Chapter Four

Description of Highland Farming in the Study Area

This chapter describes mixed farming systems in the central Ethiopian highlands to indicate some of the direct or implicit effects of crop-livestock integration. The descriptive analysis includes household characteristics, resource endowment, cropping practices, livestock husbandry, farm management problems and strategies. Where possible, a distinction is made in these features between categories of households that own livestock or those that do not. This chapter also serves to provide the information for the validation of the mathematical programming model that is applied in this study.

4.1 Household Structure and Labour Use

The average family size is about 5.02 persons with a standard deviation of 2.39 persons (Table 4.1). Crop farmers tend to have small families (3.65 ± 2.21 members) in comparison with crop-livestock farmers (5.70 ± 2.16). Female-headed households have smaller families (3.62 ± 1.72) than male-headed households (5.42 ± 2.41). Households with more livestock tend to be associated with more male members than those without livestock. The average age of the household head is 50.74 ± 15.64 years, the youngest being 20 years and the oldest about 95 years old. Heads of households without livestock are generally younger at about 48.15 ± 19.14 years of age. Female household heads tend to be more elderly than male household heads, averaging 55.24 and 49.45 years, respectively. Life expectancy in Ethiopia is estimated to be 53 years for females and 50 years for males (Appendix 1). An average household has 2.75 adult-person equivalents available as family labour daily.

All households in the study area are members of the Coptic orthodox religious faith, although other religious faiths are getting audience in the nearby urban centres. More than 90 percent of the household members reside on the farm while a few members live with relatives in nearby rural areas. Other than spouses and children, about 15 percent of those resident on the farm are relatives of the household head (e.g., sister, in-law, grandchildren) and contribute to farm labour. About 16 percent of the households are single-parent families through non-marriage, divorce or bereavement.

Table 4.1 Family Size and Labour Use Mechanisms

Variable	Whole sample n = 94	Crop farms n = 34	Mixed farms n = 23	Male-headed households n = 73	Female-headed households n = 21
Family size	5.02 ± 2.39	3.65 ± 2.12	5.70 ± 2.16	5.42 ± 2.41	3.62 ± 1.72
Adult male	1.36 ± 0.94	1.00 ± 0.55	1.52 ± 1.08	1.58 ± 0.90	0.62 ± 0.67
Young Male	1.15 ± 1.07	1.02 ± 0.76	1.57 ± 1.24	1.21 ± 1.08	0.95 ± 1.02
Adult female	1.44 ± 0.77	1.15 ± 0.66	1.48 ± 0.59	1.41 ± 0.81	1.52 ± 0.60
Young Female	1.07 ± 1.18	1.11 ± 0.74	1.13 ± 1.06	1.23 ± 1.22	0.52 ± 0.81
Age hhd head	50.74 ± 15.64	48.15 ± 19.14	51.04 ± 13.49	49.45 ± 15.92	55.24 ± 14.06
	solutions* to labour shortage as a percentage in the category				
Hire labour	12	19	10	17	21
Exchange labour	28	21	16	35	18
Work longer	54	45	67	58	41
Kinsmen	8	5	2	6	4

hhd = household * Not mutually exclusive alternatives and the percentages may not necessarily add to unity.

Source: Author's survey (1993-94) results.

Different socio-economic and cultural factors influence population growth rate. Illiteracy, pro-natalist attitudes, economic and social functions of children, relatively young age at marriage and status of women in the household are factors that will probably contribute to increasing population (Pausewang et al., 1990). Although household size may not change rapidly, increasing land fragmentation is an indication of population pressure on natural resources (especially land) in the central highlands.

4.1.1 Agricultural labour use

In terms of relative importance, ploughing and threshing each take up about 21 percent of the available labour that is devoted to crops. Weeding and harvesting activities each absorb 15 percent while crop threshing and storage accounts for about 11 percent of the labour that is devoted to crop production. Herding and barn-cleaning each take up 20 percent of the labour devoted to livestock husbandry. Supplementary feeding, livestock watering and making cow dung cakes, each takes about 14 percent of the livestock production labour. Milking and milk-processing takes about 10 percent of the labour. Time spent in going to the market accounts for less than 2 percent of the family labour.

More than 85 percent of the farmers experience shortage of labour for various farm operations during different periods in the production cycle. In the main rainy season, labour shortage is most severe (in order of importance) during harvesting (35%[1]), weeding (21%), ploughing (20%) and planting (13%) periods. This sequence of severity reflects the activities that can be delayed least as they impinge most severely on the expected crop yield. Of the livestock-related activities, hay harvesting (25%), herding (6%) and watering (7%) pose some labour allocation problems. Some livestock activities such as milking cows or supplementary feeding are done during slack periods of the day when crop activities are not being performed and do not pose conflicts in allocation of farm labour.

Despite the abundance of rainfall in absolute terms, its distribution varies between and within seasons. The wet and hot periods often coincide with the most tiresome task of land preparation, planting and occasionally

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[1]The percent denotes the proportion of sample farmers.

weeding. The soils are heavy and the demand on energy input in land preparation activities is often daunting for many farmers. Because of the short spell of actual rainfall, farmers have to work harder in a short period to maximise returns on available soil moisture. During the short rains season, labour shortage is most severe (in order of importance) for harvesting (43%), ploughing (25%), planting (11%), livestock watering (12%) and herding (9%). Harvesting, during the short rainy season, assumes higher prominence because of the risk of stray grazing by animals and the need to harvest quickly to permit timely cultivation of the fields for the subsequent main rainy season. Because seasonal rivers dry up during the dry season, watering of livestock also assumes greater importance during the short rains season.

4.1.2 Gender division of family labour

Allocation of family labour is governed by the age and sex structure of the household. Men are usually associated with farming activities that involve animal traction and use of heavy implements and equipment. Thus activities such as ploughing, planting and fencing (where done) are performed by male members of the household. Because of the unique role of animal traction in the Ethiopian highlands, men seem to be deeply involved in subsistence food production. Women are responsible for household-maintenance activities such as food-preparation, brewing, milk processing and making or repairing clothes and handicrafts (Table 4.2). Women and girls tend to be entrusted with sowing because of the presumed cultural linkage between female fertility and seed germination or soil fertility (Crowley 1994). Women and children also engage in farming activities such as weeding, harvesting and winnowing the threshed crop harvest. Speed and direction of wind are important factors during winnowing.

Each adult household member devotes between 6 and 8 hours per day to farming activities, depending on the season and task performed. Farmers generally work in the early and late cool hours of the day. The intervening lunch break is used for watering animals and resting. Women and children tended to work fewer hours than men in the crop fields, partly because they have to attend to other household chores like preparing meals and child care. Women and children are often engaged in numerous, repetitive and overlapping activities so that it is difficult to estimate the time allocation to each or its relative marginal value. Cooking, for example, is often performed concurrently with milk processing and child care.

Table 4.2 Allocation (%) of Family Labour for Various Activities

Major activities	Female household members		Male household members	
Age category	7-15 years	15-60 years	7-15 years	15-60 years
Crop operations*	10	50	15	70
Herding	15	2	55	5
Training (e.g., schooling)	35	2	15	5
Domestic chores (e.g., cooking)	15	35	0	0
Marketing	10	5	5	10
Weaving and handicrafts	10	2	5	5
Miscellaneous	5	4	5	5
Total	100	100	100	100

Source: Author's survey (1993-94) results.

* These activities include ploughing, sowing, weeding, harvesting and threshing.

During slack periods, household labour is allocated to different non-farming activities according to gender and age of household members. Major non-farming tasks include fencing/building, gathering firewood, collecting cow dung cakes, going to the market, food processing (e.g., milling grain, churning milk) and collecting water. Slack periods are also devoted to visiting friends and relatives, social discussions and helping neighbours and relatives accomplish various activities. There is a strong social obligation to help old people, widows, bereaved families and young couples.

Some tasks overlap and impose restrictions in the use of adult-person hours in quantitative estimation techniques. A child can be engaged in the indivisible task of herding livestock or bird-scaring the whole day yet the same child may be deployed to sell any farm produce by the road-side such hats or fruits. Bird-scaring is time-consuming, often, requiring virtually permanent vigilance over the crop fields until the whole field is harvested, although it may involve a person walking/sitting under the shade. Ploughing or weeding require substantial energy input. Although weeding and bird-scaring require very different expenditures of energy, both activities contribute significantly to the expected farm output.

Apart from observing or participating in religious and social occasions, rural holds tended to be busy throughout the year in various farming and non-farming activities. However, some of the activities that households are engaged in seem to indicate disguised unemployment. Leisurely pace of work through exchanging of labour between households or high frequency of non-farming activities such as visiting relatives is indicative of disguised unemployment. Inter-household exchange of labour is a social insurance (e.g., against illness) scheme of guaranteeing availability of future reciprocal labour and also helps to foster or improve social harmony (Aredo 1994). However, the boundary line between leisure and work is often blurred in rural societies, especially due to overlapping activities. In some cases, solitary labour may yield lower average returns than working in an entertaining group (such as exchanged group labour).

4.1.3 Agricultural labour market

During the (1974-1991) period of collectivist agrarian structure, hiring of agricultural labour was officially prohibited. This restricted households to use only family labour in farming operations despite availability of surplus labour from large households. However, farm labour bottlenecks were reduced through informal inter-household exchange of labour (*debo*) on alternate working days. Following the ousting of the socialist regime, labour markets have been quick to re-emerge. Farmers have developed intricate mechanisms of solving labour shortage problems through hiring of labour, exchanging labour between households on alternate working days, depending on kinsmen from more labour-abundant households, occasional assistance from neighbours, working long hours on their farms as a trade-off to leisure, or leaving land fallow at the start of the crop season.

About 20 percent of the households hire labour. Wage rates depend on the activity and gender of the wage labourer. Female labourers are paid between 3 birr (US $ 0.50) and 5 birr per day. Male labourers are paid between 4 birr and 8 birr per day. Ignoring gender differences and tasks performed, an average wage rate of 0.35 birr per hour represents the marginal wage rate available to all households during the weeding and harvesting period. A mean wage rate of 0.65 birr per hour is an acceptable marginal rate during ploughing time. Hired labour is mostly devoted to harvesting crops or herding livestock (Omiti et al., 1994b).

More than 75 percent of the household members are primarily engaged in farming activities. Only 5 percent of the household members are engaged in non-farm employment such as military or civil service, retail trade or teaching. Agricultural wage labour accounts for less than 10 percent of the sample population. More girls than boys attend school. This could be partially attributed for the need for male children to herd livestock while older members of the household attend to crop production activities. Informal discussions with teachers in nearby elementary schools indicated that there was increased pupil absenteeism from school during periods of peak demand of agricultural labour.

Permanent employment of agricultural labour was observed for annual herding of livestock and other livestock-related activities. Payment is often in the form of some livestock output such as milk or being given a proportion of the progeny (e.g., half of the lambs weaned). This is a wealth-sharing strategy for people who have lost their livestock to begin re-building their own livestock herd. Permanent employment was not observed for crop production activities during the survey period. Farmers generally do not wish to set a precedent for higher wages and thus depend more on exchanging labour between neighbours and kinsmen. Crop-livestock farmers depend more on their own family labour and less on hired or exchanged labour than crop farmers. This is largely because difference in household size and resource endowment. Payment for exchanged labour or kinsmen is usually in-kind rather than cash money, like some grain at harvest time.

Sometimes crop residues and grazing land are given after harvesting time as livestock feed in exchange for labour. Work oxen can also be given to those assisting in farm work so that they use the oxen to plough their fields in exchange of their human labour. There is a strong sense on community belongingness whereby more labour-abundant families help less resource-endowed families in their farming activities.

4.2 Farm Size, Land Use and Land Rentals

The average size of agricultural land per household is 3.32 ± 1.98 hectares. Farm size varies from zero (absolute landlessness) to 10 hectares. Differential household ownership of agricultural land is an important socio-economic feature in the Ethiopian highlands. Farm area can be classified as irrigated land, non-irrigated crop land and pasture land. On average, the size of crop land, irrigated land and pasture land is 2.10, 0.97 and 1.16 ha, respectively (Table 4.3).

There is a distinct difference in farm area per household in relation to livestock ownership. For households without livestock, the size of crop land, irrigated land and pasture land is only 1.65 ha, 0.17 ha and 0.69 ha, respectively. For households with livestock, the size of crop land, irrigated land and pasture land is 2.69 ha, 0.22 ha and 2.23 ha, respectively. Female-headed households have less land than male-headed households. On average, male-headed households have 2.18 ha, 0.24 ha and 1.18 ha of crop land, irrigated land and pasture land, respectively. For female-headed households, the size of crop land, irrigated land and pasture land is 1.81 ha, 0.18 ha and 1.09 ha, respectively (Table 4.3). Clearly, crop farmers have far less land than crop-livestock farmers (2.41 ha vs 5.01 ha). In a random sampling framework, like some previous studies in the study area, an average farm size of about 3.32 ha could obscure resource endowment differences between and within these household categories.

Table 4.3 Farm Size (ha) and Land Use amongst Rural Households

	Whole sample n = 94	Crop farms n = 34	Mixed farms n = 23	Male-headed households n = 73	Female-headed households n = 21
Crop land	2.10 ± 0.97	1.65 ± 0.95	2.69 ± 1.09	2.18 ± 0.97	1.81 ± 0.94
Irrigated land	0.22 ± 0.31	0.17 ± 0.28	0.22 ± 0.31	0.24 ± 0.33	0.18 ± 0.19
Pasture land	1.16 ± 1.20	0.69 ± 0.81	2.23 ± 1.19	1.18 ± 1.19	1.09 ± 1.25
Farm size	3.32 ± 1.98	2.41 ± 1.54	5.01 ± 2.08	3.42 ± 1.95	2.97 ± 2.08
	Solutions* to land scarcity				
Rent-in land (%)	23.4	32.4	17.4	26.0	47.6
Rent-out land (%)	22.3	11.8	47.8	17.8	9.5
Exchange land (%)	26.6	32.4	21.7	27.4	23.8
Fallow land (%)	63.8	52.9	87.0	67.1	52.4

* Not mutually exclusive alternatives and the percentages may not necessarily add to unity.

Source: Author's survey (1993-94) results.

Crop land falls into three categories depending on the farmer's evaluation of its productive potential. Farmer assessment of land productivity is influenced by soil type, distance from the home, susceptibility to waterlogging and frost, suitability for different crops including pasture, and duration the land has been cultivated. On average, about 30 percent of the farm is most productive (*areda* productive land or *lem*) and is nearest to the homestead. About 30 percent of crop land is fairly productive (*non-areda* land or *lem ketaf*). The rest of the crop land is not considered very productive (*yemeda* land or *taff*). *Yemeda* land is often farthest from the homestead and is usually rented-out, exchanged with households near its geo-physical location or committed to pasture. Because of their relatively superior waterlogging and frost tolerance than legumes and their need for less intensive supervision, cereals especially barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*) are the main crops that are grown on *yemeda* land.

