating capital are 5.23 and 5.47 Birr with new technology. These represent increases of 522.92% and 209.03% over the returns under the existing technology.

The marginal value products of resource with the new and existing technology are compared in Table 7.6, Column 10. The marginal value product of land under the new technology is 1382.70 and 1429.35 Birr, Which represents a 1039 and 243 per cent increase over the marginal value product of land under existing technology. Thus land is more limiting under the new technology. Under the given conditions an additional unit of land would increase the total GM by 1382.70 and 1425.30 Birr with the new technology the highest so far attained with alternative technologies.

As in the case of existing technology and other technologies simulated earlier, family labour is a contraint of production with the new technology in the harvesting period. The MVP of harvesting labour is with new technology is 0.33 and 0.11 Birr as against 4.07 and 0 Birr with existing technology. This means that family labour is more limiting during harvesting than under existing technology in farming system B and less limiting in the case of farming system A. Furthermore, the marginal value of products of labour during harvesting period is lower than the prevailing wage rate for this period. Farmers can afford to pay higher wage rates to attract hired labour during this period with the new technology. This emphazises the need for the availability of funds for hiring labour to break the labour constraint in the labour peak periods.

7.4.4 Departures from Basic Resource Situations and Relaxation of existing constraints.

In the previous section we have simulated alternative technologies with existing resource availability. We may now also use our models to estimate the effects of the relative changes in the quantities of constraints in the farming system under new technologies on overall cash surplus and relative resource productivity. Our goal here is to assess the potential of the simulated technologies when existing constraints are relaxed under alternative policies. Our procedure starts from the basic situation of each farming system in the presence of new technologies and adds to this in turn successively increasing quantities of one of the three major resources which are limiting, while the other two are held constant. We also examine the results of increasing land and farming labour simultaneously. Table 7.6 shows the resource requirement of the simulated model. The shadow prices which are the best guide to the identification of the limiting factors of production indicates that harvesting labour and land are the two factors with the higher shadow prices. Therefore, net farm income would be increased if more of the two factors could be used. In this study, as with the prevailing technology, the contraints governing availability of labour and land were relaxed to assess the effect of a policy on the use of casual labour and additional family labour on farm income and resource use. Again as in Chapter VI up to 300 man-hours hired casual labour, 0.5 and 1.0 unit of additional family labour, were assumed available in the farming systems.

As improved technology crops are necessarily more labour consuming than prevailing technology ones, the further availability of labour during critical peak periods makes a greater difference to family income and resource use than is seen to be the case under the existing technological situation. Table 7.7 shows the removal of family labour constraints through hired and additional units of labour for each operation. In section 1 of Table 7.7, the effect of additional hired labour supply availability during critical periods consistently increases farm income. In the two farming systems given that there are enough other resources to use, a combination with additional harvesting labour will allow more production and increase farm income. This causes the optimum plan to deviate from these specified as optimum in basic alternative technologies. The only exception to this conclusion is that in farming System B; labour is not a limiting factor in the farming system, when existing technology with high yielding variety, fertilizer and combine; with high yielding variety, fertilizer, combine and herbicides are simulated (Table 7.6).

As argued in previous Chapter, knowledge of the labour markets suggest that it is only possible to get limited man hours of hired labour in the study areas during peak periods. Therefore, any further increase of farm income and resource productivity with additional use of labour may come through increased availabiltiy of family labour. At present, there has been no additional family labour to increase the size of family labour of the representative farming systems. However, for designing future labour policy, an analysis of the effect of increasing different units of family labour in the farming systems might yield some valuable information. This kind of analysis might

Table 7.7 Effects of the use of hired labour, simultaneous changes in family labour on farm income and resource productivity under alternative technology (unlimited credit)

Policy Changes	Alternative technology	Farming System A: Level of land resource use	% change	Total labour used	% change	Net farm income	% change	Farming System B: Level of land resource use	% change	Total labour	% change	Net farm income	% change
1. Existing		1.90		1124		523.70		2.10		1589		308.47	
2. With hired labour	1.	4.04	112.63	1569	47.64	1227.90	134.47	2.26	7.62	1377	-13.34	370.05	19.96
	2.	2.62	37.89	1611	43.33	1485.10	183.58	4.68	122.85	2014	26.75	1604.41	420.44
	3.	2.40	26.31	1006	-10.49	1265.57	141.65	3.71	76.66	1931	21.52	1853.21	500.13
	4.	1.40	-26.31	1176	4.63	1402.60	167.83	4.59	118.57	1842	15.92	1595.58	417.25
	5.	2.62	37.89	1182	5.16	1431.78	173.40	4.66	121.90	1761	10.82	1592.81	417.37
	6.	2.40	26.31	1171	4.18	1216.62	132.31	3.95	88.08	1778	11.89	1751.69	467.86
	7.	1.48	-22.10	908	-19.22	1373.03	162.17	4.59	118.57	1742	9.63	1575.85	410.87
	8.	3.57	87.89	1114	-0.89	3463.93	561.43	5.00	139.09	1849	16.36	3263.62	958.00
	9.	3.22	69.47	1160	3.20	3738.75	613.91	5.00	139.09	1439	-9.44	3219.84	943.81
	10.	3.22	69.47	1831	62.90	3768.63	619.67	3.46	64.76	2019.12	27.26	3444.70	1016.70
3. With 0.5 unit of family labour	1.	3.20	68.42	1790	59.25	1182.53	125.88	4.13	96.67	1927	21.27	1137.04	268.61
	2.	2.40	26.32	1664	48.04	1389.78	165.38	4.27	103.33	1932	21.58	1448.85	369.69
	3.	2.18	14.73	1616	43.77	1183.65	126.01	3.38	60.95	1951	22.78	1723.47	458.72
	4.	1.35	-40.74	1254	11.56	1308.42	149.84	4.00	90.48	1820	14.54	1422.55	361.16
	5.	2.38	62.63	1259	12.01	1341.37	156.13	4.17	95.24	1768	11.25	1433.58	364.74
	6.	2.18	14.73	1246	10.85	1139.40	117.56	3.38	60.95	1595	0.38	1656.84	437.11
	7.	1.35	-40.74	1092	-2.85	1281.53	144.71	4.00	90.48	1054	-33.67	1412.86	358.02
	8.	3.20	68.42	1931	71.89	3863.11	637.65	6.36	202.86	2181	37.25	3354.72	987.54
	9.	3.10	63.15	1307	16.28	3793.16	624.30	6.58	213.33	1862	17.18	3329.95	978.76
	10.	3.20	68.42	1422	26.57	3838.53	632.56	3.28	56.19	2167	36.37	3446.01	1016.36
4. With 1.0 unit of family labour	1.	4.04	112.63	2824	151.24	1607.95	207.04	7.50	257.14	2335	46.95	2189.89	609.92
	2.	3.18	67.37	2014	79.18	2011.07	284.01	4.35	107.14	2503	57.52	2015.88	553.51
	3.	3.02	58.94	2233	98.67	1867.79	256.65	3.71	76.66	2109	32.72	1942.74	529.60
	4.	1.84	-3.15	1662	47.86	2038.89	289.32	3.46	64.76	2444	53.80	1900.70	516.09
	5.	3.18	67.37	1246	10.85	1945.96	271.58	4.35	107.14	2140	34.67	1948.84	531.77
	6.	3.02	58.94	1717	5.27	1806.06	244.86	3.71	76.67	1731	8.94	1870.32	506.32
	7.	1.84	-3.15	1404	24.91	2001.92	282.26	3.46	64.76	2150	35.30	1840.88	496.78
	8.	3.27	72.10	2018	79.54	3974.10	658.86	7.50	257.14	2806	76.59	3441.72	1015.74
	9.	3.27	72.10	1507	34.07	3902.67	645.21	7.50	257.14	2246	41.35	3406.02	1004.17
	10.	3.27	72.10	1645	46.35	3951.77	654.58	3.42	62.85	2484	56.32	3548.32	1050.29

also be useful for other ongoing land reform policies in allocating land to farmers.

The results of this investigation are summarized in section 2 and 3 of Table 7.7. It is clear that in all cases farm income and resource productivity have substantially increased. An increase of 0.5 units of labour, increased cultivated land from existing 1.90 hectares in farming system A and 2.1 in B to 3.2 and 3.3 hectares, respectively. As a result farm income increased from 523 .70 and 308.47 Birr to 3863.14 and 3354.22 Birr in the two farming systems. This occurs when existing technology with high yield variety, fertilizer and combine are used. A wide range of farm size and income increase obtained with other alternative technologies between this range are given in the Table 7.7. Furthermore, with additional units of available family labour, the increase in both cultivated land and farm income is very high. The highest increase occurs again when high yielding variety, fertilizer and combine are introduced reaching 3.27 and 3974.10 Birr for farming System A and 7.50 hectares and 3441.72 Birr in B.

7.5 Simulated Alternative Technologies and Criteria of Appropriateness

The foregoing experiments have been devoted to simulating conditions on representative farming systems in Ethiopian highland under a variety of assumptions about the nature of agricultural technology available. Given the number of experiments performed, it is not surprising that the results display a wide range of diversity in net farm income and resource productivity. Policy makers and planners, however, will need specific criteria if they have to introduce these alternative technologies to raise productivity of small holder agriculture and alleviate rural poverty.

It has been argued in Chapter I that one of the main objectives of the Ethiopian development plans is to devlop a farming system that produces the highest net income possible. A development strategy which accepts this basic point obviously needs to consider technological alternatives available to increased farm income, since such choices affect overall levels of income and productivity. Although income is only one of the number of considerations in the choice of appropriate technology, it is nevertheless one of the most important, in view of the critical poverty situation in Ethiopia. It is to the problems of appropriate innovation in agricultural development, in terms of income effects, that this study is dedicated. In selecting and ranking the alternative potential technology for policy dialogue, therefore, the incremental income per farm as the particular technological component is introduced into the farming system, was taken into consideration. Technology which among the whole range of alternative technologies that generate the higher increment of net income is ranked as the highest priority for introduction into the farming systems. This is on the basis of the understanding that small farmers in Ethiopia could adopt technology which is profitable. Table 7.8 shows the simulated net revenue and priority ranks of potential technologies if the technolgies are introduced with unlimited credit.