In the central highlands, crop land and pasture land each account for about 40 percent of overall land use. Community forests, wasteland and other unproductive lands account for the remaining 20 percent. Annual and perennial crops account, respectively, for 85 and 3 percent of the cultivated area. Land left fallow is approximately 10 percent of total cultivated arable land while irrigated land is less than 1 percent of the land.

Irrigation is mainly through intricate traditional gravitational systems along mountainous river valley locations. The importance of irrigation is incidental and limited by geo-physical location of households. Less than 5 percent of the households can be considered irrigation-only households. Households with access to irrigation were observed to cultivate land more intensively (e.g., in Bakelo PA). High value crops were grown on such irrigated fields such as potatoes, horticultural produce and vetch (leguminous fodder) for feeding crossbred dairy cattle or sale.

4.2.1 Changing farm size and exchange arrangements

Concomitant with increasing land scarcity, rental markets for agricultural land are evolving in the Ethiopian highlands. About 23 percent of the households rent-in agricultural land while 22 percent reported rent-out farmland. About 27 percent of the households exchange agricultural land. There is probably a general tendency to over-state the incidence of renting-in land than renting-out, perhaps, because households do not wish to appear to be over-endowed with land. As would be expected, crop farmers tend to rent-in more land than crop-livestock farmers due to the differential land endowment between these categories of households and vice-versa with respect with renting-out agricultural land. Compared with male-headed households, proportionately fewer female-headed households lease or exchange agricultural land.

Before the 1974 land reform, 18 percent of the households in the study area were landlords, 17 percent usufruct tenants, 60 percent tenants, and 5 percent were landless tenants. Usufruct tenants did not have any rights to claim ownership (ownership rights) over land although they were given varying degrees of access (user rights) to cultivate land by the landlords, often involving different arrangements of field-sharing or share-cropping. The land reform proclamation in 1975 was meant to achieve equal land size per household and improve agricultural performance. Sale of land and hiring of agricultural labour were prohibited. Some of the policy issues pertaining to agricultural performance in Ethiopia since the 1975 land reform are discussed by Belete et al., (1991).

Following the ousting of the military regime in 1991, selling[2], renting and traditional exchange of agricultural land among rural households is increasing. However, within the same period, 32 percent of the respondents reported that their farms have become smaller while 23 percent have now larger farms. Interestingly, these changes have occurred more with crop farmers than crop-livestock farmers. More than 40 percent of the crop farmers and 20 percent of the crop-livestock farmers now have smaller farms (Omiti et al., 1994b).

Sub-division of land among households members, sub-division and re-distribution of agricultural land to other households by local administration officials, respectively, account for 10 percent and 5 percent of the reduction in crop land. Voluntary land sales or long-term leases and afforestation programs account for 20 percent and 5 percent of the reduction in farm size,

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[2]It was quite difficult to elicit correct responses regarding distinction between land purchases or sales and long-term land rentals. Part of the difficulty was attributed to lack of clear public policy on land tenure and farmers' unwillingness to discuss emotional aspects of land tenure. It may be appropriate to treat land purchases or rentals as an indication of existence of a land market.

respectively. Extensive soil erosion and social problems (e.g., divorce) account for 5 percent and 2 percent of the reduction in crop land, respectively.

Reduction in crop land is said to reduce the capacity of households to produce enough food by one third of the respondents and ability to support livestock by about 18 percent of the respondents. In spite of the changes in land size through different acquisition and exchange mechanisms, only about two fifths of the farmers satisfy their subsistence food requirements with their current land holdings. Crop farmers have been affected more by changing land availability than crop-livestock farmers.

Either because of a better income base or pasture requirements, crop-livestock farmers have purchased relatively more land and have larger farm size than crop farmers. Accompanied by less use of defensive measures against land degradation and soil fertility maintenance, crop farmers would become more vulnerable to food insecurity than crop-livestock farmers. If such trends continue, crop farmers are likely to practice more intensive methods of cultivation with little regard to conservation of the land's productive potential because, among other reasons, they cannot afford the necessary defensive and restorative measures.

Increase in the area of crop land has occurred through cultivation of grazing land for 45 percent of the respondents, through long-term leases for another 40 percent of the respondents and through land amalgamation for 15 percent of the households. There is a general tendency towards intensification of crop cultivation for about 60 percent of the respondents. About 32 percent of households with bigger crop land are experiencing increasing grazing pressure than three years ago. Resorting to intensive use of communal and public forests is limited because the area that is under state forests and communal woodlots is generally small. Moreover, forests tend to be located on the worst and most steep hillsides although they provide open access grazing, firewood, honey and, inter alia, medicinal herbs.

4.2.2 Fragmentation of agricultural land

Continuous subdivision and inheritance of land results in excessive fragmentation of non-contiguous land holdings. Studies in the central highlands suggest that land fragmentation has increased and is of greater magnitude than before the land reform. This increase is largely due the consequences of villagisation and re-settlement programs enforced following the 1975 land reform (Fassil 1980, Dessalegn 1984, Yohannes 1989). In the central highlands, about one half of the land parcels are less than 1.0 ha while most households own more than five parcels. Only about 10 percent of the parcels are bigger than 2.0 ha. About half of the parcels are within 1 km radius from the homestead. However, more than 10 percent of the plots are more than 5 km from the homestead. Thus some parcels are as far apart as five kilometres (Table 4.4).

There are many reasons for households holding several fragmented parcels of land. Many of these motivations are likely to be driven by socio-economic and cultural forces. Igbozurike (1970) provides an instructive overview of some of the factors that lead to land fragmentation including land tenure institutions, population pressure, competing land use alternatives and infrastructural development (road and rail construction). In addition to these factors, land fragmentation in the central Ethiopian highlands is attributed to continuous land re-distribution (following the 1975 land reform proclamation) to accommodate the landless or displaced persons, frequent modification of boundaries of peasant associations and subdivision of land among household members (Gebeheyu 1994). In an egalitarian sense, land fragmentation results from the desire to equitably distribute land of different productivity potential amongst households or household members. With a burgeoning population, land fragmentation and attempts to equitably re-distribute land seem to be a poverty-sharing scheme among rural households.

Land fragmentation has some beneficial features in rainfed agriculture. First, cultivation of different non-contiguous parcels of land enables farmers to take full advantage of differences in topography, drainage and soil types. Second, land fragmentation permits households to stagger crop production to mitigate against various types of risk (e.g., frost). Third, it permits scheduling of labour requirements to suit family labour availability profile. Fourth, staggered planting allows staggering of harvesting activities and enable households to have continuous supply of fresh produce and minimise the need for storage (Jabarin and Epplin 1994). Sixth, sometimes, households owning land in nearby lowland areas acquire land in the highlands for settlement (building homesteads) purposes in order to avoid the risk posed by malaria in the lowland areas (Save the Children 1992). Seventh, some parcels are located in valley bottoms while others are located on hillsides, permitting the household to engage in a more diversified combination of crops.

Table 4.4 Fragmentation of Agricultural Land in the Central Highlands

Field size (ha)	Percentage of total farm		Distance of plot from homestead (km)	Percentage of total parcels
< 0.25	5.0		< 0.50	22.5
0.25 - 0.50	10.0		0.5-1.0	20.0
0.50-0.75	15.0		1.0-2.0	20.0
0.75-1.0	15.0		2.0-3.0	15.0
1.0 - 1.25	12.5		3.0-4.0	10.0
1.25- 1.50	12.5		4.0-5.0	5.0
1.50-1.75	10.0		5.0-6.0	5.0
1.75-2.0	8.0		> 6.0	2.5
2.0-2.5	5.0			
2.5-3.0	5.0			
> 3.0	2.0			
Total	100		Total	100

Source: Author's Survey (1993-94) results.

Nonetheless, land fragmentation imposes some additional costs on the household in performing the various activities that would enhance total farm output. First, there is increased travel time from the homestead to cultivate land parcel(s) that are farther away from the homestead. About two-thirds of the sample households complained of the long walking distances, loss of effective working time and the cost of moving farm tools and inputs (e.g., manure or fertilisers) to and from such distant fields. Second, excessive land fragmentation inhibits farmer motivation to adopt or maintain soil conservation techniques (Yohannes 1989). Third, land fragmentation over wide geographical areas increases costs of supervision and protection of crops from wild animals and trespassers or thieves.

Fourth, land fragmentation may necessitate some distant parcels of land being kept uncultivated, reducing total farm production. Indeed, many farmers often leave some of the *yemeda* land under fallow. Fifth, households find it difficult to obtain additional rental land in adjacent locations due to excessive land fragmentation. Sixth, land fragmentation may eventually lead to small parcels of land that may be uneconomic to operate. However, as population increases and land becomes increasingly scarce, individuals will tend to claim private and exclusive use of resources such as communal grazing lands. Public and rural institutions would have to evolve to accommodate problems arising from land scarcity and encourage investment in improved technologies (e.g., high-yielding crop varieties, external inputs).

4.3 Livestock Population and Work Oxen

Less than one percent of the households pursue livestock production as the only farming activity. About 20 percent of the households are crop-only farmers. About 80 percent of the farmers are crop-livestock farmers. Unless they are relatively young households yet to accumulate capital to purchase livestock, most households have at least one or two sheep, a few chicken or one cow. The average number of livestock per household stands at 7.00 ± 6.29 sheep, 1.68 ± 1.33 cows and 1.65 ± 1.12 work oxen (Table 4.5).

The number of sheep, cows and oxen per household tended to be associated with farm size. Male-headed households have more sheep, cows and oxen than female-headed households. Some farmers have as many as 18 cattle, 50 sheep, 6 oxen, 5 donkeys and 4 mules while some have no livestock. The wide social differentiation in ownership of livestock influences livestock herding and other livestock husbandry management practices.

Table 4.5 Herd Size, Oxen Rentals and Some Farming Practices

Variable or Activity	Whole sample n = 94	Crop farms n = 34	Mixed farms n = 23	Male-headed households n = 73	Female-headed households n = 21
Sheep	7.00 ± 6.29	3.12 ± 3.94	10.24 ± 4.58	7.59 ± 6.69	4.95 ± 5.16
Cows	1.68 ± 1.33	0.62 ± 0.78	2.91 ± 0.85	1.79 ± 1.30	1.29 ± 1.38
Oxen	1.65 ± 1.12	0.88 ± 0.95	2.22 ± 0.90	1.86 ± 1.08	0.90 ± 0.94
	Solutions* to oxen scarcity as a percentage of households in the category				
Hire oxen	11.7	17.6	8.7	8.2	23.8
Exchange Ox	19.1	23.5	8.7	20.5	14.3
Sell cow dung	53.2	26.5	100	54.8	47.6
Manure fields	75.5	61.8	95.7	80.8	57.1
Use fertiliser	41.5	26.5	100	39.7	47.6
Soil burning	44.7	69.6	35.3	49.3	28.6

* Not mutually exclusive alternatives and the percentages may not necessarily add to unity.

Source: Author's survey (1993-94) results.

4.3.1 Distribution of draught oxen

Six years ago, the proportion of households with zero, one, two, three and more than three work oxen was 14, 43, 9, 21 and 12 percent, respectively (Getachew et al., 1993). The proportion of households with zero, one, two, three and more than three work oxen during the survey period was 21, 22, 41, 11 and 4 percent, respectively. It is speculated that below an average of about 0.7 ox per household, farming loses its viability for the community as a whole (Save the Children 1992). It is apparent that the proportion of farmers with many oxen is decreasing. About half of the rural households had nil or one ox six years ago compared with only two-fifths during the survey period. Relatively more farmers have a pair of oxen than before and this is attributed to reduction in the category of farmers that owned more than two oxen six years ago. The proportion of households without oxen has increased partially due to increasing land scarcity.

Oxen availability has important implications on the availability of traction and food production for many farm households. Associated with a reduction of ownership of work oxen, about 56 percent of the farmers experience shortage of work oxen for various farm operations during different periods in the production calendar. The most affected farmers are those households with one ox or none.

During the main rains season, shortage of draught animals is most severe (in order of importance) for threshing (26%), ploughing (22%) and transportation (18%). During the short rains season, shortage of draught animals is most severe (in order of importance) for threshing (28%), transportation (24%) and ploughing (22%). About one third of the farmers produce less grain than they would if availability of work oxen was not a constraint. These farmers do not own any oxen. They have to hire or acquire oxen from households with surplus oxen through various animal traction rental or exchange arrangements. Hired oxen are often in poor body condition since they have been ploughing the owner's fields.

Sometimes, ox-owners may require the family borrowing oxen to work for them (as a payment arrangement) at crucial periods which affects availability of the labour of the oxen borrowers for their own fields. Poor land preparation leads to poor crop performance and results in lower crop yields. The desire to minimise cost of traction rentals may prompt households to plough less intensively than is ideally necessary under rainfed agricultural conditions.

4.3.2 Mechanisms of exchanging animal traction

There are many and varied inter-household mechanisms enabling access to animal traction. Adaptations to scarcity of work animals include oxen rentals, exchanging oxen, leaving land under fallow, renting-out arable or pasture land. Twelve percent of the households hire oxen. Crop farmers hire work oxen more than crop-livestock farmers. About 20 percent of the households exchange oxen while less than 10 percent of the respondents borrow oxen (*ribi-in*) from relatives or neighbours.

There is cash payment for hired oxen especially during the ploughing period. The rental rate varies with the type of work being performed and is usually about 8 birr per day for a pair of oxen. The rental rates are highest during the first ploughing and decrease with the number of subsequent ploughing passes. A deferred payment option is to rent one ox at the beginning of the crop season and then give the oxen owner about one third (or some other agreed proportion) of the grain at harvest time. Another alternative is for households to give part of their land to farmers with oxen and receive one third of the grain output in return. A number of households without livestock prefer this less risky, deferred payment option because the amount of payment is not fixed but will depend on the output level that is realised at harvesting time.

Farmers with one ox usually exchange the ox with another household on alternate working days. There is not any cash payment except feeding the animals while the animals are working for either household. In other cases, households without any oxen acquire draught power from kinsmen or sympathetic neighbours on non-cash terms. In-kind payments are usually through feeding the animals with crop residues or giving grazing land to the oxen owner. Many crop farmers, often in a queue for oxen or wishing to minimise risk in a particular season, reduce level of input use (labour and other external inputs) on their fields and instead engage in sharing crop-output with another household with better access to work oxen. In such desperate situations, households without oxen often lose their independence of ploughing and planting different fields with different crops because the oxen owner may have vested interests in ignoring differences in land productivity.