Table 7.8 Income and policy ranks of in troducing alternative new technologies in Ethiopian highland farming systems
(Unlimited credit)

Alternative Technologies	Farming Systems A Income (Birr)	Priority ranks	B Income (Birr)	Priority ranks
1	523.70	8	308.47	10
2	655.00	4	829.81	7
3	499.51	9	848.87	6
4	577.95	6	960.00	4
5	625.05	5	783.15	9
6	472.95	10	809.02	8
7	561.14	7	939.23	5
8	1999.18	2	1938.11	2
9	1962.62	3	1898.38	3
10	2011.25	1	2032.86	1

On the basis of above results, production priority for introduction of alternative technologies should be:-

a) For farming Systems A as: (1) All combinations of competing new technologies with existing resource levels which appeared to be highest, followed by (2) Existing technology with a combination of high yielding variety, fertilizer and combine. (3) Existing technology with high yielding variety, fertilizer, combine and herbicide. (4) Existing technology with high yielding variety. (5) Existing technology with high yielding variety, and herbicides. (6) Existing technology with high yielding variety and fertilizer. (7) Existing technology with high yielding variety, fertilizer and herbicides. (8) Existing technology only. (9) Existing technology with fertilizer and (10) existing technology with fertilizer and herbicide.

b) For farming Systems B as: (1) All combinations of competing new technologies with existing resource levels. (2) A combination of existing technology with high yielding variety, fertilizer and combine. (3) Existing technology with high yielding variety, fertilizer, combine and herbicide. (4) Existing technology with high yielding variety and fertilizer. (5) Existing tchnology with high yielding variety, fertilizer and herbicide . (6) Existing technology with fertilizer. (7) Existing technology with high yielding variety. (8) Existing technology with fertilizer and herbicide. (9) Existing technology with high yielding variety. (10) Existing technology.

Decision priority on the introduction of the above technologies depends upon the weights given to by the policy makers in terms of income generation and competing demands for national resources both real and administrative. The work in this study is in the nature of signposts, pointing the way but not indicating at what one is to arrive. A methodology has been developed which is of some use in exploring the effects of alternative technologies in several dimensions, and therefore, in helping to identify technologies which may serve the purpose of agricultural development and alleviation of rural poverty.

It should be noted here that the author is aware that it is a mistake to portray the decision for the introduction of any of the alternative technologies by policy makers based only on income generation criteria. The actual decision matrix which Ethiopian policy makers employ will undoubtedly have many other criteria, although income criteria as argued earlier is an important national policy, on which this study is based. Policy makers may be interested in employment generation or minimizing foreign exchange which has not been dealt with here. However, this study has suggested that the choice of problem will be simplified if a greater number of technological possibilities are available to which the various criteria of appropriateness could be applied. There appears to be scope for policy makers to make further decisions on the basis of other criteria. If the major concern is minimizing foreign exchange component of the technology, this could be avoided by introducing other non-combine and herbicide-based technologies. If employment is the main concern, technologies that generate more jobs for family and hired labour could be selected and introduced into farming systems. In this context, what is important is the prior choice of a strategy for agricultural development. The analysis of this thesis has shown that productivity increases that can alleviate rural poverty can be achieve by introducing simple new alternative technologies in the form of improved seed, fertilizer, herbicides, combine thresher, along with adequate supplies of complementary operating capital. Based on this study, planners and policy makers should design strategies and programmes that enhance agricultural development in Ethiopia.

7.6 Sensitivity Analysis and Stability of Priority Ranks of the Simulated Model.

Having devised a model which may be used by policy makers to identify a number of alternative technologies for agricultural development, it is now necessary to consider the stability of the model to make future plans. The priority ranks of technology sets may be unstable. Given that the model is the most probable value of the parameters farmers face at the time of the survey, it is reasonable to expect some changes in priority ranks with a relatively small change in the values of the parameters used. The values of the input and outputs, such as crop yield, price of inputs and outputs, may change due to policy change or weather, over a period and could affect the farmers' circumstances. A limited sensitivity analysis was, therefore, carried out to test the stability of the model giving some idea of the stability of priority ranks of alternative technologies. Wheat, barley and teff, the important cereal crops grown in the area, were taken as examples to minimize the cost of computation involved for many crops.

The technique of the sensitivity analysis is not complicated. The model was tested for its sensitivity and percentage increase or decrease in the values of the parameters used in the model. Changes in crop yield were simulated by a decrease of 15% and increase of 30% while output price decreased and increased by 25 and 50 per cent respectively and input price decreased by 30 per cent. Tables 7.9 to 7.11 show the result of the test in the two farming systems.

The result of these limited sensitivity analysis indicated that models in both farming systems were reasonably stable. The movements of price of food grains, input or yield of major crops will have only a limited effect in changing the established priorities for policy decision to introduce simulated technologies. Even those which were changed did so at a very high level in price of outputs: changes which would normally not be expected to occur under current government restrictive price policies. Therefore, even if agricultural policy makers change output and input prices in the short-term to provide incentives or encourage farmers to adopt any of the simulated

Table 7.9 Effects of yield changes on farm income[1] and "priority ranks"[2] when alternative technologies are introduced

Farming System	Model	Alternative technologies	Model Price	WHEAT 15% dec	WHEAT 25% inc	BARLEY 15% dec	BARLEY 25% inc	TEFF 15% dec	TEFF 25% inc
				- - - - Ethiopian Birr - - - -					
A.	1	Existing	523.70(8)	461.68(8)	770.89(8)	507.03(8)	644.83(8)	481.89(8)	570.84(8)
	2	HYV	655.00(4)	526.74(4)	869.26(4)	632.10(4)	681.01(4)	609.50(4)	706.55(4)
	3	Fertilizer	499.51(9)	381.29(9)	695.98(9)	481.16(9)	567.57(9)	455.57(9)	549.18(9)
	4	HYV & fertilizer	577.95(6)	457.11(6)	779.34(6)	559.32(6)	634.81(6)	532.46(6)	629.48(6)
	5	HYV & herbicide	625.05(5)	496.79(5)	839.31(5)	602.11(5)	651.11(5)	580.05(5)	676.04(5)
	6	Fertilizer & herbicide	472.74(10)	354.52(10)	669.21(10)	454.18(10)	532.72(10)	429.27(10)	521.89(10)
	7	HYV,fertilizer & herbicide	561.14(7)	440.30(7)	762.53(7)	542.31(7)	610.23(7)	515.96(7)	612.34(7)
	8	HYV,fertilizer & combine	1999.18(2)	1682.41(2)	2608.17(2)	1966.44(2)	2036.28(2)	1969.94(2)	2032.35(2)
	9	HYV, fertilizer, combine & herbicide	1962.85(3)	1646.09(3)	2571.80(3)	1930.12(3)	1999.15(3)	1932.62(3)	1995.58(3)
	10	Combination of all technologies	2011.25(1)	1651.25(1)	2641.58(1)	1979.57(1)	2047.25(1)	1983.17(1)	2043.07(1)
B.	1	Existing	308.47(10)	308.47(10)	308.47 10)	308.47 10)	308.47 10)	231.68(10)	533.12(10)
	2	HYV	820.81(7)	764.50(7)	952.35(7)	793.50(7)	851.82(7)	752.21(7)	999.32(7)
	3	Fertilizer	848.87(6)	804.34(6)	968.34(6)	818.24(6)	883.44(6)	778.17(6)	1007.32(6)
	4	HYV & fertilizer	960.00(4)	825.73(4)	989.08(4)	926.28(4)	998.41(4)	934.56(4)	1330.91(4)
	5	HYV & herbicide	783.15(9)	678.20(9)	903.21(9)	756.12(9)	813.85(9)	717.48(9)	981.50(9)
	6	Fertilizer & herbicide	809.02(8)	717.78(8)	941.01(8)	778.39(8)	843.61(8)	738.32(8)	986.97(8)
	7	HYV,fertilizer & herbicide	924.25(5)	805.34(5)	991.91(5)	905.95(5)	978.02(5)	914.48(5)	1229.30(5)
	8	HYV,fertilizer & combine	1938.11(2)	1884.42(2)	2565.07(2)	1898.83(2)	1982.64(2)	1561.94(2)	1998.96(2)
	9	HYV fertilizer, combine & herbicide	1898.38(3)	1810.47(3)	2489.77(3)	1835.92(3)	1914.73(3)	1502.72(3)	1943.57(3).
	10	Combination of all technologies	2032.86(1)	1656.68(1)	2659.82(1)	1994.26(1)	2076.60(1)	1983.91(1)	2134.33(1)

[1] The farm income is for all crops with yield change for one crop at a time.
[2] Figures in brackets are priority ranks for new technology.

Table.7.10 Effects of outprice change on farm income[a] and priority ranks[b] for alternative technologies.

Farming Systems	Model	Alternative Technologies	Model Price	WHEAT 25% decrease	WHEAT 50% increase	BARLEY 25% increase	BARLEY 50% increase	TEFF 25% decrease	TEFF 50% increase
	1	Existing	523.70(8)	432.69(8)	770.89(8)	507.03(8)	644.83(9)	499.51(8)	570.84(7)
	2	HYV	655.00(4)	466.24(4)	1032.51(4)	655.00(4)	669.29(8)	655.00(4)	655.00(4)
	3	Fertilizer	499.51(9)	394.07(9)	840.74(9)	499.51(9)	697.30(6)	481.89(9)	499.57(9)
	4	HYV & fertilizer	577.95(6)	457.27(6)	929.00(6)	577.95(6)	768.15(4)	577.95(6)	577.95(6)
A	5	HYV & herbicide	625.05(5)	461.68(5)	1002.57(5)	625.05(5)	637.98(10)	625.65(5)	625.05(5)
	6	Fertilizer & herbicide	472.74(10)	359.23(10)	813.93(10)	472.74(10)	662.46(7)	471.74(10)	472.74(10)
	7	HYV, fertilizer & herbicide	561.14(7)	436.30(7)	912.18(2)	561.14(7)	743.37(5)	561.14(7)	561.14(8)
	8	HYV, fertilizer & combine	1999.18(2)	1497.99(2)	3186.77(2)	1999.18(2)	1999.18(2)	1999.18(2)	2119.42(1)
	9	HYV, fert. combine & herb.	1962.85(3)	1460.78(3)	3150.39(3)	1962.85(3)	1962.85(3)	1967.85(3)	2083.18(2)
	10	Combination of all tech.	2011.15(1)	1702.23(1)	3220.18(1)	2011.15(1)	2011.15(1)	2011.15(1)	2011.15(3)
	1	Existing	308.47(10)	308.47(10)	308.47(10)	308.47(10)	308.47(10)	231.68(10)	533.12(10)
	2	HYV,	820.81(7)	772.95(7)	1018.40(6)	828.81(7)	835.85(7)	750.11(9)	1089.54(9)
	3	Fertilizer	848.87(6)	794.36(6)	1083.21(4)	848.81(6)	848.87(6)	848.87(4)	1109.99(8)
	4	HYV & fertilizer	960.00(4)	960.12(4)	997.40(8)	960.12(4)	960.12(4)	812.21(5)	1461.06(4)
B	5	HYV & herbicide	783.15(9)	731.26(9)	989.81(7)	783.15(9)	808.36(9)	712.46(7)	1130.80(7)
	6	Fertilizer & herbicide	809.02(8)	754.51(8)	1043.37(5)	809.02(8)	809.12(8)	809.02(6)	1153.70(6)
	7	HYV fertilizer & herbicide	924.25(5)	939.73(5)	983.06(9)	939.73(5)	939.73(5)	797.88(8)	1434.01(5)
	8	HYV fertilizer & combine	1938.11(2)	1337.02(2)	3140.29(2)	1938.11(2)	1938.11(2)	1938.11(2)	2044.90(2)
	9	HYV fert. combine & herb.	1898.38(3)	1284.82(3)	3054.92(3)	1872.86(3)	1872.86(3)	1872.86(3)	1872.86(3)
	10	Combination of all tech.	2032.86(1)	1542.14(1)	3215.62(1)	2032.86(1)	2032.86(1)	2032.8611)	2459.95(1)

a. The farm income refers to income for all crops when output price charge for single crop

b. Figures in brackets are priority ranks for alternative technologies with output price change for single crop.

Table 7.11 **Effects of inputs price changes on farm income[a] and priority ranks[b] of alternative technologies**

Model	Alternative technologies	Farming System A: Model price	Farming System A: Wheat 30% decrease	Farming System A: Barley 30% decrease	Farming System A: Teff 30% decrease	Farming System B: Model Price	Farming System B: Wheat 30% decrease	Farming System B: Barley 30% decrease	Farming System B: Teff 30% decrease
1.	Existing technology	523.70 (8)	568.10 (8)	523.28 (8)	534.62 (8)	308.47(10)	318.05(10)	312.63(10)	320.86(10)
2.	HYV	655.00 (4)	677.87 (4)	658.00 (4)	656.11 (4)	820.81 (7)	833.20 (7)	824.30 (7)	827.59 (7)
3.	Fertiliser	499.59 (9)	573.25 (9)	512.11 (9)	509.32 (9)	846.87 (6)	871.30 (6)	855.28 (6)	860.51 (6)
4.	HYV and fertilizer	577.95 (6)	604.08 (6)	583.65 (6)	581.14 (6)	960.00 (4)	963.04 (4)	965.73 (4)	984.93 (4)
5.	HYV and herbicide	625.05 (5)	653.82 (5)	628.94 (5)	627.24 (5)	783.15 (9)	799.27 (9)	787.82 (9)	796.84 (9)
6.	Fertiliser & herbicide	472.95(10)	513.89(10)	479.60(10)	473.32(10)	809.02 (8)	835.18 (8)	816.60 (8)	820.75 (8)
7.	HYV,fertilizer & herbicide	561.14 (7)	586.92 (7)	566.38 (7)	564.70 (7)	939.73 (5)	943.05 (5)	946.20 (5)	965.93 (5)
8.	HYV, fertilizer, combine	1999.18 (2)	2088.53 (2)	2006.45 (2)	2007.66 (2)	938.11 (2)	2027.64 (2)	1930.14 (2)	1937.37 (2)
9.	HYV, fert. combine, herb.	1962.62 (3)	2060.20 (3)	1970.74 (3)	1971.92 (3)	1898.38 (3)	1993.311(3)	1887.25 (3)	1894.73 (3)
10.	Combination of all tech.	2011.15 (1)	2061.44 (1)	2037.90 (1)	2036.00 (1)	2032.86 (1)	2113.631(1)	2016.29 (1)	2014.77 (1)

[a] The farm income refers to income from all crops with input price change for one crop at a time.
[b] Figures in brackets are priority ranks for new technology.

technologies, the established priority which is laid down in a much longer perspective, is unlikely to change.

7.7 Policy Implementation and some Constraints on the Farming Systems

7.7.1 Working Capital as a Possible Constraint

The above analysis indicated that substantial potential exists to increase income in the future through adopting income maximizing plans in Ethiopian highland farming systems. However, with the improvement of agriculture from its traditional form, more working capital would be required to meet the costs of high yielding variety seed, fertilizer, hired labour, combine thresher and harvester etc. Operating capital is a scarce resource in the study area and is one of the factors leading to low income and resource productivity. In this section the working capital requirement for the simulated model which should be financed through ARDU/MMP credit programme will be examined. Table 7.12 shows the programme estimates of working capital requirements for both farming systems. As compared to the existing level, the models showed that in farming System A plan 2,4,5 and 7 would require 34.83, 19.03, 15.19, 8.01 per cent less working capital and plan 3,6,8 and 9 about 19.28, 36.76, 171.14 per cent more working capital respectively. In farming System B, all plans except plan 5 (less 25.23%), would require 42.96, 66.23, 11.96, 10.07 per cent more capital respectively. Furthermore, the models showed that in Table 7.4 and 7.5 crop returns net of all operating expenses would rise to around 344.73, 372.77, 664.31,419.46, 352.76, 644.82, 1052.20, 1033.08, 1068.45 Birr per hectare in farming system A and 390.86, 371.17, 457.14, 372.85, 385.24, 447.14, 922.90, 903.99, 968.03 in B,

Table 7.12 **Working capital requirements in the nomative farm plans as compared to existing levels.**

Alternative Technologies and Plan[a]	Farming System A: Working Capital required	Farming System A: per ha working capital required	Farming System A: % change over existing level	Farming System B: Total working capital required	Farming System B: per ha working capital required	Farming System B: % change over existing levels
	--- Birr ---			--- Birr ---		
1.	153.29	80.64	-	174.46	83.08	-
2.	100.03	67.11	-34.83	198.59	94.57	+13.83
3.	182.85	136.45	+19.28	249.41	118.77	+42.96
4.	124.12	142.66	-19.03	175.00	83.33	0
5.	130.00	87.25	-15.19	130.44	62.11	-25.23
6.	209.64	155.97	+36.76	290.44	138.10	+66.12
7.	141.00	162.07	-8.01	195.33	93.01	+11.96
8.	415.63	218.75	+171.14	465.94	221.88	+162.07
9.	452.03	237.93	+85.61	511.42	243.53	+193.14
10.	388.09	204.25	+153.17	371.50	176.66	+112.94

[a] 1. Existing technology, 2. existing technology with HYV, 3. existing technology with fertilizer, 4. existing technology with HYV and fertilizer, 5. existing technology with HYV and herbicides, 6. existing technology with fertilizer and herbicides, 7. existing technology with HYV and fertilizer and herbicides, 8. existing technology with HYV, fertilizer and combine, 9. existing technology with HYV, fertilizer and combine and herbicides, 10: combination of all technologies.

respectively. Corresponding figures at the existing level are only 275.68 and 146.89 Birr per hectare in farming System A and B respectively. The potentially high profitability of the alternative simulated plans using alternative technologies suggests that during intervention and policy implementation periods, the availability of working capital should also increase to match the adoption of alternative new technologies. As some credit was available at the initial stage of the adoption process, and the amount required is small compared to profit, it is hoped that the availability of working capital during the adoption of the simulated technology would not be a constraint. However, the relatively high level of productivity achieved in the models leads to profitable net returns from agricultural production. For example, in Model 8 the net income is 1999.18 and 1938.11 Birr in farming Systems A and B respectively. These returns are about four times the total working capital needed. It would thus appear the optimal resource use in the study area would result in the creation of self-sustaining agriculture which could rely entirely upon its own savings to finance agricultural production.

7.7.2 Bullock Power as a Possible Constraint

As discussed earlier, draught power was included as a constraint in the model on the understanding that draught power requirements follow a similar seasonal pattern to human labour requirements. Major changes in the draught power requirement would come from the expansion of high yielding varieties hectarages. However, this is traditionally a slack period of agriculture and because of that it would utilize draught power in the slack season and is not likely to be a limiting factor. Even during threshing periods where shortage could arise, farmers would be able to use co-operative

Table 7.13 Comparisons of draught power supply and requirements under alternative technology

Farming Systems	Alternative Technologies	Total Bullock Power Supply	Total Bullock Power requirements Ploughing	Planting	Threshing	Total	Bullock Power Supply & Req. Balance
		hrs					
	1	2240	518	169	324	1011	1229
	2	2240	456	177	327	960	1280
	3	2240	406	155	309	870	1370
	4	2240	257	97	324	678	1562
A	5	2240	456	177	327	960	1280
	6	2240	406	156	309	931	1309
	7	2240	257	97	314	668	1572
	8	2240	578	228	158	964	1276
	9	2240	574	228	159	897	1343
	10	2240	598	250	314	1162	1078
	1	2240	517	139	373	1029	1211
	2	2240	550	149	795	1494	746
	3	2240	586	135	766	1487	753
	4	2240	458	109	801	1368	872
B	5	2240	550	150	804	1504	736
	6	2240	586	135	766	1487	753
	7	2240	458	109	800	1367	873
	8	2240	670	175	55	900	1340
	9	2240	670	175	52	897	1343
	10	2240	670	175	753	1598	642

exchange oxen labour as they do traditionally. Other livestock might also be used for this purpose. The assumption that human labour always becomes limiting before draught power, can now be tested by applying input coefficients for draught power use derived from the farm survey to the cropping patterns determined by the linear programming procedures.

Table 7.13 presents total bullock power requirements for the study areas in operational periods for the programming solutions. In comparing the supply of animal power hours with requirements, the table shows that there would be no shortage of draught power in critical periods even in the most labour demanding plans. Therefore, given the labour constraints in the model, these results suggest the availability of draught power will limit the attainment for patterns in production and resource use represented in the farm solution under alternative technologies.

7.7.3 Response to Technological Change

Although the methods are premised on the adoption of new practices and technologies, which will bring about large increases in output and incomes, the task of persuading the farmers to accept these innovations is both difficult and expensive. In this study the type of changes suggested affect the crop mix, varieties of seeds used, change in the amount of fertilizer used etc. However, it is unreasonable to expect the average farmer to follow the same crop combination for pursuing profit as vividly as the models implicitly assume. It is true the farmers have economic goals to be achieved by their production and they do in fact respond to technological innovations in order to achieve their economic goals. For example, as regards to the adoption of highly divisible technology (fertilizer) in an area of Ethiopia

(Chilalo and MMP), Ingvar (1975) found that usually there had been a lag of one or two years between early adopters and late adopters. However, the diffusion of this technology has spread quickly to virtually all the study areas. The same trend was observed in adopting high yielding varieties of wheat and teff by the sample farmers. However, there are some economic as well as social reasons why farmers might decline to accept technological change. Even if it is assumed that the farmer can identify the crop combination which would yield the highest profit, yet he may not consider it worthwhile to adopt precisely that combination, because he may feel that the extra monetary gains do not justify the extra managerial effort involved or he may prefer to produce those crops which require less pocket expenditures. However, if farmers feel that the management and supervision of crop production as shown in the models would create much strain, then it is very likely too that hectarags actually devoted to different crops and those indicated int the simulated models will vary to some extent.