Another in-kind alternative way of acquiring work oxen involves borrowing untrained oxen from wealthier households. The recipient farmer is responsible for training the oxen how to plough, which is a difficult and time-consuming exercise. After a couple of crop seasons, the borrower returns the oxen. This arrangement (*kollo*) is commonly practised amongst relatives and involves the trainer being responsible for feeding the oxen and other general animal husbandry practices.

Oxenless households can also lease different types of arable land to households with two or more oxen and then share the output in different proportions. On good productive land (*areda land*), either household takes half of the produce (known as *yekul* arrangement). On *areda* non-productive land, the land owner receives one third of the produce (known as *siso ande* sharing). From y*emeda* (least productive) land, the land owner takes 25 percent of the grain output (known as *karate ande* arrangement). An interesting adaptation to oxen scarcity has been observed in the nearby northern highlands (e.g., around Kombolcha in southern Wollo region) where households without oxen use hand cultivation to ensure some food production (Save the Children 1992). Sometimes households without oxen do borrow oxen from households with surplus oxen without any direct payments but with a pledge of performing certain obligations of mutual reciprocity.

In other nearby highland areas (e.g., Inewari), farmers are increasingly using horses for cultivation. Horses can survive on lower-quality feed than oxen yet produce twice as much traction compared with same number of oxen on flat fields. The cost of acquiring and replacing a pair of horses is lower (at current prices) than for a pair of oxen. Apart from social prestige attached to ownership of horses, horses provide transport for both farm produce and people (Beyene and Yirga 1989, Mamo et al., 1993). However, equines graze considerable amounts of pasture and impose a high opportunity cost on land resources devoted to pasture production.

Households without oxen and with some surplus labour often offer to exchange human labour for animal traction. Such an arrangement involves working for two days for the oxen owner for each day of oxen work. Households without livestock face a number of constraints that inhibit crop-livestock farming. In order of importance, the most constraining factors to livestock ownership are insufficient land, lack of money to purchase livestock and insufficient herding labour. Diseases, endoparasitism and risk of theft are also considered major factors that constrain livestock farming. Land scarcity and resultant feed shortage will influence the role of oxen as the engine of agricultural development in the Ethiopian highlands in the future.

4.4 Household Farming Goals

Farming goals and aspirations were elicited from each household head (in some cases also from the spouse) in order to gain some insights about highland farming. Households were interviewed twice, at an interval of at least four weeks, to rank the order of priority attached to different households goals. Enumerators were trained how to elicit ranking of conflicting as well as complementary goals. Doubtful ranking was cross-checked by the author with specific household (with the assistance of ILCA field research team(s)).

Despite some inconsistencies, it was possible to obtain reliable preference rankings from 89 out of 94 sample households. In all responses, pursuance of household food production was the most predominant farming goal. The most preferred food crops are *t'eff (Eragrostis abyssinica),* barley, wheat and horse bean. Increasing the number of livestock (cow, work ox or sheep) was the second most important goal. In terms of ranking, farmers attached more importance to increasing the number of cattle than sheep. This is probably because they already have some sheep and would thus like to possess some cattle. Other goals in order of importance were improving housing, income generation, inventory of cooking fuel and educating children.

The villagisation mode of social and agrarian organisation is collapsing. Many farmers would like to fence their plots and build houses to fortify individual claims to private use of land. Already tenure of urban land has been relaxed to permit medium-term property leases. It is anticipated that privatisation of rural land may eventually follow suit if problems of moderating urban land use and ownership rights are articulated and overcome. The scarcity of trees and building materials also imply that many households live under conditions that they would ordinarily not wish to endure, considering the inclement weather at about 2 800 metre altitude.

The importance attached to cooking fuel indicates the scarcity of alternative sources of cooking energy and reinforces the need to increase the number of cattle. Livestock play a crucial role in household food security, family welfare-enhancement and the general functioning of the farming system. These goals are typical of peasant agriculture in terms of subsistence food production and household welfare-enhancement (Parton 1993) through pursuit of more cash income and less drudgery (a motive of income maximisation, as outlined in the linear programming model in chapter five).

4.5 Crop Production Systems

Barley, wheat and oats (*Avena sativa*) are the main cereal crops grown in the study area. Field peas (*Pisum sativum*), lentils (*Lens culinaris*) and horse beans (*Vicia faba*) are the main pulses and linseed (*Linum usitatissimum*) is the main oil crop. Pasture, fallow land and other minor crops occupy the remaining land. Less than 5 percent of the farmers use improved crop varieties although they grow different landraces of the main crops under different climatic conditions. However, the acreage committed to these crops varies with farmers' perceptions of both the climatic and marketing environment. There is more varied crop mix during a good season than during a bad season because of the generally more dependable rainfall, that induces sequential planting as the season unfolds.

Despite its lower price compared with that of wheat, barley accounts for more acreage in the farming systems because of its increasing importance as a staple food crop, ability to withstand frost and it is a more reliable short season crop. Other than being food crops, pulses and oil crops are grown mainly for income purposes. Presence or absence of livestock affects acreage combinations of cereals, pulses and oil crops.

Oats is declining in importance despite its better pest and frost tolerance. However, the story of oats is complex. Farmers incorporated oats into the farming system about 15 years ago when it was mandatory to deliver a fixed quota of wheat and barley to government stores at fixed prices. Since oats was not under the quota requirements, farmers slowly converted into oats production to avoid meeting compulsory cereal quota deliveries. Since the ousting of the socialist (1974-1991) regime, the quotas have been phased out and oats is losing its relative importance. The production of oats may have been misconstrued to imply eventual technology adoption rather than an adaptation to counter official quota requirements at low prices. However, because of its low labour requirements and high straw yield, some farmers still grow oats despite its low price.

4.5.1 The cropping calendar

Rainfall is bimodal and averages about 963 mm per annum, with the short rains season (*belg*) occurring between February and May, and the long rains (*kremt*) season (*meher*) is between June and September. *Belg* rainfall is less predictable than the *kremt*. The cropping calendar varies with crop type and farming strategy (e.g., early planting). In general, land preparation and sowing are conducted between June and August for the *meher* season and between January and February for the *belg* crop (Table 4.6).

Weeding is done between August and October and between March and April for the *meher* and *belg* seasons, respectively. The crops are harvested between November and January and between April and May for the *meher* and *belg* seasons, respectively. Between January and February in the *meher* season and between June and July in the *belg* season, the harvested crop is threshed, winnowed and stored. At the end of either the *belg* or *meher* season, land preparation and threshing activities overlap and are the busiest periods of farming. Depending on the relative importance attached to each farming activity, households perform both activities with varying use of farm resources.

Table 4.6 Generalised Cropping Calendar in the Central Highlands

Belg Season (Jan-June)	Crop Activity	**Meher** Season (June - January)
January - February	Ploughing - Sowing	June - August
March- April	Weeding	August - October
April - May	Harvesting	November - January
May-June	Threshing	January - February

Source: Franzel and Houten 1993, Mamo et al., 1993.

4.5.2 Cropping strategies

There is considerable unpredictability and fluctuations in weather in the highland farming systems. Households pursue different cropping intensities during different rainfall seasons. Because of the importance of timely cultivation, rainfall starting early and ending early was seen as a bad season by more than 65 percent of the respondents. Rainfall starting early and finishing late (excessive and protracted rain) in the cropping season was viewed as a bad season by at least 69 percent of the sample households. Such rains cause serious problems associated with waterlogging, seed germination and weeding. In a wet season, weeds do not wilt quickly and often re-grow, thus waterlogging increases the labour required for weeding.

About 80 percent of the sample farmers consider rainfall starting late and yet ending early (insufficient moisture) as a bad season. The extreme case of not receiving any rainfall (drought) was considered the worst season by all households. Late rains that persisted late into the crop season were viewed as a bad season by at least 90 percent of the households.

During the *belg* season, barley, wheat and lentils are the main crops. If the short rains are expected to be good, more wheat and legume crops are planted leading to a higher share of legumes in the cropping system than when the situation is not anticipated to be favourable. Farmers seem to plant more cereals when the rain is not expected to be good because failed cereal crops can still provide some straw or dry matter to feed animals. Legume crops tend to be more expensive and thus farmers prefer to save seed for domestic consumption than sowing the seeds so that they are subject to the unpredictable weather (Table 4.7).

Weather differences in the *meher* (main rains) season do not cause much difference in the percentage of crop land committed to the various crops. Farmers seem to pursue a less flexible approach regarding crop acreage shares during the *meher* season. This may arise out their farming experience and the willingness to take risk against the vagaries of nature in trying to secure minimum food production levels. As a result of weather uncertainties, more than 56 percent of the respondents opt to plant early while 23 percent plant late in the cropping season. About 12 percent stagger their planting dates while another 5 percent plant in different parcels of land to cope with risk of rain fluctuations, including waterlogging. Of those households that use inorganic fertilisers, about 5 percent deliberately reduced fertiliser application under unpredictable weather regimes.

Table 4.7 Land (percentage) Allotted to Crops in Different Seasons

Crop planted	Bad *belg*	Good *belg*	Bad *meher*	Good *meher*
Season	Short (`small') rains		Main rains (*kremt*)	
Barley	60.3	46.3	39.9	36.5
Wheat	16.4	20.7	20.3	18.6
Oats	6.0	4.3	5.5	5.3
Field Pea	0.9	9.1	7.0	7.9
Horse Bean	0.9	4.3	18.1	22.0
Lentil	10.4	13.4	3.0	4.9
Linseed	3.0	0.0	5.2	4.8
Fallow and Other crops	2.1	0.9	1.0	0.0
Total	100	100	100	100

Source : Author's survey (1993-94) results.

The *belg* crop is very important to at least 20 percent of the farmers and great importance is attached to a successful *belg* strategy irrespective of the expected price. It is apparent that as the weather profile changes from the more uncertain short rains towards a less unpredictable main rains season, the importance attached to crop failure diminishes to permit households to cultivate preferred food crops (Table 4.8). Not less than 30 percent of the households thought that their cropping strategies would fail in the different seasons. The rather high degree of pessimism in their strategies arose from other farm management problems created by pests, disease and other natural factors that affect crop yield potential.

Table 4.8 Selection Criterion (Percentage) for Crops by Season

Farmer's reason	Bad *belg*	Good *belg*	Bad *meher*	Good *meher*
Expected yield	59.5	43.9	42.8	31.4
Expected Price	11.2	24.4	14.8	18.9
Straw yield	12.1	6.1	14.8	16.4
Weed-tolerance	6.9	3.0	7.0	4.4
Staple food	10.3	22.6	20.6	28.9
Total	100	100	100	100

Source : Author's survey (1993-94) results.

4.5.3 Labour and animal traction requirements

Different crops and livestock have different labour requirements during different periods of the year. Similarly, different crops have different requirements for animal traction during ploughing, sowing, harvesting and threshing. The requirements for labour and draught power will also vary between traditional and improved varieties or breeds if the expected output differences are to be achieved. To avoid the differing farmer definitions of a day's work, measurement of labour use was expressed in hours of work rather than in days.

Estimates of requirements of labour and work oxen for crop and livestock production were obtained from field surveys using enterprise-specific requirements per hectare of land and per herd unit basis. To obtain adult-person hour requirements, labour from children (between 7 and 15 years old) and elderly household members (more than 60 years) has been reduced by a factor of 0.5. Average labour and animal traction requirements for various field operations for the different crops are shown in Table 4.9.

The total demand for labour and animal traction for farming and livestock husbandry activities is influenced by the family size, farm size, number of oxen and the desired household production targets. Due to inter-household variations in the type and quality of work performed by different household members, average values of the input-output coefficients for labour and animal traction are used in the linear programming model for both categories of farmers (i.e., those with and without livestock).

Table 4.9 Labour and Traction (hrs/ha) Requirements

	Barley	Wheat	Oats	Field Peas	Lentils	Horse Beans	Linseed	Fenugreek
Ploughing Labour	155	160	115	140	110	135	90	125
Ploughing Traction	140	150	110	90	105	110	60	120
Weeding Labour	70	90	50	70	50	60	30	50
Harvesting Labour	115	105	90	110	80	145	90	70
Harvesting Traction	50	65	55	45	30	50	25	40
Threshing Labour	65	75	55	60	60	75	35	100
Threshing Traction	60	55	50	65	45	140	65	95

Source : Author's survey (1993-94) results.

Note: Farmers spend more time to manually make a finer seedbed for legumes than cereals and hence more labour hours are required than traction hours (during ploughing period) for field peas, horse beans and linseed.

4.5.4 Harvesting crop residues

Farmers in the study area practise different ways of harvesting their crop to maximise on straw yield depending on the resource exchange mechanisms that they are engaged in or whether they expect to experience shortage of animal feed. Three generalisable harvesting practices were observed. First, farmers cut the mature crop at ground-level, heap the unthreshed crop on the field, transport it by livestock (mainly donkeys) to the threshing ground to thresh later, and plough the field almost immediately. This allows any remaining crop biomass on the field to decompose before the next cropping season, and thus improving crop yields in the subsequent season.

A second harvesting practice involves cutting the upper part of the standing crop that is containing the grain, transporting the harvested crop to the homestead or threshing ground and leaving livestock to graze freely on the stubble. Such a field receives manure from the grazing animals and is often ploughed a few weeks before the onset of rains.

A third harvesting practice is to cut only the grain heads and transport the harvested grain to the threshing ground. The rest of the straw is cut separately. Such straw is gathered and used in various ways such as thatching houses, supplementary feeding of animals or is sold in the straw market. Because it permitted estimation of both the grain and straw yield, this harvesting practice is employed to generate estimates of the input-output coefficients that are used in the linear programming model.

Threshing is often staggered depending on a number of factors including the harvesting schedule, crop type and varieties, availability of animals and on-farm storage capacity. Different livestock species (donkeys, horses, cows and oxen) are often used in a group for threshing purposes. Naturally, the more animals that are used the quicker threshing is completed.

4.5.5 Crop yields

Crop grain and straw yields vary depending on several factors including the season, weather, timeliness of planting, land characteristics, varietal characteristics, seed rate, farmer management and input usage. Farmers in the study area sow, if any, low rates of improved seed. For those that do, they use at most 20 percent of improved seed either on a separate plot or mix the improved seed with farm-produced seed on same field plot. The average seed rates (kg/ha) are about 125 for wheat, 100 for barley, 75 for oats, 105 for field peas, 80 for lentils, 140 for horse beans and 50 for linseed (MoA 1987-1993).