7.7.4 Government Price Policy as Possible Constraint

One of the major problems under the present administration is that farmers do not seem to get adequate support in terms of prices, sufficent to generate an incentive for the farms to increase their output. Often government policy seems to be aimed at achieving conflicting multiple objectives. On the one hand, the aim is said to be to provide incentives for farmers to produce more by inducing them to increase the use of production inputs such as high yielding varieties and chemical fertilizers, while on the other hand, the aim is also said to be to protect the urban population from unreasonably high food prices. (Tecle, 1975; World Bank, 1983). If price policy is to achieve both of these conflicting objectives, as it is now, then it is likely that producers' incentives will be seriously affected. The government has fixed the price of most agricultural products at a point which has discouraged agricultural production by smallholder farmers (ILCA, 1983; Rahmato, 1984:66). Ceilings have been set at such low levels, that the production of some major crops has been reduced by farmers, while the prices of major farm inputs like fertilizers, pesticides and petroleum have escalated (World Bank, 1983:22). In fact the price policy has been designed to benefit the urban population whose incomes are relatively higher than those of the rural population. In the absence of a price subsidy programme benefitting farmers, such a programme has a regressive effect on adoption of the new technologies.

If the present price policy is allowed to continue for a long time, farm income will inevitably decline, due to low farm gate prices. Furthermore, the combination of low farm gate prices and high prices of farm inputs, implies that agricultural development schemes such as ARDU and MMP will be adversely affected because farmers' incentives to adopt innovations could be greatly diminished, leading to a reduction in food production in future years in spite of the growing demand for food.

Given the above major problems with regard to government control of prices and the failure to adopt a coherent price policy which would encourage farmers to increase their production, a changed price policy becomes necessary during the implementaton of the alternative plans. A favourable price should be one that results in an increased supply of farm products by providing incentives to farmers to use their resources and the new production technology efficiently, in order to increase farm productivity. We suggest the government intervention through price support programmes. This needs to be announced in advance and should be backed up by a guaranteed purchase to provide a minimum expected price to reduce the risk in planning production decisions by farmers.

7.7.5 Notes

1. Some of the collection, processing and reporting of the data generated under on-farm trials programmes in some areas, is not of a high standard. The World Bank (1983:35), Nichola (1985:60) reported that due to inadequate transport facilities and funds at the right time, in some areas, it was not possible to monitor the plots very closely to generate the data that would be of a practical value for policy.
2. It should also be noted that over a period, a number of crop varieties of wheat and barley are released in the case study areas (Table 7.14) but some are abandoned as their yield has broken down due to disease and other problems (Nichola, 1985:30; World Bank, 1983:35). The experience at ARDU and MMP areas shows that new varieties are grown on the average for about four years only, before they are abandoned.
3. for further details on yields see appendix G

Table 7.14 Wheat and barley varieties released and abandoned in the study areas

Crop	Variety	Year of Release	Reason for abandonment
WHEAT			
	Kenya	1967	Stripe and stem rust
	Kentana Frontana X		
	Mayo 48	1968	Stem rust
	Yaktana 54	1968	Stem rust
	Salmoyo	1969	Stem rust
	Supremo	1969	Stem rust
	Romany	1970	Stem rust
	Laketch	1970	Stem rust
	K. Mamba	1970	Stripe rust
	K. Kanga	1971	Leaf blotch
	Romany Backcross	1973/74	Under cultivation
	Dereselgnekcross	1976	Under cultivation
	Enkoy	1976	Under cultivation
	K 6290-Bulk	1978	Under cultivation
	K 6295-4A	1983	Under cultivation
BARLEY			
	Atlas	1970	Smut
	C-63	1971	Smut
	Mari	1971	Low yield
	Beka	1971	Variety was mixed
	Proctor	1972	Under cultivation
	Arussor	1973	Under cultivation
	Holker	1979	Under cultivation
	Bedi Black	1979	Under cultivation
	Composite 29	1979	Under cultivation
	IAR/HI 485	1979	Under cultivation

Source: Nichola, T. (1985). Agricultural Research and Extension in Ethiopia: The State of the Art, IDR Research Report No. 22, pp. 31-32

CHAPTER VIII

SUMMARY AND CONCLUSIONS

8.1 Introduction

This chapter provides a summary of the study and highlights of the main findings and conclusions. It does not attempt to provide a detailed resume of the entire analysis but seeks to provide salient features of the methodology and major empirical findings and their policy implications.

8.2 Summary

Among the major policy issues facing agricultural planners in Ethiopia is that of how to raise the productivity of small holder agriculture. Improving the productivity of existing farming systems requires, at the very least, a knowledge of resource use pattern and technological change. Yet there has been little empirical research which helps policy makers to determine development opportunities and formulate an agricultural development strategy in Ethiopia. Until a substantial amount of research has been conducted to fill the gap in this important area, planners are unlikely to be able to offer with any degree of precision, a solution to the problems of low productivity, nor to predict the effect that any policy decision is likely to have on people at production levels.

This study was designed to explore empirically the means and possibilities of improving existing farming systems through the introduction of new technological packages.

Specific objectives were:-

1. To study the historical experience of the impact of new technology on agricultural production and its effect on farm resource use.
2. To identify factors that tend to constrain production of farm crops at farm level.
3. To explore the means and possibilities of development under existing and potential alternative technologies.
4. To discuss the implication of the result to formulate technology and research policy.

In the light of these specific objectives, the principal hypothesis investigated was that low productivity in Ethiopian agriculture is mainly due to the use of traditional technology, and an increase in farm productivity is most likely to arise from technological improvements in agricultural production.

In testing the stated hypothesis the methodological approach of enquiry embraced a comparative time series method (Historical Method) and formal modelling of the farming systems.

In a comparative time series approach of analysis, an attempt has been made for the first time in Chapter III, to give empirical content to the change in production technology from the introduction of technological packages in the Ethiopian highlands. The data for the study were taken from 1967/70, 1974/76 and 1979/80 FMS. Methodological and data problems in technological change studies were discussed. A shift in parameters of production were estimated at three points in time using the Cobb-Douglas production function.

The result of limited empirical data indicated that the introduction of technological innovation has led to the adoption of new technology which has considerably raised the productivity of traditional agriculture. The findings indicated an upward shift in production, establishing conclusively the important role of new technology in agricultural production. The estimate derived on the basis of the coefficients of a dummy variable which was interpreted to represent percentage upward shifts, shows that the production function of period II and period III is higher by 21% and 19%, respectively, above the production surface of the base year.

The next step in this line of enquiry was to investigate the relative performance of small and large in the farms post-technological change period, (that is, 1974/76 and 1979/80). Theoretical and methodological issues in farm size and productivity were first assessed. Translog production function was used to estimate the production relationship. However, the findings of this study have shown the weakening of the generally accepted inverse relationships of farm size and land productivity in peasant agriculture. The extent to which appropriate analytical tools are needed and misleading policy implications drawn in agricultural development theory are also highlighted.

The limitations of a comparative time series approach of analysis, were the lack of sufficient comparable time series data and the limited use of the production function techniques to provide essential insights into the farming systems. Given the time span involved between the periods of study, the variety and quality of the data used, raises some question about comparability. There was a variation in the coverage of the area and sample size of the data collected between the periods. Furthermore, the aggregate production function techniques which were used, provided only limited knowledge regarding the impact of technological change. It was, therefore, important to examine further the possibilities of raising the productivity of the agriculture of smallholders. This involved the use of formal modelling of the farming systems. Static linear programming models were used to identify constraints in crop production and to explore possible production frontiers available to farmers at the present time in two representative farming systems. The structure of the basic linear programming model is described in Chapter V. The model was formulated to maximize net income after meeting the food consumption requirements of the household. The activities in the model were crop production, consumption, marketing, labour hiring and borrowing and the constraints included land, family labour, animal power, machine power and operating capital. Using the data from 1979/80 average input-output coefficients on per hectare basis for family and oxen labour by crop operation, average seed input and output per hectare by crop were estimated. Similarly, the average coefficients for objective function, consumption and the price of output were also estimated. The unit of analysis was a representative farming system based on an average farm derived from the sample farms. Using the above model, Chapter VI investigated constraints in farming systems and opportunities for raising farm income through re-allocation of existing resources. In the study area, favourable natural and human resources would suggest the opportunity for improvement in this way.

Yet examination of a representative farming system does not indicate that such is the case. When the optimising solutions are compared with the actual farm performance, the opportunities for improved resource allocation appear limited; few major differences in cropping patterns between actual farms and programmed models are disclosed and farm net revenue are raised by an average of only 8% and 11% in the farming Systems A and B, respectively.

The models are also used to indentify constraints in the farming systems. The programming solution shows that the improvement in farm income and resource productivity are limited by scarcity of land and seasonal farm labour during harvesting and weeding periods. Based on this result, it was argued in Chapter VIII that, a necessary condition of the problems of low resource returns and deficiency in agricultural production is relaxation of constraints in farming systems by:

1. the introduction of new agricultural production technology in the form of new and improved inputs such as high yielding varieties, fertilizers, improved ploughs for better soil cultivation, combine harvesters and threshers;
2. increased use of labour on household farms during critical periods;
3. use of increased amounts of operating capital along with efficient allocation of farm resources and improved production technologies.

The initial step in the analysis was the identification of proven innovations in the farming system and some estimation of the input-output coefficients for technological packages. The imputed resource values derived from the base model's dual solutions are used as the basis for proposing specific technological innovations. An estimation of input-output relationships for identified potential technologies is based on the information from on-farm experimental trials in the study areas. This has been suitably modified based on the field observations and resource endowment of the farmers under study.

The results of a series of linear programming experiments covered three types of analysis. First; experimentation with the developed model by introducing selected potential technological packages to a representative farming systems revealed the following technological possibilities:-

1. Farming system A

The increase in income per farm by introducing 1) high yielding varieties; 2) fertilizers; 3) high yielding varieties and fertilizers; 4) high yielding varieties and herbicides; 5) fertilizers and herbicides; 6) high yielding varieties with fertilizers and herbicides; 7) high yielding varieties with fertilizers and combiners; 8) high yielding varieties with fertilizers; combine and herbicides; 9) combination of all new technologies produced an income increase of Ethiopian Birr 655.00(+25.10%), 499.51 (-4.49%); 577.95(+10.35%); 625.05 (+19.35%); 472.95(-9.73%); 561.14(+7.15%); 1999.18(+281.74%); 1962.62(+274.80%); 2011.25(+287.64%) respectively.

2. Farming System B

The introduction of 1) high yielding varieties; 2) fertilizers; 3) high yielding varieties and fertilizers; 4) high yielding varieties and herbicides; 5) fertilizers and herbicides; 6) high yielding varieties with fertilizers and herbicides; 7) high yielding varieties with fertilizers and combiners; 8) high yielding varieties with fertilizers, combine and herbicides; 9) combination of all new technologies produced an income increase of Ethiopian Birr 820.81(+166.68%); 848.87(+152.68%); 960.12(+211.21%); 783.15(+153.83%); 809.02(+162.27%); 939.73(+204.64%); 1938.11(+528.29%); 1898.38(+511.42%); 2032.86(+559.01%).

Secondly the analysis of the MVP of resources showed that the amount of land and labour in peak periods was a critically limiting factor in agricultural production. The redistribution of land, the introduction of credit opportunities to permit the availability of operating capital for purchasing new inputs and hiring additional labour during peak periods or an increase in the amount of family labour, substantially improved the potential for achieving increases in farm income, output, resource use and productivity with the selected new technologies in both farming systems.

Thirdly, the ranking of policy strategy for the introduction of selected alternative potential technologies revealed the following order of production priority:-

1. Farming System A:

1) a combination of all technologies; 2) HYV fertilizers with combines; 3) high yielding varieties with fertilizers, combines and herbicides; 4) high yielding varieties; 5) high yielding varieties and herbicides; 6) high yielding varieties and fertilizers; 7) high yielding varieties with fertilizers and herbicides; 8) existing technology; 9) fertilizer; 10) fertilizer and herbicide.

2. Farming System B:

1) a combination of all technologies; 2) high yielding varieties; fertlizer and combine; 3) high yielding varieties; fertilizers; combines and herbicides; 4) high yielding varieties and fertilizer; 5) high yielding varieties and herbicides; 6) high yielding varieties; 7) fertilizers and herbicides; 8) technology with high yielding varieties and herbicides; 9) fertilizer; 10) existing technology.

Fourthly, sensitivity analysis of the effects of output and input changes and change in yield on the established priorities of technological packages indicated that there would be no substantial alteration in the order of established priorities.

Hence the results obtained in this study strongly support the main hypothesis made earlier on the strategy of increasing productivity and alleviation of rural poverty in Ethiopia. The findings of this thesis have shown that a significant improvement in farm income and productivity can be achieved by introducing the most appropriate technologies along with favourable credit policies.

8.3 Conclusions and Policy Implications

On the basis of the findings of this study, certain policy implications can be made. These refer to agricultural development policy, improved data collection methodology and technology policy.

8.3.1 Implication for agricultural development policy

Some policy implication emerging from the results of the study are presented in this section on the assumption that the data, the analytical framework and the unit of analysis have a reasonable degree of validity. The quantitative estimates obtained may not be of the exact magnitudes but they could provide relevant insight and guidelines that would aid the understanding of the role of new technology in the development of smallholder agriculture.

The perspective implied by the results of this study for agricultural development in Ethiopia is essentially encouraging. It is clear that there is some potential for achieving significant increases in farm income, output, resource use and productivity through the adoption of the new technology. Therefore, based on this study, planning for agricultural development should continue to focus on the design and implementation of programmes aimed at facilitating expansion in the use of new technology among smallholders. This is especially true of programmes that are concerned with improved access of smallholders to credit and new technology; programmes for making the inputs or elements of the technology available to smallholders at the right time and of programmes that are aimed at improving profitable marketing and output and extension programmes designed to improve the farmers' familiarity with, and competence in, the use of technology.

The results of the study have also indicated that labour in peak periods is a critically limiting factor in agricultural production both under existing and alternative new technologies. The potential for achieving increases in farm income, output and resource use and productivity is substantially improved when measures are taken to break the labour bottlenecks in peak periods. One such measure is the relaxation of current government policy that forbids hiring seasonal labour and the provision of credit opportunities for small farmers to enable hire of additional labour required during such periods. The capacity of credit availability to enhance the potential of new technology for achieving improvements in farm income and productivity is demonstrated by the results of the study. The introduction of unlimited credit opportunities with new technology substantially increased farm income and productivity. This emphasises the complementary relationship of credit services and new technology and suggests that credit should be made an important component of the new technology package.

The long-term solution to the labour problem during harvesting and weeding periods is likely to consist of measures such as selective mechanization of farm operations and use of herbicides that significantly improve the efficiency of labour used during peak periods. This suggests the expansion of the renting programme and the number of combine harvesters and threshers within ARDU and MMP extension schemes.

8.3.2 Implication for improved data collection methodology

Although it has been established that the choice of models was appropriate for the purposes in hand, the shortcomings of an Ethiopia data base have frequently been alluded to. Indeed, some important criticisms have been set out and problems of the difficulties of constructing and estimating models to study the impact of technological changed discussed. Nevertheless, the data base used was unique in that it was collected with the clear intention of increasing knowledge about the farming systems, without a sufficiently developed analytical and methodological framework. The considerations suggest at least two important questions. First, if efforts to evaluate the impact of technological change in this way are worthwhile, what are the implications for data collection? Secondly, if current approaches are not practical, what can be done to improve the data collection procedures?

The first question relates to measuring the performance of technological change through comparative time series method of data collection. With a comparative time series approach of data generation proposed for this type of study, it is suggested that suitable baseline studies should begin long enough before the introduction of new technologies. Data collections should continue at intervals in post-technological change. Without time series information spanning a sufficient period, it is difficult to obtain a real understanding and a measure of the magnitude of structural changes that have taken place resulting from new technology. It would seem then, that if there is a serious intention to monitor and ultimately evaluate the rate of new technology, policy makers should allocate time and resources to generate the data base.

These general approaches of data collection procedures contain other implications. Those who undertake the evaluation studies must approach their survey work with a clear idea of the nature of the data required for this type of study. Furthermore, there must be an explicitly stated set of questions to be answered and a carefully selected analytical framework before the data collection begins. The collection of data should be part of a systematic and consistent analytical structure. In the past, although data has been extensively collected through multi-visit surveys and crop sampling studies in areas where new technology is introduced, it seems to the author that little thought has been given to precisely what it is that should be monitored or evaluated, or the likely role that properly conducted studies should play in the formulation of future policy.

For example, in the light of the importance of new varieties of crop in this type of study, the sample survey and crop cutting survey in the area should have observed the varieties grown by farmers. Observations on various draft inputs and estimates of the field farm size also needed greater attention than the existing approach allowed. Data on pest and disease incidence would have increased the knowledge of factors that affect output. Given this consideration, it is recommended that in future, basic biophysical data such as rainfall, incidence of pest and disease, land and cropping patterns and socio-economic data on farm level inputs and outputs and their producer prices be collected. Background knowledge is also needed on the structure of farms, families and other local institutions. These data will help researchers and policy makers to follow the impact of technology over a period of time and also establish relevant resource and environmental constraints. Potential technologies for the sets of conditions defined in this way may then either be developed or chosen from other places. Such technologies can be released through on-farm research programmes, which are observed in trials and demonstration plots over the target areas.

It is suggested that these data be collected under the FSR programme of the IAR. Such work should be encouraged through close collaboration between the already established institutions of Ethiopia, such as AAU, ARDU, Ministry of Agriculture, IDR, ILCA and other interested international organisations. Given proper supervision, it can be also handled in student papers and theses.

8.3.3. Implications for Technolgical Development

The extent to which agricultural development can take place in the highland farming systems will depend much on the availability of appropriate technology, smallholders can use. This study has shown that a lag in agricultural growth in the study areas is attributed to the failure of the country to shift from traditional agriculture to a science based agriculture. Long-term growth in agricultural production therefore, requires a research programme that continually generates new production technology

In Ethiopia, as shown in this study, the past screening work of crop varieties by the IAR has resulted in the identification, selection and release of improved crop varieties of wheat, teff, barley, maize and sorghum. However, the release of new varieties has slowed down significantly in the past five years and there seems to be even less potential value in the pipeline. Some of the existing improved varieties which were developed earlier, in many instances, started to break down in their resistance to disease, and intermixing of varietites seems to have taken place. Further more, IAR's performance in the improvement of pulses and oilseeds has not been successful. Re-establishing of vigorous screening of important and local genetical material, selection and breeding would thus need to be given very high priority. This will need to be given close attention in the design of the research projects now under preparation by IAR. Both local and international resources must be employed.

8.3.4 Implications for On-farm Experimental Research

On-farm experimental research is designed to screen empirically the potential technological improvemts arising from station research and to evaluate their potential in the context of the local and regional situation (Clayton, 1983: 152). In essence, this activity is a continuation of a station based research, with respect to technology testing, except that the technologies are recommended for further testing on farmer's fields and economic circumstances, before final extension recommendations.

In Ethiopia, the high degree of physical, economic and cultural variability in agriculture, demands a large quantity of resources in regionally decentralized adaptive research. At present our study shows, that on-farm trials are carried out in each of 440 development districts, on a one-hectare plot. This plot is divided into many sections where trials with different fertilizer application rates, seed varieties, culture practices and crop rotations, are carried out. While such plots are expected to visually demonstrate to the farmers the advantage of the recommended package, and also provide the research input to development projects, the performance in some areas is far from satisfactory. It was concluded that some of the monitoring procedures and the data generated are inadequate to be of any practical value. One of the major reasons for weak monitoring and data collection, is the inadequate transport facilities and the unavailability of funds at the right time during the implementaion periods. Owing to the varied excological features within Ethiopia, there is a need for greatly expanded programmes of co-ordinated applied research that can provide information to be disseminated through the extension programme. This requires sufficient allocation of research funds to strengthen the current programmes and to expand to other geographical areas in the country. International agencies should be asked to support these projects with a carefully prepared study.

8.3.5 Implications for Analysis and Interpretation of Already Collected and Available Data

Recent years have seen an explosion of rural data gathering in developing countries. The collection of these data is almost always an expensive operations. Data are in most cases collected with multivisit surveys to minimize errors in the recall period. This method is very expensive. Further more, the greater relative need for physical counts and measurements of the variable add substantially to the cost per sample unit. A country can not afford to waste scarce resources on collecting data that will not put to good use in planning and policy decisions. Every data collected need to be carefully analyzed and interpreted to aid the improvement of resource allocation decision by policy makers. However, despite the importance of the available data in terms of cost savings and a potential in economics research many of the survey data has never been analyzed as is the case with FMS data in Ethiopia. Results from many more are delayed in LDC and much of their value has been lost by researcher because they are difficult to process.

It is a disturbing feature that important resource allocation decisions are made on the basis of limited knowledge and often inadequate information while the available data are stored in computer data bank or in Ministries files. These precollected data as demonstrated in this thesis have a tremendous potential for accomplishing original research that may be used to improve decision making process of planners and policy makers. Furthermore, in as much as original data can not be gathered for the time past, existing data can be used to probe shifts in the parameters of production over periods of time. Add to these important considerations are also is its potential for resource savings. It requires less money, less time and few personnel that is needed only for obtaining the data and preparing for processing. Given the scarcity of resources and manpower in data collection in LDC and the importance of existing data for policy, it is recommended that more emphasis is given in the analysis and interpretation of already collected and available data in the country. New data collection scheme should be based on lessons that have been drawn from previous surveys and should not be encouraged until available data are analyzed and interpreted.