According to extension officials, overall seed rates are generally high for a number of agronomic and economic reasons. First, farmers sow large amounts of seed to mitigate risk of crop failure. Second, pests especially rodents gnaw the seed before and during seed germination. Third, high seed rates tend to improve chances of good crop establishment from the low genetic potential of the sown seed. Fourth, high seed rates and quick crop establishment tend to suppress weeds apart from providing for livestock feed during later crop thinning to improve yield potential as the weather conditions become less unpredictable. Fifth, high seeding rates also permit quick crop establishment to protect the soil surface from excessive soil erosion.

Average crop grain and straw yields, for the main rains (*meher*) season, are shown in Table 4.10 with and without the use of inorganic fertilisers. These average crop yield estimates (for both grain and crop residues) are used in the linear programming model to determine the most profitable enterprise combinations. With the current single-season data set, it was not possible to examine the nature of correlations between cash income and crop yields in the study area. However, there is a general improvement in crop yields over time, ignoring drought years of the early 1980s and especially the good weather during the early 1990s. Improvements in crop yields reflect on-going and desirable changes in the agricultural performance of Ethiopian agriculture in its transformation from semi-collectivist agrarian structure towards market-driven production. There is scope to improve on-farm crop yields if the various constraints to improved performance are addressed appropriately.

Yields of dry matter of grass or natural pasture are estimated at about 3.5 to 4.5 tonnes per hectare. It is estimated that such pasture yield can support two head of cattle (per ha) for at least six months or 10 sheep (per ha) per year with weight gains of 86.4 and 154.7 kg per ha. Improved perennial grasses (e.g., *Trifolium spp*) can yield more than 5 tonnes per ha dry matter (Gebrehiwot 1988). However, due to high incidence of overstocking and overgrazing, yields of 3 tonnes per ha are used in the linear programming model to approximate the empirical farm situation. An additional 1000 kilograms in the yield of grass hay is technically feasible and can be produced with a reduction in stocking rates and use of fertiliser or manure on pasture fields.

Table 4.10 Average Crop Yields (Kg/ha) for the *meher* Season in the Study Area

Crop		1987	1988	1989	1990	1991	1992	1993
Barley	grain[1]	650	535	620	630	730	790	830
	grain[2]	800	750	900	950	1000	1030	1200
	straw[1]	900	840	870	920	1080	1280	1300
	straw[2]	980	1170	1250	1360	1370	1460	1500
Wheat	grain[1]	620	680	700	690	710	770	780
	grain[2]	700	730	800	750	890	855	900
	straw[1]	1000	1080	1150	1100	1200	1050	1125
	straw[2]	1120	1250	1300	1200	1430	1320	1470
Oats	grain	N/A	420	580	420	560	590	625
	straw	N/A	800	1000	900	980	1030	1050
Horse Beans	grain	645	580	650	630	680	730	755
	straw	800	730	850	770	920	950	1100
Fpeas	grain	600	700	800	730	750	740	755
	straw	900	950	1150	1000	1180	1200	1240
Lentil	grain	610	600	500	555	600	620	610
	straw	400	450	350	370	380	400	460
Fenugreek	grain	185	210	265	260	310	280	300
	straw	230	250	280	275	300	280	250
Linseed		610	615	590	630	610	650	660

[1] without fertiliser application

[2] with 20 percent of the recommended fertiliser application rate

Source: MoA (1987-1993), Author's survey (1993-94) results.

4.6 Livestock Production

Management of livestock production employs traditional methods that appear to be similar for given household and resource endowment characteristics. Livestock herd size is associated with farm size (with a correlation coefficient of $r = 0.56$) although stocking rates do not vary across household categories. Livestock are generally herded together as mixed herds of cattle, sheep and equines. Breeding is through natural mating except for crossbred cows and, occasionally, equines. Usually farmers who want to have a mule will attempt deliberately to mate a donkey and horse (or vice versa).

4.6.1 Herding and watering livestock

Depending on the schedule of activities on the crop production calendar, livestock feeding is carried out differently reflecting the availability of feed resources and herding labour. Animals are grazed on communal grazing lands, private individual farmer's pasture, available public lands such as forests, school compounds or military training grounds and stubble grazing (during the post-harvest period). On average, livestock are grazed for about 8 hours per day during the dry season and about 6 hours during the wet season. There is a deliberate effort to keep close watch over livestock during the crop growing period to reduce the potential risk of crop damage. Except for hay harvesting, there is generally an even demand of labour for livestock production throughout the year. Including the requirements for milking and barn cleaning (removal of manure from animal shed), the total daily labour requirement for livestock husbandry is about 10 hours.

Livestock in specific physiological or production phases are given supplementary feed. Draught oxen are supplemented to improve traction output and compensate for the time lost for grazing while oxen are ploughing. Gestating and lactating animals are also supplemented. There are many different feed supplements offered to specific or all animals and these include crop residues, grass hay, thinned plants and weeds, crop leaves and brewer's residue (*atella*). Haulms (i.e., pulse residues) are usually mixed with cereal straws or hay before being fed to livestock. Animals are supplemented with crop residues during the wet season when the crop is on the field and feeds are easily and adequately available. During the dry season, there is heavy dependence on communal grazing areas. Grass hay is the commonest feed supplement during the dry season. Supplementation is usually done either early in the morning before animals go out for grazing or late in the afternoon when animals are brought back from the grazing fields.

Old people and children are usually charged with herding responsibilities. Young children commonly look after sheep while older children agist cattle and equines. Households experiencing serious labour and feed scarcity often entrust their livestock to full-time herdsmen at an average annual herding cost of 50 birr (US $ 8.50).

The distance to the water source has an important influence on the number of times and time of the day when animals are given water. Animals are trekked to seasonal rivers, swamps and ponds for watering at least once daily. However, during the rain season the frequency of watering is not very important because the pasture are generally moist and surface run-off is available on depressions around the homesteads or in the pasture fields. Animals have to trek longer distances during the dry season in search of water, pasture and browse. Because of the communal grazing and watering, livestock are susceptible to endoparasites from various sources of feed and water.

4.6.2 Scarcity of livestock feeds

Irrespective of the season, scarcity of livestock feed is severest during the ploughing period and during the dry spell for about 48 percent and 22 percent of the respondents, respectively. The main feedstuffs offered to livestock (in order of importance) are grass hay, crop residues (mainly cereal straw) and grazing along the road-side and communal grazing lands. Apart from on-farm production, about 15 percent of the households buy animal feedstuffs. About 5 percent exchange animal feeds for some livestock output such as animal traction or milk.

Shortage of pasture and browse is mainly a problem with households with large livestock herds. Farmers with one or two animals can often cope with feed shortage through supplementation with grass hay and crop residues. Households with few livestock consider communal grazing land and open access grazing areas as important sources of alternative pasture and browse. However, because of overgrazing in communal and public forests, many households supplement their animals with hay and crop residues to ameliorate animal nutritional status. In all cases, shortage of livestock feed is more of a problem during the *meher* than during the *belg* season because more arable land is devoted to crop production.

When the feed situation gets worse, farmers consider more austere measures to save animals although some strategies may not appear very effective. For example, 28 percent of the households considered resorting to more intensive grazing of communal lands, road-sides and forest areas. About 20 percent of the farmers opted to rent pasture land. Rental markets for pasture land are not well developed and involve both cash and non-monetary payments. About 22 percent of the households would opt to sell cattle while another 18 percent would sell sheep and obtain cash to buy animal feedstuffs to salvage the remaining livestock. About 10 percent of the households with livestock considered entrusting their animals to relatives or neighbours (known as *ribi-out*) with pasture resources as a socially and economically beneficial alternative strategy. However, some farmers depend entirely on communal pasture throughout the year.

4.6.3 Fodder production

From the field surveys, very few farmers commit land to fodder production. Though faced with the same problems as crop cultivation, fodder production is erratic and incidental. Households with crossbred animals and large farm size grow some fodder (e.g., in Bakelo PA). The fodder crops grown are fenugreek (*Trigonella foenum-graecum*), native clover (*Trifolium spp*) and an intercrop of oats and vetch (*Vicia dasycarpa*). Cultivation of fodder crops is affected by several factors including farm size, labour requirements, fodder yields relative to crop straw yields, availability of natural pasture (on own or communal land), prices of fodder relative to crop residue prices and the cropping patterns of both mainstream crops and fodder crops. Fodder production is not commonly practised because of the perceived competition for scarce land and the limitations imposed by soil fertility especially phosphorus deficiency.

Fodder crops provide opportunities for intensification of livestock production and, by removal of livestock from grazing on the fragile hillsides, would help protect such lands from overgrazing, soil erosion and de-vegetation. Furthermore, integration of tree fodder crops into existing farming systems helps serve long-term sustainability concerns by easing fuelwood scarcity and permitting use of animal droppings as manure. In a farming system dominated by annual cereals and legumes, the root residues of tree forages would provide both organic matter when they decompose and also hold the soil together against soil erosion.

Burgeoning population will continue to generate debate about the sustainability of farming practices and the need for intensification of agriculture. Adaptations to resource scarcity such as constriction of fallow periods and increased continuous cultivation of cereal crops will deplete soil fertility and reduce the area of grazing lands. However, there is an increasing dependence on crop residues for livestock feed whose production is influenced by soil fertility maintenance. Fodder production, of especially nitrogen-fixing crops, potentially offers solutions to soil fertility depletion as well as livestock nutrition. Fodder crops can relieve both soil fertility problems and livestock nutrition and thus improve livestock productivity and subsistence food production.

4.6.4 Estimates of livestock productivity

Estimating the yields of various livestock products presented substantial challenges. Milking is done early in the morning or late in the evening when farmers have spare time during the peak of the crop season. Estimates of milk output were derived through field observations, direct measurement, recall interviews and authenticated with other previous studies. It is important to note that milk, egg and meat consumption take place within the household. Because of socio-cultural reasons, recall methods can suffer from measurement errors due to farmer under-reporting or exaggerating consumption levels. Herds are composed of various breeds (due to high incidence of uncontrolled mating) and there may be no such animal as pure local breed or pure crossbred. This makes estimation of on-farm yield levels difficult and the use of data from experimental or research stations may be inappropriate.

Production parameters for cattle

The productivity of Ethiopian highland zebu cattle (also known as Abyssinian Zebu) is generally low. They are used to provide traction, milk and meat though the basic and unique role is to provide traction especially for cultivation and threshing. After accounting for milk for feeding calves, between 240 and 290 kg of milk is available, on average, for household consumption or sale (Mukasa-Mugerwa 1981, Gryseels 1988). However, most households sell more butter and cheese than liquid milk.

The average calving age is estimated to range from 4.4 to 5.1 years. The zebu calf weighs about 21.6 ± 2.5 kg at birth. Other household goals and survival strategies considered, old animals are usually sold for slaughter (Getachew et al., 1993). Total annual herd offtake is low and estimated to be about 8 percent for cattle. Cattle are valued more for their intermediate roles especially in the provision of draught power and risk-insurance against crop failure than for final products such as live animal sales or milk.

The local zebu cow has an average prolificacy of 0.6 weaned calves per cow per year and an average lactation milk yield of about 240 litres. However, on an improved nutritional plane and better husbandry management, the prolificacy can be improved to 0.70 and lactation milk yield to 420 litres. Although more milk, manure and calves are produced per herd unit, there is higher feed requirement. A crossbred cow will produce more milk, manure and calves per year, but will also involve increased feed requirements. An average local cow produces about 1000 kilograms of manure in a year (Assefa 1989, Barrett 1992, Scoones 1992). With better grazing and health management, the quantity of manure yield could be increased to 1.5 tonnes from crossbred cows (Table 4.11). To sustain such output levels, farmers attempt to carefully manage their crossbreed cows to avoid mating with unimproved bulls.

Parameters for sheep production

Sheep are kept for a number of reasons including guarding against crop failure, income generation and investment. Sheep are often liquidated easily during periods of financial stress. In spite of their low wool quality and fleece yield, sheep are periodically shorn (usually yearly). Breeding ewes and lambs account for more than 50 percent of the sheep flock in the study area. Farmers take rams out of the breeding pool at about 2 years of age. Non-breeding rams are usually castrated to enhance fattening because castrated rams (*mukets*) fetch higher prices. Sheep are fattened for a variable period of time, usually 4 to 8 months, depending on feed availability and the targeted market outlet.

Table 4.11 Livestock Production Parameters

Parameter	Local cow (Zebu)		Improved Zebu		Xbred Cow		Improved Xbred cow		Local Sheep		Improved Sheep	
	M	F	M	F	M	F	M	F	M	F	M	F
Prolificacy	0.6		0.7		0.80		1.0		1.2		1.6	
Mortality %	0.27	0.27	0.32	0.32	0.36	0.36	0.45	0.45	0.46	0.46	0.72	0.72
Replacement %	Nil	0.20	Nil	0.20	Nil	0.20	Nil	0.20	0.05	0.20	0.05	0.20
Progeny pool %	0.27	0.07	0.32	0.12	0.36	0.16	0.45	0.25	0.41	0.26	0.67	0.52
Progeny sold %	0.34		0.44		0.52		0.70		0.67		1.20	
Culled matures %	Nil	0.20	Nil	0.20	Nil	0.20	Nil	0.20	0.05	0.20	0.05	0.20
Average weight (kg)	300		380		450		550		30		40	
Straw[3] (kg) reqts/yr	1 600		1 800		2 000		2 500		200		300	
Hay (kg) reqts/yr	1 000		1 200		1 600		1 800		300		500	
Lactation period (Months)	7.8± 2.4		10.1 ± 2.0		14.2 ± 3.0		16.1 ± 3.5		N/A		N/A	
Lactation milk yield (kg)	240 ± 10		420 ± 20		1 000 ± 200		1 500 ± 400		N/A		N/A	
Manure yield (kg)	1 100		1 300		1 500		1 700		100		160	

M = Male F = Female
Source : Gryseels (1988), Assefa (1989), Belete (1989), Author's field (1993-94)surveys)

NB. Fractional units of livestock represent proportional units of the herd that are affected by a particular event (e.g., mortality, offtake) in a stable herd structure.

3 Animals are usually fed haulms (residues from threshing pulses) mixed with cereal straw.

Local sheep have an average prolificacy of 1.2 weaned lambs per ewe per year. However, on an improved nutritional plane and with better husbandry management, the prolificacy can be improved to 1.6 lambs per ewe (Table 4.11). Like other livestock, this improvement will have to be accompanied by higher levels of feeding and management. Being more divisible and smaller in body size, households slaughter about 3 sheep in a year for family consumption. Few animals die of old age. Sick or injured animals are often slaughtered before they die (salvage slaughter) even if such meat is fed to other valuable animals such as shepherd's dogs. Sheep are often slaughtered to mark a cultural or religious occasion. There is substantial and mutual food leakage (sharing food with friends, relatives and the poor) in the farming system. It was not possible to precisely quantify the magnitude of food leakage because of its rather personal and irregular nature.