8.3.6 Implications for the Development of Less Complex Data Management Systems

FMS data management possess a major problems for researcher in many Developing Countries. There has been a tendency to collect a wide range of data, paying little attention to how the data is to be analyzed and interpreted until after the data collection is finished. As a result, many of the collected data are frequently never analyzed let alone published. It often took more than a year, sometimes several years, from the start of field work to final reporting. Much of this time was absorbed in manual tabulation of the data(Dixon, 1983:6).

Researchers are now slowly starting to realize that data processing must be considered as an integral part of the entire survey design, data collection and data analysis chain of events. Data Processing and analysis take as many resources as data collection but the manuals on survey methodology pay little attention to processing problems. Furthermore, there are no computer facilities that may be used easily to process FMS data in LDC.

Until recently, researchers had three options with respect to data processing in LDC's. They could rely on hand processing, use local computer facilities if available, rely on computer in developed countries.

The expectations and requirements of the sponsoring agency, together with the researchers own desire to be comprehensive, and lack of pool of reliable numerate clerks, almost always rules out a revision to hand methods with large samples. Those who have attempted to use local main frame computers facilities have almost always had to accept considerable delays due to machine maintenance and engineering support, power fluctuations, poor operating procedures and a lack of trained personnel.

The reliance of developed countries computer has also lead to a number of undesirable delays and often unforseen results. There is a divorce in both time and space in data collection and processing. Data have been collected and transcribed to form suitable for key punching or put on tape, and then shipped out of the LDC for processing. This has meant that large data sets which often require regular and careful checking (validation) during the collection process have either been left unchecked or manually checked by the supervisors and enumerators or checked only in an environment far from their origin. The powerful tool of immediate and routine computer checking has been foregone. This inability to feed back in a timely fashion has limited the ability of the surveys to produce reliable data and has adversely affected the timeliness of the analysis and the survey results.

The above experience in LDC suggests the need to give emphasis to the problems of the processing of the survey data as of the dominant factors in survey design. This could be done by application of micro-computers to conventional aspects of processing data from sample surveys and developing less complex data management packages for subsistance agriculture.

The use of micro-computer in LDC agriculture will prevent the distancing of the surveyors from the data that occurs often with main-frame installations and can further the validation and analysis of the data at the time of the survey. However, this potential role of micro-computer in enhancing the processing of th FMS data depends on the development of simple software packages that can be easily learned and used in LDC at field level. This package should be based, as far as possible, on standarized FMS terminology, pre-coded questionnaires and computer programmes that can be modified under specific situations. It should be simple to learn without any knowledge of computer languages and how computer systems operates. Furthermore it needs to be an interactive package that would enable the user to undertake all commonly required task of data collection, processing and analysis of FMS data that is collected from subsistance agriculture. More importantly, the package should also offer a basis for unified system of rural data collection , analysis, storage and retrieval.

To date to the knowledge of the author, there are no such packages. Experience from this study shows that the packages available in Developed Countries for FMS data processing and analysis are too complex for the use in subsistance agriculture. Others packages such as FARMAP and SNAP that are developed for rapid and flexible processing and analysis of rural survey data in LDC are also in early stage of development. These packages requires a lot of modifications and field testing before they match the claims. It is recommended that more resources should be devoted in the development of less complex data management systems for use by field researchers. Extensive test is needed to be carried out in many countries in which the data are collected before introducing any packages for practical uses.

8.3.5 Implications For Further Research

Discussion on the need for further research will be based on perceived weaknesses in the current study. The study of technological change can be undertaken at a number of levels ranging from the individual farm to aggregate economy. A full understanding of the nature and process of technological change would demand study at all levels within the framework of ex-post and ex-anteanalysis. This study was directed to technological change at micro level and is based on aggregate data. It represents an experiment in the use of primary and secondary data and the documentation of the analysis of the impact of new technology in specific locations in the area of Ethiopia. It was not intended to generalize for Ethiopia as a whole. This limits the scope of the application of the results of the study. The results of the study need to be complemented with the results of similar studies in different agro-ecological zones and in different years, in order to obtain a comprehensive picture that permits broad generalization to be made concerning the impact of technological change. Therefore, there is a need to study the impact of technological change at farm, regional and national level.

Another limitation of the study has been the static nature of the analysis. Static models used in this study approach are useful when production decisions are short-term in the farmers' decision-making framework. However, farmers operate in a dynamic world. Unlike dynamic models, static models cannot provide detailed information about the adjustment path of the production environment as it proceeds from one set of policy variables to another. Time series information is likely to be of greater use for policy evaluation than simple knowledge of one period.

The usefulness of the study is also limited by its failure to provide any insights concerning the distributive effects of new technology. This used to be an important area for study in pre-agrarian reform given the Government's was concerned with the issue of income differential. Research is thus required to shed some light on the effects of income distribution which result from the use of new technology in the post agrarian reform period.

Despite limitations, the results of the study provide useful insights into the likely micro level impact of technological change in smallholder agriculture and broaden the scope of knowledge concerning the role of new technology in agriculture.

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APPENDICES

Appendix A. Cropping Patterns and Input-Ouptut Data in Ethiopian Highland Farming Systems, 1979/80

Appendix Table A.1 Input/Output data for farming system A.

	CROPPING PATTERN								
	Wheat	Barley	Teff	Maize	Sorghum	Horse Beans	Field Peas	Flax	Total
A. Technical data									
1. Total cultivated land (has)	0.54	0.70	0.21	0.12	0.05	0.17	0.08	0.03	1.90
2. Labour inputs (hrs/farms)									
Ploughing	89.64	83.30	35.70	13.02	6.15	18.53	7.44	2.31	256.15
Planting	38.34	25.20	9.87	4.08	0.78	5.27	2.32	0.81	86.67
Weeding	101.52	120.40	60.27	14.28	7.00	13.94	6.16	0.60	324.17
Harvesting	83.70	91.00	58.17	31.20	7.75	31.11	10.56	4.44	317.93
Threshing	46.44	46.20	17.43	7.20	2.75	6.80	2.56	1.14	130.52
Total	359.64	366.10	181.44	69.84	24.43	75.65	29.04	9.30	1115.44
3. Ox-pair (hrs/farm)									
Ploughing	179.28	166.60	71.40	26.16	12.30	37.06	13.28	4.32	510.40
Planting	80.46	40.60	18.27	7.20	3.40	7.99	4.00	1.26	163.18
Threshing	100.44	123.30	55.02	14.40	5.50	15.30	6.40	2.67	323.03
Total	360.18	330.50	144.69	47.76	21.20	60.35	23.68	8.25	996.61
4. Physical input (kg/farm)									
Seeds	73.44	102.20	7.56	4.80	0.05	34.51	9.44	0.87	
Fertiliser	45.90		13.86						
5. Total crop production (kg/farm)	820.80	1211.00	203.30	158.40	48.25	173.40	66.40	15.30	
6. Yield (kg/per ha)	1520	1730	1070	1320	965	1020	831	510	
7. Consumption per household	199	260	207	133	81	200	38	3	
B. Economic Data									
1. Producer price (Birr/kg)	0.52	0.34	0.59	0.33	0.35	0.36	0.52	0.56	
2. Gross value of production (Birr/farm)	426.92	387.52	119.52	52.14	16.89	62.28	34.32	8.87	1108.74
28. Variable costs (Birr.farm)									
Seeds	38.18	32.70	4.46	1.58	0.17	12.42	4.88	0.50	
Fertiiser (0.90 Birr/Kg)	41.31		12.47						
Total	79.50	32.70	16.93	1.58	0.17	12.42	4.88	0.50	148.72
4. Consumption Birr/household	103.48	83.20	122.13	43.89	28.35	72.00	19.76	1.74	474.55
5. Net income (Birr/farm)									485.47

Appendix Table A.2 Input/Output data for farming system B.

	CROPPING PATTERN								
	Wheat	Barley	Teff	Horse Beans	Field Peas	Chick Peas	Lentils	Flax	Total
A. Technical data									
1. Total cultivated land (has)	0.19	0.49	0.90	0.27	0.13	0.11	0.04	0.05	2.10
2. Labour inputs (hrs/farms)									
Ploughing	34.20	79.38	152.10	37.26	13.00	10.34	2.88	3.00	332.16
Planting	10.45	19.60	43.20	9.18	3.25	4.07	0.76	1.15	91.66
Weeding	36.10	129.85	258.30	25.38	2.54	5.03	0.96	2.25	465.41
Harvesting	47.12	93.10	304.20	32.40	17.16	16.94	5.00	6.50	522.42
Threshing	17.67	29.89	76.50	11.80	8.06	4.73	1.20	1.35	151.20
Total	145.54	351.82	834.30	116.02	49.01	41.11	10.80	14.25	1562.85
3. Ox-pair (hrs/farm)									
Ploughing	68.40	113.60	214.20	74.52	26.00	20.68	3.12	6.00	526.52
Planting	17.86	32.34	63.00	12.15	4.68	5.83	1.20	1.50	138.56
Threshing	33.63	72.52	176.40	41.85	21.71	18.70	6.16	7.95	378.95
Total	119.89	218.46	453.60	128.52	52.39	45.21	10.48	15.45	1044.03
4. Physical input (kg/farm)									
Seeds	18.05	56.35	43.20	36.99	14.30	7.15	0.52	1.85	
Fertiliser	15.01		78.30						
5. Total crop production (kg/farm)	159	331	1012	313	126	71	23	24	
6. Yield (kg/per ha)	795	828	1124	1160	966	643	572	474	
7. Consumption per household	210	312	387	231	57	40	38	4	
B. Economic Data									
1. Producer price (Birr/kg)	0.52	0.34	0.59	0.36	0.52	0.37	0.63	0.58	
2. Gross value of production (Birr/farm)	82.68	105.92	597.08	112.68	65.52	26.27	14.49	13.34	1017.98
3. Variable costs (Birr.farm)									
Seeds	9.39	18.03	25.49	13.32	7.44	2.65	0.33	1.07	
Fertiliser(0.90 Birr/kg)	13.50		70.47						
Total	25.60	18.03	95.96	13.32	7.44	2.65	0.33	1.07	158.84
4. Consumption Birr/household	103.48	99.84	228.35	83.16	26.52	14.82	23.94	2.32	582.39
5. Net income (Birr/farm)									276.75

Appendix B. Sensitivity analysis of the basic model

A simple method of assessing the effects of possible changes in key variables on the basic model and in turn, on the farmers circumstances is the sensitivity test. The sensitivity test indicates how possible changes in events resulting from uncertainties about the future can affect the income of the farmers. In this study we have carried out this test on key factors such as yield, land and labour constraints which affects farmers income. Table B.1, Table B.2 and Table B.3 show the effect of increase and decrease of these factors. The results of these tables show that only a slight change occurred in income in changing the availability of weeding labour. Harvesting labour and land availability appears to have a more critical effect on income.

Appendix Table B.1 Effect of yield increase on total farm income (% yield increase)

	Farming systems					
	A			B		
Crop	25%	50%	75%	25%	50%	75%
Existing	523.70 -	-	-	308.47 -	-	-
Wheat	717.70	932.80	1137.90	340.39	361.65	420.71
Barley	644.63	813.14	981.00	349.80	375.86	394.46
Teff	570.00	602.38	624.83	485.69	664.77	844.46
Maize	545.01	560.97	570.49	-	-	-
Sorghum	534.55	541.78	546.97	-	-	-
Bean	556.26	579.96	593.46	329.86	374.85	468.85
Pea	529.27	554.97	643.88	331.39	429.45	529.95
Chickpea	-	-	-	-	-	-
Lentil	-	-	-	-	-	-
Flax	524.44	524.98	525.29	309.68	309.77	311.48

Table B.2. Changes in model solution for a given change in land parameters.

Farming Systems	Level of constraints	Level of resource	Change in net income	Model solution MVP/ha
	1.42	1.42	269.12	643.18
	1.75	1.75	666.27	643.18
	1.90	1.90	523.70	12.64
	2.31	1.99	524.82	0
	2.77	1.99	524.82	0
A	2.24	1.99	524.82	0
	3.70	1.99	524.82	0
	4.16	1.99	524.82	0
	4.62	1.99	524.82	0
	5.09	1.99	524.82	0
	5.55	1.99	524.82	0
	2.10	2.10	308.47	416.90
	2.31	2.31	389.89	376.95
	2.77	2.77	563.31	376.99
B	3.24	3.24	740.49	376.99
	3.70	3.70	913.78	373.72
	4.16	4.12	1070.30	0
	4.62	4.12	1070.30	0
	5.09	4.12	1070.30	0

Appendix Table B.3. Changes in model solution for a given change in labour parameters

Level of constraints	level of resources	Change in net income	Model solution MVP/ha
Harvesting labour (Farming System A)			
316	316	523.70	4.07
450	328	570.99	0
500	328	570.99	0
600	328	570.99	0
Weeding labour (Farming System B)			
371	371	308.47	0.49
310	310	398.25	
474	419	311.15	0
500	486	311.15	0
600	486	311.15	0

Appendix C. Estimation of Input-Output Coefficient for Technolgical Change

C.1. Methodological Approaches

Actual observation of some input-output requirement for the alternative technological packages in Table 7.3 were not possible. Therefore, for anyalysis reasonable estimates on the basis of experience and professional advice was used to derive the coefficients.

1. Family Labour

a) Fertilizer was applied during the planting period. The planting labour input where fertilizer was used as packages were assumed to increase by the amount of labour required to apply fertilizer.

b) Seeds had to be planted at the recommended seed rate given in Appendix Table C.7. Therefore, the labour input of the existing farming system for planting was also assumed to increase by the amount of labour required to plant the increased or decreased seed rate.

c) All harvesting and threshing labour were assumed to require an increase by the amount of labour to harvest and thresh the increased yields due to alternative technologies. With packages where combine harvesters and threshers were used, harvesting and threshing labour however, was replaced by machine time for the two operations. It was assumed that combine thresher and harvesters are available on a rented basis.

d) Labour for ploughing and weeding was kept at the same level as observed as the existing methods. It was assumed that the farmers practices were of acceptable standards.

e) In packages where herbicides were used, hand weeding was replaced by herbicides application time. It was assumed that the labour input for hand-weeding was the amount required to apply herbicides.

Tables C.2 and C.3 shows the estimated labour requirements for alternative technological packages by crop and operations.

2. Oxen Labour Input

For all packages, oxen labour for ploughing and planting were maintained at the same level as that for the existing farming methods. However, because of yield change over to the new technological packages, the oxen labour input for threshing was assumed to increase by the amount required to thresh the increase in yield.

Table C.2 and C.3 shows the estimated labour requirements for threshing when alternative new technologies are used.

Recommended Inputs and Outputs Used

Fertilizer

The recommended rates of fertilizer applied and their respective costs are given by the type of fertilizer in Table C.4.

Appendix C.2. Estimated family, oxen and machinery labour requirements of selected crops for alternative packages in farming systems A.

Crop	Operation	1	2	3	4	5	6	7	8	9
						Hours/ha				
Wheat	Ploughing	166	166	166	166	166	166	166	166	166
	Planting	71	65	88	81	65	88	81	65	65
	Weeding	188	188	188	188	14	14	14	188	14
	Harvesting	155	178	188	326	178	188	326	0	0
	Threshing	86	99	104	181	99	104	181	0	0
	Oxen									
	Threshing	186	214	226	391	214	226	391	0	0
	Machinery/harvesting/threshing								1	1
	Family Labour									
Barley	Ploughing	119	119	119	119	119	119	119	119	119
	Planting	36	24	51	39	24	51	39	24	24
	Weeding	172	172	172	172	14	14	14	172	14
	Harvesting	130	165	119	173	165	119	173	0	0
	Threshing	66	125	61	178	125	61	178	0	0
	Oxen									
	Threshing	177	169	162	235	169	162	235	0	0
	Machinery/harvesting/threshing								1	1
Teff	Ploughing	170	170	170	170	170	170	170	170	170
	Planting	47	39	81	63	39	81	63	39	39
	Weeding	283	283	283	283	14	14	14	283	14
	Harvesting	277	316	342	569	316	342	569	296	296
	Threshing	83	92	102	170	92	102	170	0	0
	Oxen									
	Threshing	262	292	323	551	292	323	551	0	0
	Machinery/threshing								2.5	2.5
Maize	Ploughing	109	109	109	109	109	109	109	109	109
	Planting	34	23	54	43	23	54	43	23	23
	Weeding	119	119	119	119	14	14	14	119	14
	Harvesting	260	650	728	825	650	728	825	825	825
	Threshing	60	150	168	227	150	168	227	227	227
	Oxen									
	Threshing	120	300	336	454	360	336	454	454	454
Sorghum	Ploughing	123	123	123	123	123	123	123	123	123
	Planting	39	19	61	41	19	61	41	19	19
	Weeding	140	140	140	140	14	14	14	140	14
	Harvesting	155	403	417	642	403	417	642	642	642
	Threshing	55	142	148	227	142	148	227	227	227
	Oxen									
	Threshing	110	286	296	455	286	296	455	455	455
Beans	Ploughing	109	109	109	109	109	109	109	109	109
	Planting	31	22	51	42	22	51	42	22	22
	Weeding	82	82	80	14	14	14	14	82	14
	Harvesting	183	225	518	546	225	519	546	546	546
	Threshing	40	101	113	109	101	113	109	109	109
	Oxen									
	Threshing	90	227	255	268	227	255	268	268	268

Appendix C.3. Estimated family, oxen and machinery labour requirements of selected crops for alternative packages in farming systems B.

Crop	Operation	1	2	3	4	5	6	7	8	9
		Hours/ha								
	Family Labour									
Wheat	Ploughing	180	180	180	180	180	180	180	180	180
	Planting	55	72	71	88	72	71	88	88	88
	Weeding	190	190	190	190	14	14	14	190	14
	Harvesting	248	389	411	712	389	411	712	0	0
	Threshing	93	204	216	374	204	216	374	0	0
	Oxen									
	Threshing	177	545	576	998	545	576	998	0	0
	Machinery									
	Harvesting/threshing								1	1
	Family labour									
Barley	Ploughing	162	162	162	162	162	162	162	162	162
	Planting	40	34	55	70	34	55	70	77	70
	Weeding	265	265	265	265	14	14	14	265	14
	Harvesting	190	296	284	411	296	284	411	0	0
	Threshing	61	122	117	169	122	117	169	0	0
	Oxen									
	Threshing	148	380	365	527	380	365	527	0	0
	Machinery									
	Harvesting/threshing								1	1
	Family Labour									
Teff	Ploughing	169	169	169	169	169	169	169	169	169
	Planting	48	31	72	55	31	72	55	55	55
	Weeding	287	287	287	287	14	14	14	287	14
	Harvesting	338	208	230	383	208	230	383	383	208
	Threshing	85	90	100	166	90	100	166	0	0
	Oxen									
	Threshing	196	319	397	661	359	397	661	0	0
	Machinery									
	Harvesting/threshing								2.5	2.5
	Family Labour									
Beans	Ploughing	138	138	138	138	138	138	138	138	138
	Planting	34	37	54	57	37	54	57	57	57
	Weeding	94	94	94	94	14	14	14	94	14
	Harvesting	120	285	182	237	285	182	337	337	285
	Threshing	44	81	51	95	81	51	95	95	81
	Oxen									
	Threshing	155	221	247	261	221	247	261	261	261

Appendix Table C.4 Recommended type and rate of fertilizers and average costs of fertilizer

Crop	Fertilizer, Kg/ha[a]		Fertilzer, Birr/ha		Total
	DAP	Urea	DAP	Urea	Cost[b]
Wheat	70	45	42	34.20	76.20
Barley	46	41	41	31.16	72.16
Teff	60	40	54	30.40	84.40
Maize	75	75	67	57.00	124.00
Sorghum	100	100	90	76.00	166.00
Beans	100	-	90	-	99.00

Source: [a] IAR (1979) Handbook on Crop Production in Ethiopia
[b] SIDA (1985). Review of Arssi Rural Development, p.5
World Bank (1983). Review of Farmers' Incentives and Agricultural Marketing and Distribution Efficiency, Working P, p. 92

N.B. Fertilizer costs were calculted from the range of prices for the period 1980-84 in which the average price of nitrogen and phosphous was 0.76 and 0.90 Birr per kg, respectively (See SIDA, 1985: p.5).

Seed

Seed rates used are the level recommended by IAR or ARDU and are given in Table C.5. Improved seed costs were estimated on the basis of 4 years average price for a period between 1980-84.

Appendix Table C.5. Recommended seed rate and average cost of improved seeds

Crop	Seed rate[a]	Price per 100Kg(Birr)[b]	Total Cost
Wheat	125	64.50	80.62
Barley	100	61.80	61.80
Teff	30	76.85	23.00
Maize	27	50.50	13.64
Sorghum	5	49.95	2.50
Horse bean	150	50.00	75.00

Source: a) IAR (1979) Handbook on crop production in Ethiopia; Socio-economic Department. Progress report for the period 1979-80

b) SIDA (1985). Review of ARSI Rural Developlemt, p.51

Herbicide

Herbicide recommendation for type, rate and cost of herbicide per hectare is given in Table C.6. Costs of herbicides were estimated on the basis of 2 years average for the cropping season of 1982 and 1983, the average cost being 20.86 Birr per hectare.

Appendix Table C.6 Recommended type and rate of herbicides and average cost, 1982-83

Herbicide	Rate litres/ha	Cost Birr/La
Grammaxon	3.5	24.50
Brominal U -		
46 V	2	23.08
Fluid 600	3	15.00
Average		20.86

Source: Ethiopian Government, unpublished report, Research Department, Ministry of State, Farm Development, 1982-83

Mechanical inputs

Recommended machinery hours are based on ARDU experience and are given in Table C.7.