Sheep weigh about 30 kg at market age. Despite targeting festive cultural/religious occasions, there is no identifiable household plan for livestock sales. Offtake is estimated to range between 20 and 35 percent for sheep. Farmers sell sheep irregularly depending on household financial needs. Prices are determined by a number of factors including the season, animal characteristics, purpose of sale or purchase (retail resale, home or commercial consumption, fattening or breeding) and bargaining skills.

Colour, age, sex and weight are important factors that buyers or consumers consider when engaging in livestock transactions. From field surveys and other demand analysis studies in the region (e.g., Andargachew and Brokken 1993), there is neither regular market information on prices, the supply-demand situation, grades nor quality standards. Prices are set in numerous one-to-one buyer-seller haggling negotiations over price on a per-head (animal) basis.

4.7 Soil Fertility Management

The major soils in the central Ethiopian highlands are considered fertile. The major soil types are vertisols (black cotton or clayey soils), nitosols (highly weathered brownish soils) and a mixture of either vertisols or nitosols. However, these soils are highly deficient in phosphorus, nitrogen and major trace minerals. Some areas of the Ethiopian highlands are highly degraded mainly due to soil erosion and de-vegetation (SCRP 1984-1991, Kidane and Abler 1994).

Over time and with static production techniques, increasing demand for agricultural land will induce changes in land use intensity and soil fertility management practices. For rural households, land is one of their most valued assets that guarantees a flow of returns to meet subsistence consumption and income needs (Eicher and Staatz 1982, Ellis 1993). Households often attempt to invest or engage in land use practices that restore or maintain soil fertility.

Households employ different farming techniques to improve or resuscitate soil fertility including leaving the land under fallow, soil-burning (guie), applying organic or inorganic fertilisers and spreading crop residues. There are considerable differences between different categories of households in their soil fertility management practices.

4.7.1 Leaving land under fallow

In the study area, about 64 percent of the households leave some of their land under fallow. However, only 53 percent of crop farmers leave part of their land fallow compared with 87 percent of crop-livestock farmers. Most crop-livestock households have more land and thus experience less cropping pressure. About half of the female-headed households leave land under fallow compared with about two-thirds of male-headed households (Table 4.3).

However, compared with visual observations during field surveys, this statistical result may overestimate the land that is under fallow. In a strict economic sense, not all uncultivated land can be considered as deliberately being kept under fallow. Some land may be left uncultivated either because it is unprofitable or the farmer does not have sufficient resources (e.g., oxen, labour) to commit to its cultivation. In the short-run, the opportunity cost of such uncultivated land may be zero. In a way, the statistical estimates presented above may represent land that is both under fallow and farmer's fields that are left uncultivated.

Farmers leave land under fallow for a number of reasons including the problems associated with waterlogging, shortage of animal traction, shortage of labour and deliberate fallow practice. In some cases, crop farmers leave land under fallow in order to produce pasture that can be exchanged for animal traction with households that own livestock. Low crop yields, the need to expand pasture area and water-logging were the main reasons for leaving land fallow by 42, 23, and 14 percent of the respondents, respectively. Other less important reasons for leaving land under fallow include lack of farm labour and draught oxen by 5 and 4 percent of the respondents. Moreover, the greater the distance from the homestead the greater the frequency and duration that such distant parcels of land are kept under fallow.

About 50 percent of the fields are left under fallow for one year while 20 percent are left under fallow for as long as three years. About 10 percent of the respondents would not elucidate any particular fallow patterns and are considered to leave fields under fallow at random intervals (Table 4.12). Land that is kept under fallow for long periods is naturally covered by grass and is used for pasture.

Table 4.12 Fallow Intervals as Practiced by (Percentage of) Households

Fallow period interval	Whole sample n = 94	crop farmers n = 34	mixed farmers n = 23	10 years ago n = 94
Less than one year	38	39	36	13
One to three years	18	25	8	3
Four to six years	8	11	9	25
Seven to nine years	25	17	34	25
Ten or more years	1	0	0	2
Random	10	8	13	32
Total	100	100	100	100

Source: Author's survey (1993-94) results

Farmers with few or no livestock tend to be associated with more continuous land cultivation that those with more livestock. Perhaps because of greater need for pasture, crop-livestock farmers tend to leave more land under fallow. Moreover, because of having access to manure, crop-livestock farmers usually obtain better crop yields and have less incentive for intensive continuous cultivation. Therefore, even allowing for differences in farm size, ownership of livestock seems to reduce the need for erosive cropping practices and seem to contribute to better land use practices. Nonetheless, with population growth, fallows will constrict or disappear and do not seem a feasible soil fertility management option in the future.

4.7.2 Organic and inorganic fertilisers

Estimating the extent and magnitude of use of both organic and inorganic fertilisers was quite difficult. Many respondents tended to overstate their use of fertiliser in order to be seen as successful farmers and perhaps thought they could potentially stand to benefit from some field fertiliser trials where fertiliser would be provided at subsidised prices or freely. Indeed, all crop-livestock farmers claimed to be using chemical fertilisers. About 25 percent of the more resource-poor crop farmers claimed to use fertilisers. About half of the female-headed households use fertiliser compared with 40 percent of the male-headed households.

Nonetheless, rigorous effort was made to counter-check claims of fertiliser use against actual fertiliser application on the cultivated fields. More than 72 percent of fields do not receive any form of fertiliser application other than through natural processes such as rhizobial nitrogen fixation or manure from grazing animals. More than 13 percent of the fields receive varying amounts of either Di-Ammonium Phosphate (DAP) or urea fertiliser. More than 10 percent of the cultivated fields receive manure while only 5 percent of the fields are covered with crop residue either as grazed animal feed waste or recyclable household waste. Fertiliser is mainly applied once in a cropping season and is usually applied on fields where cereal crops - barley, wheat and oats (in that order of importance) - are grown.

The main reason prompting farmers to use inorganic fertiliser is their willingness to increase crop yields, especially of preferred food crops. However, more than one third of the farmers complained of the lack of labour to meet the challenge of increased weeding requirements. More than half of the farmers complained of the nullifying effects of soil erosion. Reasons provided by farmers for non-use of fertilisers included lack of purchasing power, non-availability of fertiliser at planting time, unpredictable weather, use of alternative methods of reviving soil fertility and insufficient crop response to fertiliser at the levels that farmers can afford and apply chemical fertilisers.

About 20 percent of farmers use inorganic fertilisers in the study area. Against recommended levels of 100 kg/ha (Di-Ammonium Phosphate) and 50 kg/ha (Urea), average applications rates are estimated between 15 kg/ha and 25 kg/ha, respectively for those farmers using fertiliser. This figure presents a general increase in the use of fertilisers. Belete (1989) reports that about 10 percent of the farmers were using fertiliser at an application rate of between 5 kg/ha to 10 kg/ha in a survey conducted in 1986 (six years earlier than this study) in the study area. There are difficulties harmonising data regarding the volumes of fertiliser sales with how much of the fertiliser is actually used, resold or otherwise diverted or wasted (through improper timing and application methods) at the farm-level.

Important alternative practices to inorganic fertilisers include crop rotation, leaving land fallow, soil burning, manure by 48, 42, 50, and 55 percent of the respondents. About 20 percent of the respondents have resigned themselves to not attempting use of any of the alternatives to chemical fertiliser. The commonest factors (according to the farmers' ranking) inhibiting more widespread use of manure as organic fertiliser were its non-availability (24 percent), lack of cooking fuel (21 percent), some of the fields are distant (18 percent), lack of labour to spread and incorporate manure (14 percent) and inadequate manure contracts (12 percent) among farmers. Manure is used more in the medium altitude highlands where its main use is to improve the relatively acidic soils (e.g., in the Sodo area of the Rift Valley).

4.7.3 Crop rotations

About 85 percent of the households indicated that they were practising crop rotation involving cereals, legumes and fallow land. During the main crop season, the main crops planted are cereals (e.g., barley), legumes (e.g., horse bean), fallow land and pasture land with each category accounting, respectively, for 50, 20, 20 and 8 percent of the land. However, intercropping of cereal and legumes is not prevalent in the Ethiopian highlands. Given that some pasture can have legumes sown on it, the appropriate constraint carried forward to the linear programming model has a `cereal' to `legume' ration of 2 : 1 (see the crop rotation constraint - section 5.5.3.4).

Combined with their knowledge of the farming system and the environment, farmers grow a complex mix of different crop varieties for construction, culinary, medicinal and decorative purposes. Crop rotations improve soil fertility through biological nitrogen fixation and protect the soil from water and wind erosion. With their diverse rooting systems, crop rotations improve soil structure and reduce the need for intensive ploughing at the start of the next cropping season. Farmers are quite aware of the merits of crop rotation such as improving the total crop yield, reducing disease problems, pest attacks and improving the soil structure. The crop rotation involves alternative combinations of cereal-legume-fallow activities within a three-year cycle when a long-term conversion to pasture production is not planned.

4.7.4 Soil conservation

Land degradation through soil erosion and de-vegetation is a major agricultural and economy-wide problem in Ethiopia. Smallholder agriculture remains the cornerstone of the economy and largest employer. Soil erosion in the highlands averages about 42 tonnes/ha/yr (although rates of up to 300 tonnes/ha/yr have been observed), and causes an average annual reduction in soil depth of 4 mm. Average soil loss from pasture land is about 5 tons/ha, which is nearly in equilibrium with the rate of soil formation. It is estimated that some 1.9 billion tonnes of soil are eroded yearly from the Ethiopian highlands (SCRP 1984-1991, Pausewang et al., 1990). The massive soil loss is often referred to as `Ethiopia's largest uncompensated export' (to the Sudan and Egypt) (Virgo and Munro 1978).

Current rates of soil erosion reduce Ethiopia's food production by an estimated 2 percent annually. Accompanied by inability to withstand moisture stress, soil erosion contributes to variations in crop output, undermines household food security and contributes to the economy-wide food deficit problem. At current rates of soil erosion, some 38 000 km^2 of agricultural land will disappear to expose the bed-rock by the year 2010 and some 60 000 km^2 will have less than 10 cm of top soil. Such magnitude of loss of agricultural land will deprive at least 10 million people of their livelihood derived from agriculture (Hurni 1987, FAO 1992, pg. 5).

In the study area, more than 85 percent of the households viewed soil erosion as an important problem especially on less sticky soil types. The main causes of soil erosion (as cited by the percentage of respondents) include the land slope (40 percent), soil type (14 percent), cultivation technique (10 percent), intensive cultivation (6 percent) and overgrazing (5 percent). Cultivation technique refers to the land tillage practice while cultivation intensity refers to the number of times the field is tilled before planting.

The most visible effects of soil erosion as reported by sample farmers are not any different from those reported in contemporary literature (e.g., Napier 1991, Ndiaye and Sofranko 1994). Farmers' responses to the effects of soil erosion included reduction in crop and pasture biomass yield (26 percent), damage to soil conservation structures and other farm structures (31 percent), damage to pastures (9 percent) and pollution of water resources (5 percent). Not all households have resigned from fighting soil erosion. About 15 percent of the respondents reported starting soil conservation about seven years ago. Within the last three years, more than half of the farmers have attempted soil conservation with varying degrees of success.

From the field surveys, there were indications that farmers were aware of the problems associated with soil erosion and de-vegetation. Some farmers have elected to construct different types of grass terraces, planted private woodlots to replace trees and grass strips. About 40 percent have tried making terraces (i.e., graded or level bunds and terraces) while another 17 percent have attempted making diversion canals (or tied ridges or cambered beds) to minimise intensity of surface run-off.

About one quarter of the respondents have not attempted any defensive measures against soil erosion. The main impediments to soil conservation include lack of labour to make terraces (26 percent), destruction of soil conservation structures by livestock especially during the post-harvest period (15 percent) and the inability of other households to make restorative measures (9 percent).

There are opportunities to combat soil erosion through well-founded research and extension messages to farmers. Opportunities exist to modify cropping sequences, crop combinations, mulching practices, cover cropping, minimum (or zero-) tillage systems and other land use and soil management practices. Agro-forestry interventions offer potential benefits but will have to involve economically attractive returns considering opportunity cost of land and labour. Leguminous tree crops (e.g., *Sesbania spp, Leucaena spp*) with multiple benefits can easily fit in the farming systems to provide for fuel, building materials, fodder and nitrogen fixation.

To be adopted, soil conservation innovations will need to be inexpensive, require few skills to effectively manage, require little labour and capital to maintain, generate a stable flow of short-term and long-term benefits and involve little use of sophisticated technologies. Efforts to improve agricultural production will have to confront the problem of increasing land degradation and the predominance of cereal production (FAO 1992). With little inter-cropping with legumes, continuous cultivation of cereal and legume crops contributes to `soil mining' agriculture and does not augur well for low-input sustainable farming.

4.7.5 Planting trees

The actual area under forest or tree cover in Ethiopia today is unknown due to inadequate recent data. It is estimated to be about 3 percent of the total land area. Deforestation and de-vegetation over many decades has contributed to severe soil erosion and general agricultural decline. Deforestation and de-vegetation have accelerated in the last 90 years. About 40 percent of the highlands were covered by forests at the turn of the century but only about 6 percent of the Ethiopian highlands had any forest cover by 1988. Deforestation - of which fuelwood accounts for 80 percent - exceeds afforestation by about 94 000 ha each year. Within the next two decades, demand for fuel will outstrip current resources (Appendix 1, FAO 1992).

Within the past three years, there has been considerable transformation from semi-collectivist agrarian structure towards partially liberalised and individualised ownership of or access to agricultural land. Many farmers are planting trees and expressed the wish to plant and own various tree species than during the period of collectivised agrarian structure. The common tree species planted in the study area include eucalyptus, cypress, sesbania, acacia and indigenous trees. Farmers usually buy seed from nearby markets or obtain seedlings from the local office of the Ministry of Agriculture.

Important reasons why farmers want to plant more tree (as a percentage of the respondents) include the desire to build house (26%), obtain firewood (25%), generate income (20%), obtain fencing materials (10%) and provide wind-breaks for the homestead (10%). Other reasons for planting trees included provision of shade, fruits, beauty (aesthetic value), land rehabilitation and fodder for animals.

However, some 21 percent of the households complained that their land was too small to accommodate any afforestation efforts. Others reported that the weather is too cold for any reasonable tree growth while other households felt that lack of seed and ownership of trees on communal lands were major problems. It would be expected that for farmers with small land, food crops play a dominant role in their land use decisions. Trees have a longer maturation period than most food crops and are thus less regular and reliable sources of food or cash income.