Appendix Table C.7 Estimated labour and machinery requirements per hectare for Ethiopian highlands.

Crop	Machinery Hrs/ha Tractor	Machinery Hrs/ha Combine	Costs Birr/ha Tractor	Costs Birr/ha Combine
Wheat	7.0	1	228.62	77.85
Barley	7.0	1	228.60	77.85
Teff	7.0	2.5	228.60	194.63
Maize	7.0	2.5	228.62	194.63
Horse bean	7.0	1.5	228.62	116.78

Source: ARDU Publication No. 20 (1982) Costs of production of major crops and grain selling prices. Planning evaluation and budget section. Publication No. 20, pp. 16-17

Appendix D. Summary tables of results for simulated technologies

Appendix Table D.1. Optimal resource and activity levels under alternative technologies in farming system A

	Alternative technologies									
Crop produced	1	2	3	4	5	6	7	8	9	10
Wheat	0.59	0.95	0.81	0.48	0.9[illegible]	0.82	0.48	1.27	1.27	1.48*
Barley	0.68	0.16	0.16	0.11	0.16	0.16	0.11	0.11	0.11	0.11
Teff	0.19	0.17	0.16	0.09	0.17	0.16	0.09	0.09	0.09	0.09
Maize	0.10	0.04	0.04	0.03	0.04	0.04	0.03	0.27	0.17	0.06
Sorghum	0.08	0.03	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.02
Horse beans	0.20	0.09	0.08	0.08	0.09	0.08	0.08	0.08	0.08	0.08
Peas	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Flax	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Resource	**Resource used**									
Land (ha)	1.90	1.49	1.34	0.87	1.49	1.34	0.87	1.90	1.90	1.90
Family labour (hrs) total	1124	1045	1000	798	795	776	660	1030	807	1050
Ploughing	259	228	203	128	228	203	128	286	285	300
Planting	90	77	103	56	77	103	56	99	99	123
Weeding	327	274	245	153	24	22	15	330	30	168
Harvesting	316	316	316	316	316	316	316	316	316	316
Threshing	132	151	133	145	151	133	145	77	77	145
Oxen labour (hrs) total										
Ploughing	518	456	405.75	257	456	406	257	578	574	598
Planting	169	177	155.68	97	177	156	97	228	228	250
Threshing	324	327	308.61	327	309	314	327	158	159	314
Combine thresher (hrs)	0	0	0	0	0	0	0	2	2	1
Operating Capital (Birr)	152.86	100.03	182.85	124.12	130.00	209.62	141.00	415.63	452.07	388.09
Limiting resource	**MVP Birr**									
Land	12.64	0	0	0	0	0	0	1429.30	1408.30	1382.70
Family labour										
Ploughing										
Planting										
Weeding										
Harvesting	4.07	4.67	4.33	4.62	4.53	4.22	4.56	0.11	0.11	0.33
Threshing										
Sales	**Quantity sold in kilograms**									
Wheat	363.65	755.03	1312.27	702.10	755.03	682.38	702.10	2008.28	3862.08	4649.73
Barley	313.43									
Teff	0									
Maize	0							406.18	1230.71	
Sorghum										
Horse beans										
Peas										
Flax										
Net revenue	523.70	655.00	499.57	577.95	625.05	472.74	561.14	1999.181	1962.85	2030.06

*All of Model 4 with the exception of 1ha of wheat.

Appendix Table D.2. Optimal resource and activity levels when alternative potential technologies of crops are simulated in the model of farming System B.

	Alternative potential technologies									
Crop produced	1	2	3	4	5	6	7	8	9	10
Wheat	0.25	0.51	0.60	0.06	0.53	0.60	0.06	1.51	1.51	1.51*
Barley	0.38	0.09	0.20	0.14	0.19	0.20	0.14	0.14	0.14	0.14*
Teff	1.03	1.06	0.29	0.69	1.08	0.29	0.69	0.18	0.18	0.18*
Horse bean	0.20	0.15	0.83	0.09	0.11	0.83	0.09	0.09	0.09	0.09*
Peas	0.10	0.05	0.05	0.98	0.05	0.05	0.98	0.05	0.05	0.05
Chickpeas	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Lentils	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Flax	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Resource	**Resource used**									
Land (he)	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Family labour (hrs) total	1589	1687	1553	1455	1253	1253	1214	1046	654	1538
Ploughing	330	339	319	272	341	319	272	352	352	352
Planting	92	87	124	86	87	124	82	163	163	162
Weeding	474	474	335	317	35	35	76	390	35	287
Harvesting	539	544	544	544	544	544	544	124	89	476
Threshing	154		231	235	245	231	235	17	16	260
Oxen labour (hrs) total										
Ploughing	517	550	586	458	550	586	458	670	670	670
Planting	139	149	135	109	150	135	109	175	175	175
Threshing	373	795	760	801	804	766	800	55	52	753
Combine thresher (hrs)	0	0	0	0	0	0	0	2	2	1
Operating capital (Birr)	174.46	198.58	249.41	175.00	130.44	290.00	195.33	465.94	511.00	388.09
Limiting resource	**MVP Birr**									
Land	416.90	384.12	634.78	52.18	497.42	613.92	63.12	1429.30	1408.30	1429.30
Family labour										
Ploughing										
Planting										
Weeding	0.49	0.34								
Harvestin		0.98	0.49	2.98	0.80	0.49	2.89	0	0	0.11
Threshing										
Sales	**Quantity sold in kilograms**									
Wheat		695.94	901.34		726.11	901.34		4629.76	4623.76	4623.77
Barley										
Teff	774.64	880.68		1131.53	908.55		1131.53			
Horse bean			1748.83			1748.83				
Peashum	48.66			898.95			898.95			
Chickpeas										
Lentils										
Flax										
Net revenue	308.47	820.81	848.87	960.12	783.15	809.02	939.73	1938.77	1898.38	2032.86

*All of model 4 with the exception of 1ha wheat

Appendix Table E.1. Rainfall record in Central Arssi, Ethiopia (mm)

Months	1968/70	1974/76	1979/80
January	7	21	18
February	38	3	16
March	93	72	109
April	76	115	39
May	98	178	68
June	106	118	134
July	257	164	210
August	217	171	173
September	163	130	167
October	113	119	67
November	57	71	12
December	0	0	0
Total	1220	1162	1013

Source: Compiled from CADU/ARDU Annual Reports

Appendix Table E.2 1974/76 Farm Gate Price

Crop	Birr per Kg
Wheat	0.35
Barley	0.28
Teff	0.42
Maize	0.21
Sorghum	0.29
Horsebeans	0.28
Field Peas	0.32
Chickpeas	0.30
Lentils	0.36
Flax	0.39
Rape Seed	0.49
Noug	0.50
Oats	0.33
Potatoes	0.24
DAP fertilizer	0.39

Source: Producer Price Survey 1974/76 in the study area by IAR

Appendix Table F. The 1967/70 and 1979/80 FMS sampling Procedures

The pioneering FMS in the period 1967/70 in the Ethiopian highlands farming systems as noted in chapter II were published by HSIU (1974), Ebba (1970) and CADU (1969). These reports shows that the farmers selected were typical of the region with respect to type of farm, land tenure, size of farms and others factors (HSIU,1974:4; CADU,1969:14)

The methodology of the sample design used is multi-stage. The initial survey included all villages in the study ares. This includes listing of villages and selecting villages by casting lots. From the selected villages all farmers in each village were recorded and one farmer were selected by casting lots. In the final survey 18 in central highlands and 12 farmers in the eastern highlands were visited weekly as part of the farm management investigations.

Similar approach were followed in the 1979/80 survey with some exception of the sampling frame. In the 1979/80 61 farm households data were successfully collected in the central highlands by multi-visit surveys(ILCA,1983; IAR,1981). The sampling frame was the Peasant Associations(PA's).In the first stage of multistage random sampling Peasant Associations were selected at random and the lists of the farmers were recorded. In the second stage, farmers were grouped on the basis of villages in the selected Peasant Associations. Finally, from the grouped villages the required number of farmers were selected at random (ILCA,1983:8).

The sample size considered are small when compared with large sample that can possibly be collected with single visit surveys in other fields. Large sample survey is not always possible for farm management surveys(Upton,1973;213). Given the intensive nature of the survey and the major emphasis on getting accurate and reliable data more weights is given to small samples. For most purpose a sample survey of 30 is regarded adequate(Upton,1973). There is little point in attempting to conduct a large sample survey that is expensive and also difficult to collect and process. Resources would be better used in improving the accuracy of the data to be collected from mangable sample.

These affirmative considerations of small samples does not, of course, imply that the results from small samples is not without problems. The main problem with small and heterogenous samples is that of generalizing the finding of the study. With small sample no statistically valid generalization of the results to a wider population can be made. However, for the developing countries, the problems are those of decisions, not generalization for science. Development policies are likely to be more effective if they take into account the small and hetrogenous samples findings than if they do not.

Appendix table G. Some additional notes on yield assumptions on table 7.2

Yield that the farmers may expect by adopting a particular package are unlikely to be the same with as those realized by researchers in experiment stations. There are differences between the soils, different practices from those employed by researchers and farmers. Unfortunately there seems to be no simple rule to correct the variability at farm levels and experiment station controlled data. Some suggest the expected farmers yield should be reduced by 20 to 30 percent from that achieved in experiment station trials to account for variability(Perrien, et al,1982:21). Others suggest the use of on-farm trials data that would better reflects the farmers circumstances. In this study on- farm trials data managed under farmer conditions were used. These yield data is some what less what can be achieved at seed multiplication farms and closer to the yield records obtained at farm level for some crops by farmers who adopted HYV and fertilizer(Table G.1). These observed difference is mainly due to management practices and the use of non-recommended level of seed and fertilizer by farmers at present time. If farmers were advised to adopt the HYV's tested on on-farm trials with recommended seed rate, date of planting and cultural practices there is a possibility to close the gap between the yield level used in the model and the current farmers practices.

Table G.1 Expected yield of the use of HYV and fertilizers(kgs)

Crops	Experimental stations(1)	25% reduction of experiment station yield data	Seed Multiplication farms(2)	On-farm trials data used	farmers field
Wheat	5300	3975	3000-4000	3200	2670a
barley	5700-6000	4388	2000-2500	2300	2050a
Teff	2200-2800	2100	1900-2800	2200	N.A.
Maize	7700-12000	7788	7000-9000	5000	4976b
Sorghum	4000-7000	4125	4000-5000	4000	4000b
H.beans	2500-3200	2138	2500-3000	2526	-

Source: 1. IAR (1979),opcit.
2. ESC (1982/83)
a. CADU (1973/74), opcit.
b. IAR (1981),opcit.