Nonetheless, the economic value of trees depends on the scarcity values attached to trees in the rural economy. With the increasing demand for energy, it is reasonable to expect more trees will be planted in future. There is scope to integrate social forestry into the farming system and reduce loss of agricultural land through soil erosion but such forestry will have to be sensitive to the social and economic needs of the majority of rural households. Quick-maturing multiple-purpose trees providing for such needs as fuel, fodder, fibre and food will have the greatest potential in complementing crop-livestock production in the household economy.

4.7.6 Soil-burning (*guie*)

Soil burning involves ploughing, moulding and burning mounds of soil to improve nutrient availability and thus crop yields. There are disagreements about the appropriateness of *guie* in resuscitating soil fertility. The disagreements revolve around the trade-offs between short-term gains in yields versus long-term losses in land productivity. Usually *guie* improves yields threefold in the first year but yields drop in the next crop season to the extent that the field plot is not productive in the subsequent years. The field has to be left under fallow for a considerable period of time to recover its lost productive potential (Abebe 1981, Roorda 1984).

About 45 percent of the farmers in the study area practise *guie*. The interval of soil burning (*guie*) has contracted from seven years to about three years. In general, most farmers practise a random interval of soil-burning. Crop farmers tend to practise soil burning of shorter intervals (one to three years) than farmers with livestock (Table 4.13).

The main motivation for farmers to practise soil burning is generated by low crop yields or the crusty soil surface structure (Abebe 1982). However, guie exposes the soil surface to the risk of soil erosion without prompt sowing. Soil burning is very labour intensive due to the drudgery of making and levelling the soil mounds. Considering the opportunity cost of human labour engaged in *guie*, it is not likely to be a continuing practice as farming systems evolve to cope with increased demand of food, fibre and animal feed (e.g., pasture) arising from population growth and urban demand for food.

Table 4.13 *Guie* Practices by (Percentage of) Households

Guie interval	Whole sample n = 94	Crop farmers n = 34	Mixed farmers n = 23	10 years ago n = 94
One to three years	8	13	3	1
Four to six years	7	6	9	3
Seven to nine years	13	3	17	28
Random interval	72	78	71	68
Total	100	100	100	100

Source: Author's survey (1993-94) results

4.8 Weather, Diseases, Pests and Rural Markets

Apart from problems of resource scarcity, farmers in the study area face several other challenges that require continuous adaptations in order to guarantee some farm output lest the farm family is prone to the pain and indignity of starvation. Amongst the major problems elicited from sample farmers include uncertainty about rainfall, price fluctuations, disease challenge, pest attacks and poor infrastructure.

4.8.1 Weather uncertainty

Perceptions about weather vary between crop farmers and crop-livestock farmers. About 68 percent of the crop-livestock farmers viewed weather uncertainty as a problem while about 88 percent of the crop farmers viewed weather uncertainty as a problem. It appears that livestock improve the confidence of farmers in the farming practices and strategies. In order of importance, the main aspects of weather uncertainty are waterlogging, frost and unpredictable rainfall. These aspects tend to affect crop farmers more than livestock farmers.

Crop farmers adopt various techniques and strategies to cope with weather uncertainty. About 50 percent make drainage channels and diversion canals to reduce the amount of surface run-off on the field plots. About 60 percent change their cropping practices and strategies to cope with weather uncertainty. These include staggered planting, non-contiguous cultivation and planting different crops.

Crop-livestock farmers adopt similar techniques and strategies with respect to crop husbandry as crop farmers, although at lower levels of commitment. With respect to livestock husbandry, farmers adopt different strategies to manage weather uncertainty. About 25 percent often vaccinate their animals to guard against the risk of pneumonia due to cold weather. With regard to waterlogged pasture fields, livestock farmers usually adopt different grazing schemes including grazing along road-sides, hillsides, communal and open access pastures.

4.8.2 Disease challenge

More than three quarters of the farmers complained of one or more crop diseases in the study area. Warm and humid weather is especially conducive for most diseases and pests. However, many farmers cannot afford cultivation of disease-resistant and pest-tolerant varieties of crop and breeds of livestock The problem of cereal scales was reported by more than 45 percent of the households. About 46 percent of the households face the problem of root-rot while about half of the farmers complained of cut-worm (*Mesek*) on cereal crops. About 20 percent of the farmers have problems with managing aphids (*kish Kish*) especially on legume and horticultural crops.

Major responses by farmers to confront the disease challenge include crop rotations, leaving land under fallow and using chemical sprays. In all cases, crop-livestock farmers use these strategies more frequently than crop farmers. For example, about 52 percent of the crop-livestock farmers and 44 percent of the crop farmers consider crop rotations as an effective strategy for disease management. About 26 percent of the crop-livestock farmers and about 18 percent of the crop farmers use chemicals sprays. Differences in ability to face disease challenges reflect differences in income that could be perhaps associated with differential resource endowment between the two categories of households.

About 73 percent of the households face one or more livestock disease challenges. The main livestock disease challenges reported are pneumonia, foot and mouth disease (FMD) and black quarter (*Aba gorba*). The main responses that farmers employ to cope with the challenge of livestock diseases are using medicinal herbs, vaccinations, rotational grazing and fencing the homestead. Households with relatively few livestock used vaccinations and local herbs more than any other alternative strategies. More than 80 percent of the crop-livestock farmers and 40 percent of crop farmers use medicinal herbs. About 75 percent of the crop-livestock farmers and about 35 percent of the crop farmers vaccinate livestock against pneumonia.

4.8.3 Rural marketing problems

Between 55 percent and 70 percent of the households face some form of marketing problems either for inputs or farm produce. About half of the households complained of low prices for farm produce. About 26 percent of the farmers face the problem of poor transport infrastructure either in the form of bad roads or insufficient vehicles. It was noted that the problem of bad roads and inadequate volume of vehicles made transportation costs high. About one fifth of the households complained of lack of farm inputs especially fertiliser. More than 20 percent of the respondents face the problem of reaching alternative market centres. The nearest towns of Mendinda or Chacha are each more than twenty kilometres while major adjacent towns of Inewari or Sheno are all more than fifty kilometres away (Figure 3.1). Households must travel long distances to reach sizeable rural markets and wait for sales to clear or be forced to accept lower prices for farm produce.

To cope with these marketing problems, farmers engage in various strategies including staggered sales, selling in different market centres and using alternative means of transport. In all cases, crop-livestock farmers tend to select more of these alternative strategies more frequently than crop farmers. About half of the crop-livestock farmers and about 30 percent of the crop farmers opt for staggered sales. About 48 percent of the crop-livestock farmers and about 12 percent of the crop farmers offer their farm produce in different market centres. The differences in marketing strategies between crop farmers and crop-livestock farmers are partly due to the differences in the volume and type of marketable surpluses from these households. Crop-livestock farmers produce more perishable products such as milk that must be sold quickly to minimise monetary losses.

Most of the transport facilities in the rural areas are not all-weather and are often impassable during the wet season. Infrastructural facilities (e.g., all-weather rural access roads) and market (e.g., prices) constraints pose formidable challenges to accessing commodity markets. Limited market access and high marketing costs limit households to low levels of production within family needs and there is little marketable surplus. Impediments in transportation hinder production of highly perishable products such as milk and horticultural produce although such enterprises may yield the highest revenue per unit of land. The revenue will not be high if the products cannot be transported to the market at reasonable cost. Infrastructural impediments contribute to inefficient production and marketing relationships and would affect opportunities for crop-livestock integration and overall agricultural intensification in the study area and rural Ethiopia in general.

4.8.4 Pest attacks

More than 90 percent of the households face problems with pest attacks on crops. Common pest problems are due to rodents, birds, weeds and animals during the crop production calendar. More than 85 percent of the households complain of mice and other rodents during planting time and harvesting time and of rats during storage. More than 30 percent of the farmers have problems with either domestic or wild animals when the crop is standing in the field.

Between 45 percent and 60 percent of the farmers either leave their land under fallow, or deliberately plough and leave the land under fallow, to reduce problems with rodents. At about harvesting time, more than half of the farmers engage in bird-scaring to reduce the amount of crop damage. About 25 percent of the farmers use chemicals to reduce the problems of rats while the grain is stored.

Endoparasites (e.g., liver flukes) and wild animals (e.g., hyenas) were reported as a major problem by about 55 percent and about 30 percent of the farmers, respectively. About 20 percent of the households use anti-helminthics to deal with the problem of worms and liver flukes. More than 20 percent of the farmers use traps and dogs to ensnare or scare off wild animals. About 20 percent of the farmers deliberately keep their animals in the house at night to guard against predation by wild animals. Almost all the livestock farmers have well-secured kraals to guard against predation and theft.

Because of the relatively high cost of fencing, the problem of endoparasitism remains economically important. Given the prevalence of communal grazing, there are externality effects of using anti-helminthics on specific animals and perhaps that why most farmers use medicinal herbs to strive for some minimum tolerable levels of endoparasitism.

While disease transmission does not necessarily prevent crop-livestock integration, minimum levels of management and veterinary practices are necessary to limit problems posed by disease-challenge. Government veterinary services have a strong tradition of whole-herd preventive strategies, but there is a limited tendency to deal with single animal disease problems such as traction-related injuries and illnesses. In many developing countries such as Ethiopia, veterinary services tend to be thinly spread, poorly staffed, lowly motivated and insufficiently equipped. Disease and pest problems will need to be carefully managed to realise the productive potential of livestock. This is especially the case with improved or crossbred livestock that are more susceptible to disease challenge.

4.9 Household Cash Income, Expenditure and Rural Credit

Sources and uses of cash income differ between households with livestock and those without livestock. Even within categories of households, farm income and expenditure vary. Eliciting responses about sources of cash income was problematic and some caution is urged in attaching weights to particular sources of household cash income. The general tendency is to reveal small expenditure profiles while concealing major cash income flows especially those associated with livestock sales.

4.9.1 Household cash income

The various sources of cash income include sale of grain, cattle, sheep, cow dung cakes and dairy products. Of the grain sales, cereals and legumes account for 32 percent and 50 percent, respectively. Sale of firewood and energy types is about 15 percent of total crop cash income. Of the livestock sales, sheep, chicken and cattle (and dairy products) constitute about 43 percent, 29 percent and 16 percent, respectively. Sale of goats and equines account for the remaining 12 percent of the cash income from livestock. The proportion of household sales of grain, livestock and expenditure across different types of households is shown in Table 4.14.

Table 4.14 Household Cash Income and Expenditure.

	Whole sample n = 94	Crop farmers n = 34	Mixed farmers n = 23
Grain sales	**As a percentage of crop sales**		
Cereal grain sales	32	35	27
Legume grain sales	50	50	26
Firewood	15	7	42
Other crops	13	8	5
Livestock sales	**As a percentage of livestock sales**		
Sheep	43	N/A	63
Chicken	29	N/A	23
Cattle	16	N/A	10
Poultry	12	N/A	4
Cash Expenditure	**As a percentage of total cash expenditure**		
Buy food	59	81	52
Buy clothes	18	3	33
Rent grazing land	4	0	5
Buy sheep	8	9	2
Inputs and other	11	7	8

Source: Author's survey (1993-94) results.

Income derived from trade in livestock, livestock products (e.g., milk) and livestock services (e.g., traction) is estimated to range between 40 and 60 percent of total cash income (Gryseels 1988, Freeman et al., 1994). Livestock thus plays an important role in income generation in the rural economy.

The effect of crop-livestock integration on cash income and expenditure can be visualised in a number of dimensions. The number of livestock increases from none (or very few) with crop farmers to the maximum possible with livestock farmers. The contribution of cereals and legume grain sales to total cash income decreases as the number of livestock increase. This suggests that livestock diversifies the income base of crop-livestock farmers compared with crop farmers. Households without livestock can hardly manage to sell fire-wood since it is their main source of cooking energy, apart from collecting cow dung from communal grazing areas. However, households with livestock can afford to sell more firewood since they can depend on their own sources of cow dung cakes and manure for their household cooking energy needs.

Sheep and chicken are the more commonly traded livestock species. As the number of livestock increases, the contribution of sheep to household cash income increases. As the contribution of chicken and other livestock species (e.g., goats) to household cash income decreases, the economic role of sheep increases. Cattle tend to be kept as an interest-earning investment account to draw upon when the worst of the financial situations arise. Unlike sheep and chicken, cattle are generally viewed as less divisible. When an household falls in need of some money, chicken and sheep are sold more frequently to meet basic monetary obligations.

4.9.2 Off-farm income

The study sites are located within a 35 km radius from a major market centre (Debre Birhan). Proximity to nearby lowland towns also permits regular exchange of grain, horticultural and livestock products between highland and lowland entrepreneurs. Because of unwillingness to indicate the volume and type of cash income from various non-farm sources, this study does not indicate the most important source of off-farm income. Eliciting the different sources of off-farm income in the study area is based on some subjective assessment of farmer responses. Except in periods of severe financial and food insecurity (e.g., droughts), off-farm income may not be very significant in the household economy in the study area.

Due to differential ownership of land and livestock, the commonest source of supplementary off-farm cash income is renting out land, work oxen and seasonal/occasional hiring out of surplus family labour. An important source of regular (sometimes daily) off-farm income is selling of firewood or cow dung cakes. The firewood or cow dung cakes can be from own farm or collected from communal grazing lands. Thus households selling firewood or cow dung cakes do not necessarily own trees or livestock. Diminishing availability of communal grazing land will deprive households without livestock of this source of income and perhaps affect income distribution within the local community.

Other sources of off-farm cash income include sale of local beer (*talla, teji, areke*), honey, pension, making handicrafts, hair-dressing and remittances. However, since only between 5 and 10 percent of the households had at least one member of the household engaged in off-farm employment, the contribution of remittances to farm cash income is relatively small. Those receiving pension were former military or civil service employees.

4.9.3 Household cash expenditure

Household cash expenditure on different items varies across household categories. Farm cash income is spent on buying food items, consumer goods, purchasing of livestock, paying school fees, covering loan repayments, purchasing farm inputs and improving general family health care. On average, purchase of food and clothes, respectively, account for about 59 and 18 percent of household cash expenditure. Purchase of sheep and renting grazing land constitute about 12 percent of household cash expenditure. The proportion of total household cash expenditure spent on food items decreases as the number of livestock increase on the farm. Since livestock fetches a relative large amount of cash income, it appears that relatively small proportion of livestock sales can enable the household to purchase substantial amount of grain than depending on crop or fire-wood sales. The main purchased inputs include seed, fertiliser and veterinary drugs (mainly medicinal herbs).

In terms of allocating the limited cash income to crop production, the order of importance is allocated to purchase of planting seed, fertiliser and manure, purchase and repair of farm tools, and purchase of chemicals (to spray on stored grain). Investment in livestock production will involve (in order of preference) purchase of livestock, building night shed or kraal, renting pasture land and purchase of curative veterinary drugs. There is limited farmer motivation to purchase whole-herd preventative drugs. The order of importance in purchasing livestock is allotted to equines, cattle and sheep. Households highly valued making investments in donkeys since they are crucial assets as a means of conveying marketed produce and inputs (grain, firewood, cow dung cakes) to and from the market. For the purchase of cattle, purchase of cows is rated higher than purchase of work oxen. This presents a substitution effect whereby cows can provide for a wider range of outputs (milk, manure, traction, replacement stock and income) than oxen (same output excluding milk).

In terms of improving overall land productivity, the order of priority is placed on improving farm water resources, pasture resources, planting trees and making soil conservation efforts. Ways of enhancing water availability reported from this study include sinking water-holes and making water ponds. While these improvement aspirations remain farmer priorities, there is considerable policy challenge in effecting these changes such as provision of appropriate extension and technical advisory services to farmers. From the farmer's point of view, important sources of agricultural information in the rural areas (ranked from most to least) are non-governmental organisations (NGOs), development agents (DAs), neighbours, radio, elders, church and local markets. There is room for better co-ordination of the activities of the various participants involved in rural development and agricultural transformation.

4.9.4 Agricultural credit

Ethiopia is among the poorest countries in the world, with per capita income of about US $ 120. Per capita GNP is declining at annual average rate of 0.3 percent. Per capita agricultural output is declining at an average annual rate of 0.3 percent (1980-1991). Per capita food production is declining at an average annual rate of 1.1 percent. There is a dominance of subsistence production, the majority of population live in abject poverty and are perhaps trapped in a vicious cycle of pervasive poverty (low productivity, low income, low savings and low productivity). Given the low income, availability of agricultural credit would enable households to acquire additional external inputs to increase farm output (World Bank 1992). Such inputs include seed, fertiliser, hired labour, land rentals, livestock feeds and other non-farm inputs. Availability of credit is especially essential for adoption of innovations that may involve large cash requirements.

The main sources of credit are the agricultural and industrial development bank (AIDB), informal money lenders, friends and relatives. AIDB imposes a minimum of 30 percent equity participation for private borrowers. Short-term loans have to repaid within one year, medium-term within 5 years and long-term to be repaid within 10 years. Interest rates are about 12 percent although varying from 7 percent to 20 percent. Inflation rate is estimated to be about 25 percent (FAO 1993, pg. 8). Interest rates and repayment conditions vary depending on the source, amount and purpose of the loan.

Non-commercial sources of credit play an important role in rural financial markets. It is estimated that non-commercial lenders account for about 78 percent of rural loans, commercial lenders supply about 3 percent and formal lenders account for 19 percent of the rural credit. Non-commercial lenders include friends, relatives and neighbours. Loans from non-commercial sources have to be repaid within 3 years while those from relatives and friends are usually repaid within 2 1/2 years (Freeman et al., 1994). Friends, as opposed to relatives and neighbours, are important sources of informal loans. Other sources of credit are mutual savings clubs (*equb*), churches (*idir* and *mehaber*) and non-governmental organisations.

Few farmers were willing to divulge information about availability of agricultural credit. Farmers seemed to depend on relatives and friends for informal credit at variable repayment modes. Like household expenditure profiles, agricultural loans are used for a variety of purposes including purchase of livestock, food, external inputs such as fertiliser and seed. Most of the impediments to seeking formal loans were associated with risk of loss of collateral in the event of non-repayment. However, there is no fixed or stringent repayment conditions for loans obtained from non-commercial sources such as friends.

From informal discussions with farmers, there is considerable degree of risk-aversion to institutional credit. Lack of agricultural credit from formal sources is considered a problem by at least 20 percent of the households. For households not taking loans, 44 percent had enough money, 22 percent could not find a lender, 8 percent were refused to borrow loans, 5 percent feared taking loans, 2 percent claimed the bank ran out money and 18 percent offered differing reasons including lack of intended items of purchase.

For crop farmers, those acquiring credit (especially from non-commercial sources) would use most of the loan for purchase of food, buying farm inputs and repairing farm tools. For crop-livestock farmers, between 50 and 77 percent credit would be used to purchase livestock, between 10 and 15 percent would be invested in petty trading to smoothen variability in non-farm income and the rest of the loan would be retained as liquid cash.

From the perspective of rural farmers, making agricultural credit available will take time and require solutions to the various institutional and economic impediments obstructing farmers from obtaining credit from various rural financial institutions. It will require co-ordination among the suppliers of (especially formal) credit to harmonise repayment conditions and interest rates chargeable. Availability of complementary inputs (e.g., fertiliser, seed) and services (e.g., price information, infrastructure) will be necessary to avoid credit being diverted to less profitable uses or wasted.

4.10 Household Food Security

4.10.1 Defining household food security

Household food security is an important policy and socio-economic problem in the study area. Measuring household dietary intake may give good estimates of calorie-income elasticities where food markets are well developed. In many rural areas like Debre Birhan, market information is scanty, sales and purchases are conducted on individual bases and market transparency is fluid. This makes it difficult to estimate income elasticity of consumption.

Measuring food availability through accounting of household food inventory is another measure of food security. However, there are methodological difficulties in making a realistic assessment of the incidence and magnitude of food insecurity in rural areas. In periods of widespread and protracted food shortage, households do not record the amount of food intake nor can they accurately recall food intake over long periods (Webb et al., 1992, pp. 102-114; IFPRI 1993, pg. 175). Although children and adults often eat together, there are variations in food intake, from time to time, and according to the age-sex structure of the household. Child anthropometry data can provide good indications of food security. A good crop harvest provides the household with enough supplies to satisfy household food needs and some surplus to sell, give out as gifts, pay agricultural workers, brew beer and display hospitality. There is substantial food leakage in the rural areas (e.g., food given to occasional visitors, poorer relatives, friends) that could blur estimates of food (in)security.

An alternative approach of estimating food security through food inventory (production, consumption and purchases) has some limitations. First, farmers grow and harvest different crops at different periods of the crop calendar. Second, it is difficult of estimate the volume of non-farm food (e.g., honey, edible roots) obtained from public or communal land. Third, many households sell and/or buy food in small quantities from time to time. It is thus not easy to estimate the overall income and expenditure levels to answer quantitative policy issues regarding food security. An attempt is made to elicit the implicit role of livestock in household food security.

4.10.2 Implicit role of livestock in household food security

To estimate the contribution of livestock to household food security, a combination of techniques were applied to elicit household responses about food security. Crop farmers tend to have smaller families and smaller farms in comparison with crop-livestock farmers (Table 4.3). More than 40 percent of the crop farmers and about 20 percent of the crop-livestock farmers have now smaller farms than they did during the semi-collectivist agrarian period (1974-1991) and cannot adequately satisfy their subsistence food production requirements. Crop farmers are more vulnerable to food insecurity than crop-livestock farmers. Crop farmers practise more intensive and continuous land cultivation than crop-livestock farmers. In the long-run, crop farmers will lose their ability to produce enough food and become more vulnerable to child malnutrition and starvation.

Most crop-livestock households have more land and experience less cropping pressure. Only 53 percent of crop farmers leave part of their land under fallow compared with 87 percent of crop-livestock farmers. Moreover, because of having access to manure, crop-livestock farmers usually obtain higher crop yields and have perhaps less incentive for intensive continuous cultivation. Livestock seems to contribute to better land use management; which would enhance food production and household food security.

Farming is seasonally labour-intensive, and the scheduling of certain farm activities (especially ploughing and weeding) and availability of labour has a significant influence on expected crop yields, *ceteris paribus*. Households without livestock experience difficulties in meeting traction requirements and often are likely to achieve lower yields. About one third of the farmers produce less grain than they would if oxen were not a constraint. With low yields, crop farmers cannot sell much grain and often do not have enough cash to purchase seed, draught power and labour. They are thus forced to seek temporary farm employment on other farmers' fields through various land, labour and oxen exchange arrangements. While these arrangements offer short-term relief to short-term household food insecurity, such households are most vulnerable to food insecurity. The greater the household food deficit, the more off-farm work will be sought, mostly at the expense of timely operations on their farms and food production capacity.

The contribution of cereals and legume grain sales to cash income decreases as the number of livestock increase (Table 4.14, columns 2 and 3). The implication is that livestock diversifies the income base of crop-livestock farmers compared with crop farmers. With lower cash income, crop farmers are likely to be affected more severely when weather is unfavourable and crop failure is protracted. They have little income base and have to resort to distress sales. Such distress sales may include selling farm implements (e.g., hoes, sickles), household items (e.g., clothes, utensils). Unlike crop-livestock farmers, such asset-stripping survival mechanisms erode the capability of households without livestock to recover even when they experience a subsequent good season.

The proportion of total household cash expenditure spent on food items decreases as the number of livestock increase in the farm. Since livestock fetches a relatively large amount of cash income, it appears that relatively small proportion of livestock sales can enable the household to purchase more grain than depending on crop sales. If a household wants to buy a preferred food item, sale of one sheep will suffice and is perhaps a less risky than selling lots of a less preferred crop, due to price fluctuations in the local markets.

4.10.3 Risk-reduction strategies

Farmers in the Ethiopian highlands face various types of risk. They often have to face uncertain weather regimes, from extreme waterlogging during a rainy season to extreme droughts and frosty weather. There are a number of pests and diseases that often attack their crops and livestock. Being price-takers, they face highly variable prices in various agricultural product markets, which in turn, affects household income and investment decisions.

In their cropping decisions, resistance to or tolerance of various risks is an important feature in rainfed farming. Thus disease-resistance and pest-tolerance are important attributes that farmers consider in selecting the crop that is likely to give the highest yield under the edaphic and agro-climatic conditions in the Ethiopian highlands. In an environment with limited savings and insurance markets, farmers take various strategies to minimise risk of catastrophic outcomes. They (1) plant different cultivars of different crops in different non-contiguous fields, (2) own various breeds (indigenous, cross-breeds, criss-crosses and pure-breeds) of different livestock (sheep, cattle, equines, poultry), (3) hold a last-resort individuated grazing area, and (4) engage in on-farm grain storage. However, it is important to note that no crop variety is likely to yield the highest returns (yield or revenue) under all conditions. Varieties that are resistant to pests and diseases are likely to give less yield when these pestilence threats are absent than more vulnerable varieties.

Farmers also engage in community risk-sharing schemes. These risk-sharing schemes include (1) exchanging labour (section 4.1), (2) exchanging land (section 4.2), (3) exchanging oxen (section 4.3), (4) membership of mutual self-help savings clubs (*equb*), (5) contributing to a burial tax fund (*idir*) to reduce monetary cost for one family in the event of bereavement, (6) giving food to friend, relatives and the poor (food leakage) and (7) giving informal credit. Crop-livestock farmers seem to engage in many of these risk reduction schemes perhaps because of being relatively more endowed with factors of production than crop farmers.

4.11 Summary

Livestock plays a crucial role in rainfed farming conditions of the central Ethiopian highlands. There are important differences in resource endowment, farming practices, constraints faced and opportunity sets available to crop-livestock farmers compared with crop farmers. Following the stratified sampling approach, crop farmers have smaller families and smaller farms than crop-livestock farmers. These differences are often concealed when other sampling (e.g., random) approaches are applied in rural surveys. This may obscure opportunities for differential technical and policy interventions in addressing various agricultural and resource management problems in rural areas of the developing countries such as Ethiopia.

Animals make a substantial contribution to the household economy through different, quantifiable and intangible, functions. Intermediate functions such as draught power and risk-insurance that may overshadow other functions of livestock such as milk, manure and meat production. Irrespective of which weight is attached to which role, there is a degree of commonality in the different functions that livestock play in the rural economy. Livestock seems to broaden the opportunity sets available to households that could enhance household welfare.

The field surveys have helped to indicate major constraints (e.g., diseases, pests, financial liquidity) to increased farm production from the farmer's point of view. Various farmer adaptations (e.g., shortening fallow periods, soil burning) to the various constraints have been elicited and discussed. The multiplicity of farmer responses suggests that a wide range of technical and policy interventions will be necessary to address specific problems of different farmers.

The results provided in this chapter provide the linkage between the field surveys and the linear programming model. First, they provide the basis to differentiate resource endowment and farming practices between crop farmers and crop-livestock farmers. Second, the input-output relationships between different crop, livestock and forage enterprises in the use of farm (e.g., land, labour, traction) resources during different (e.g., ploughing, weeding, herding) periods in the farming calendar have been estimated and discussed. Third, based on this categorisation scheme, various estimates are derived for various input and output relationships in crop and livestock farming for crop farmers and crop-livestock farmers. These parameter values will be used in the linear programming model to specify the various resource (RHS) and other model constraints; for the modelled cluster consisting of crop farmers. The modelling approach that is applied to evaluate some of the quantifiable effects of crop-livestock integration is the subject matter of chapter five.

Chapter Five

Modelling Outcomes from Crop-Livestock Integration

This chapter presents the modelling framework proposed for crop-livestock integration. An overview of the basic features of peasant farming in the study area is presented. Aspects of modelling household resource allocation on mixed farms are discussed. The analytical framework proposed for the analysis of crop-livestock integration is cast around the conventional theory of an income-maximising farm household. Two categories of households (those with and those without livestock) are the focus of the study. The analytical scenarios for the mathematical programming model that is applied in the study are presented.

5.1 Agrarian Structure in the Ethiopian Highlands

Agriculture in Ethiopia, as in most of sub-Saharan Africa, is mostly rainfed. Farming is characterised by cultivation of small, non-contiguous fields and is primarily aimed at satisfying household subsistence needs. The main inputs in agricultural production are land, labour and animal traction. Technological input, by way of improved inputs, is low. Farming is primarily low-input subsistence-oriented mixed farming (Getahun 1978, ILCA 1990).

Low levels of farm output and associated rural poverty are important economy-wide and household problems. Agricultural and resource management problems pose important challenges for meeting food production targets (Biswas et al., 1987, Blaikie 1989). Crop-livestock integration is considered one of the promising strategies of increasing food production and factor employment (McIntire et al., 1992).

Factors that are likely to play an important role in crop-livestock integration include availability of family labour, wage rates and availability of hired labour, farm size, prices of purchased inputs and farm produce and rural infrastructure. These factors affect the way households make resource allocation decisions, which in turn, would critically affect farm incomes and the sustainability of the farming systems (Furubotn and Pejovich 1974, Nordblom et al., 1994).

5.2 An Overview of Farming Goals of Peasant Households

Many different theories have been advanced to explain various aspects of peasant household production. Three broad categories of theories dealing with various aspects of household production may be identified as: (i) economic-anthropological approaches, (ii) political economy paradigms, and (iii) alternative economic concepts (income-maximisation, utility-maximisation and risk-minimisation). Economic-anthropological approaches deal mainly with the dominant influence of institutional factors (e.g., property rights, exchange relations and other institutions) on peasant production. Political economy paradigms basically deal with the role of capital accumulation and mode(s) of production in relation to peasant production. These paradigms espouse various concepts of Marxian political economy and capitalist exploitation (extraction of surplus). Economic approaches deal with maximisation of some household objective(s), such as net cash income. Detailed treatment of these approaches to household production can be found in many textbooks and journal articles (e.g., Anderson et al., 1977, Barry 1984, Hazell and Norton 1986, Kello 1992, and Ellis 1993). By the nature of the objectives of this study, subsequent discussion provides an overview of the economic concepts relating to production goals of peasant households.

Rural households consume and sell part of their farm output. They often purchase some of the essential goods that are either not produced on the farm or are not produced in sufficient quantities or quality. They also participate in marketing activities to obtain some income to defray essential cash requirements for basic food items and pay for other necessities (e.g., taxes) imposed on them by the institutions governing their modes of production and social survival (Muth 1961, Selley 1984). Farm households can, thus, be regarded as production and consumption entities and are located within larger dominant political, economic and institutional systems that affect their economic behaviour (Ellis 1993).

In pursuing opportunities that can enhance their welfare goals, farmers carefully choose what enterprises to engage in, what production techniques to employ and which best-bet strategies to adopt under their operating environment (Low 1974, Singh et al., 1986). Farm production often involves conflicts in meeting the household's socio-economic, nutritional and other welfare-enhancing goals. Household consumption is an important factor in peasant household decision-making behaviour. Household cash income provides the linkage between production and consumption decisions. When competitive factor markets exist, and consumption and leisure preferences are jointly and recursively determined by income, separability between production and consumption decisions can be assumed. The separability assumption permits the farm household to pursue an income-maximisation objective and then spend the income accruing from production activities to satisfy the household's consumption utility-enhancing activities (Hardaker et al., 1991, Ellis 1993).

However, some stringent conditions must be satisfied for the separability assumption to hold. First, effective and competitive markets must exist for both farm inputs and products. Second, prices must be independent of the decisions and economic behaviour of the household or groups of households. Third, risk and risk aversion should not play any significant role in production or prices (Delforce 1994). Rural households in developing countries are often unable to sell surplus farm resources (e.g., labour) at prevailing wage rates. They often pay higher prices for purchased items than the prices they receive for offering to sell the same commodities. Analysis to meet the separability condition demands data requirements that are difficult to satisfy. Few studies have dealt convincingly with the separability condition (Fleming and Hardaker 1993b). It is thus not easy to rationalise separability between production and consumption decisions of many rural households under rainfed agriculture in developing countries, such as in the Ethiopian Highlands.

Notwithstanding these difficulties, peasant households are generally regarded as risk averse (Dillon and Scandizzo 1978) and often do strive to achieve minimum performance levels (`survival algorithm' - an important subsistence ethic) lest they starve. Households may be regarded as pursuing safety-first production strategies (Roy 1952) when there is substantial uncertainty in expected output levels rather than gambling with prospects for more output from riskier decisions (Arrow 1951, Hanoch and Levy 1969, Robison et al., 1984). Minimisation of the chance of below-target returns may be an important goal of many households in traditional agriculture. Other peasant farmers under rainfed agricultural environments can also pursue strategies aimed at reducing chances of catastrophic outcomes; that is, to minimise downside risk (Fishburn 1977 & 1987).

In the presence of risk or uncertainty about future outcomes, common household survival strategies include securing a minimum level of subsistence food production or minimum acreage of certain food crops, or a minimum number of livestock, as insurance against crop failure. These strategies can be combined with diversification and flexibility in enterprise combinations that are commonly characterised by multi-species livestock herds and staggered multi-cultivar, multi-crop production. Farm production may partly involve a motive of maximisation of net cash income but maintain some level of risk aversion on subsistence food production (Norman 1977, Low 1986). However, risk aversion neither precludes allocative efficiency nor ignores income-maximisation at a given level of risk (Watts et al., 1984, Lyne et al., 1991, Kello 1992), considering the various physical and institutional constraints in an agro-ecosystem. Although some frontier production function analyses have questioned the assertion of allocative efficiency of peasant farmers (Hanoch and Levy 1969, Lipton 1968, Dawson 1988), suffice it to say that many households in developing countries seem to be poor but generally efficient (Schultz 1964).

Utility maximisation is another economic concept that has been advanced to explain peasant economic behaviour. Derived from the seminal work by Chayanov, various utility maximisation theories assume that peasant households bear a utility function (usually income) which is a function of some constraint (e.g., labour) faced by the household. Within such a utility-maximisation algorithm, labour faces disutility due to having to work, while cash income generates utility. Utility of cash income is maximised when the marginal rate of technical substitution of leisure for income is equal to the marginal value product of labour (Nakajima 1986). Restrictions imposed in the utility-maximisation framework (especially those regarding the functioning of factor and output markets) have been relaxed, leading to the development of new household farm models (Kello 1992). The new household farm models are more flexible and can involve maximisation of a multi-attribute utility function (e.g., optimise both cash income and leisure) conditional on fulfilling some household constraints on production, consumption and employment (Nakajima 1986, Singh et al., 1986).

On the other hand, assuming perfect knowledge and risk-neutral operating conditions, levels of farm output generally depend on the nature (e.g., productivity and quantity) of available resources, resource allocation decisions and the production environment (Figure 2.2). Peasant farmers can attain equivalent levels of physical output or income by substituting scarce resources with more abundant or cheaper resources (Doll and Orazem 1984). Farm performance (measured by some quantitative criterion such as output level or cash income) would be maximised through efficient management of resource allocation, considering the various institutional, socio-economic, technological and other operating constraints. If an isoquant map were estimated between alternative inputs, it would display an hyperbolic shape depending on the elasticity of input and output substitution (Dillon and Anderson 1977, Ritson 1977).

Selecting which of these (i.e., economic-anthropological, political economy, and alternative economic (income-maximisation, utility-maximisation and risk-minimisation) concepts may be the best at explaining peasant economic behaviour is difficult. Risk and farmers' responses to risk are probably important in influencing resource allocation decisions of peasant households in the Ethiopian highlands. By the nature of the various forms of risk faced, formal accounting for it is difficult. A few studies (e.g., Rodriguez and Anderson 1988, Belete 1989) have attempted to investigate peasant resource allocation practices under risk in the Ethiopian highlands. Various forms of risk, technical and institutional impediments and market imperfections are likely to frustrate the household goal of either income maximisation or utility maximisation. No single theory may exhaustively explain all features of farm household production. As such, all these concepts may be relevant in explaining different aspects of peasant economic behaviour. In this study, a household goal of maximisation of net cash income with some minimum insurance on subsistence consumption is considered a rational strategy for rural households in the study area.

5.3 Mathematical Modelling of Crop-Livestock Integration

Modelling aims at synthesising the essential features of a system without incorporating undue complexity or inconsequential detail. Agricultural resource allocation problems can be analysed using various quantitative techniques including statistical, econometric, simulation, budgeting, or mathematical programming methods. The analytical framework is dictated by the nature and scope of the research problem and availability of relevant and adequate data (Anderson 1974, Anderson et al., 1977, Low 1986). Application of differential calculus to analysis of resource allocation is usually limited to farm management problems that are characterised by either allocation of one or more inputs in one enterprise or allocation of one input in several enterprises. The limitations of differential calculus in analysing multi-input, multi-output farming circumstances can be overcome by the use of mathematical programming (Kihlstrom and Mirman 1974, Binswanger 1980).

Analysis of the interactions between crop and livestock enterprises, resource endowments, production techniques, socio-economic and institutional conditions, suggests the use of mathematical programming. Moreover, the separability condition that presents serious methodological limitations in econometric modelling is easily incorporated in mathematical programming models. Mathematical programming models combine production alternatives, resource and other constraints to derive optimal farm plans. These models provide effective analytical procedures to explore the consequences of different technical or policy alternatives when data on the relevant parameters are available and incorporated (Gass 1985).

Such technical or policy alternatives include economic effects of a new policy, introduction of a new technology or removal of perceived economic distortion(s). Results of such analyses can help to determine the opportunity costs of different resource allocation practices. The opportunity cost of employing any input in the production of any output should be equalised to its marginal value product to yield an efficient input-output mix in the entire production process. The derived shadow prices (i.e., scarcity values) indicate the marginal rate of technical substitution between inputs. Resource use efficiency also dictates that outputs be produced efficiently to obtain optimal trade-offs between different products in the use of scarce inputs (Bradley et al., 1977, Ellis et al., 1991, Paris 1991).

Analysis of farm management problems can be analysed at the farm-level, regional or macro-level. In farm management problems, mathematical programming techniques are usually employed to obtain baseline and optimal farm plans with/out production, technological and environmental restrictions. Iterative changes in production, resource endowment and technological parameters are separately and sequentially introduced to investigate effects of alternative policy and technology options, or impediments to optimal production levels. Finally, sensitivity analyses are conducted to reveal which of the parameters are critical to the solutions obtained. These results will show what further research is needed to evaluate or estimate potential benefits of policy or technology adjustments associated with the identified impediments (Cooper and Steinberg 1974, Barnum and Squire 1979, Sankhayan and Cheema 1991).

Linear programming (LP) was the earliest of the mathematical programming models and is, today, one of the most important optimisation tools of economic research, especially at the farm-level. Linear programming assumes, inter alia, that the problem being solved has a single-valued objective of either maximisation or minimisation nature. The coefficients are single-valued constants and hence the framework is deterministic. The productive resources are divisible, non-interactive and finite in quantity. There are constant returns to scale, perfect elasticity of supply and demand and thus no diminishing marginal returns; and, of course, linear input-output relationships (Keeney and Raiffa 1976, Hazell and Norton 1986, pp. 13-18).

Different mathematical programming techniques have been developed to overcome restrictions imposed by one or more of assumptions of linear programming, including variants of linear programming itself (e.g., multi-objective linear programming). Linear programming has wide applications in military, agriculture, industry, transportation and finance (Wiens 1976, Zimet and Spreen 1986). Linear programming has been widely applied to analyse several farm management problems including enterprise selection, farm adjustments to new technologies, price changes, financial alternatives and purchase or rental of additional farm inputs (Zeleny 1974, Thampapillai and Sinden 1979, Zusman 1983, Klein and Narayanan 1992).

In this study, linear programming is applied to maximise net cash income from the bundle of farm resources that are engaged in crop or livestock production, or in both. The model assumes that farmers are rational decision makers, pursuing the welfare-enhancing objective of income maximisation from employment of their resources. The objective of maximising net cash income (**z**) may be specified, in its canonical form, as:

$$\max \quad z = cx, \qquad \text{s.t.} \qquad ax \leq b, \qquad x \geq 0$$

where **c** is a (1xr) matrix of net income per unit of $\mathbf{x}^{th}$ activity, **x** is a (rx1) matrix of farming activities, **a** is a (mxr) matrix of input-output coefficients, **b** is a (mx1) matrix of resource constraints.

As a safety-first household survival strategy, a subsistence consumption goal can be specified as a constraint. Feasibility conditions can also be specified to ensure that the solution to the resource allocation problem bears a non-empty opportunity set for both the primal and its dual

(Blackorby 1978). To obtain the optimal solution along the production possibility frontier (PPF), the necessary and sufficient (Kuhn-Tucker) conditions must satisfy the first and second order derivatives of the objective function with respect to its various arguments. When a LP model is correctly constructed and well-behaved with respect to its various arguments, the Kuhn-Tucker conditions require that complementary slackness conditions be fulfilled between the primal and its dual (Intriligator 1971). The derived optimal solution has the highest value of the objective function subject to satisfying the specified resource inventory conditions under the existing levels of technology, input and product prices, and other constraints (Paris 1991).

A linear programming formulation of crop-livestock integration can be used to evaluate and advise farmers in the determination of the optimal mix of crops and livestock activities within their resource and other operating constraints (Swanson 1955, Held and Zink 1992). It can also be used to determine alternative ways of enhancing farm incomes through the selection of more profitable enterprises, farming practices, rental of additional farm inputs, etc. (Woubshet and Anderson 1985, Morrison et al., 1986).

Subject to maximisation of household net cash income, some caution is required about modelling crop livestock interactions in developing countries. First, production and transaction costs may not reflect the true opportunity costs of resources due to various institutional, inter-household debt obligations and infrastructural limitations that characterise rural markets in many developing countries such as Ethiopia (Scott 1984, Aredo 1989). Production and consumption activities may thus not be amenable to analysis in purely monetary terms. Second, estimation and incorporation of non-monetary costs, benefits and leisure preferences present many difficulties and are often omitted in linear programming models (Bawa et al., 1979, McPherson 1986).

Third, household division of labour, according to age and sex, depends on learning, training, skill, intelligence and efficiency in performing specific farm and off-farm activities. When opportunities for off-farm employment exist, family members can live and work outside the household. Non-family members can live and work with a farm family. Opportunity cost of labour in different activities will vary with age and sex of the individual household member and status. Thus leisure and other welfare objectives may be difficult to fully capture in a monetised modelling framework (Bernstein 1979). Fourth, varying household size affects specification of minimum consumption requirements and household perception of risk-aversion. With increasing household size, subsistence surplus might decline or subsistence deficit increase (Becker 1990).

Fifth, degrees of risk preference (or risk-aversion) vary between households (Low 1974 & 1986). Sixth, a modelling approach that employs average household resource allocation practices may not necessarily capture the potential effects of different technology and policy interventions at the specific household level (Klein and Narayanan 1992). With these caveats, optimisation of resource use within a linear programming framework is considered an acceptable optimisation approach for modelling outcomes from crop-livestock integration.

5.4 Application of Linear Programming to Highland Agriculture

The theoretical framework and application of linear programming to agriculture is discussed extensively in literature (e.g., Heady and Candler 1958, Hazell and Norton 1986). Many applications of linear programming in agriculture have dealt with identification and evaluation of the constraints in traditional agriculture. Other applications of linear programming have evaluated the profitability of alternative potential technology or policy interventions (e.g., Singh et al., 1986, Paris 1991, Klein and Narayanan 1992).

There are a number of applications of linear programming (LP) in the investigation of farm management problems in sub-Saharan Africa. Most have been concerned with evaluating alternatives that would improve agricultural and factor productivity. The neoclassical household resource allocation theory and consumer behaviour theory have been applied with this LP framework to the analysis of farm management problems characterised by rainfed low-input, semi-subsistence agriculture (Ogunforowa and Norman 1974, Okuneye 1985, Becker 1990, Schaefer 1992, Holten 1993).

Linear programming has been applied to evaluate development strategies for subsistence oriented households in the Ethiopian highlands. These applications have explored the technical and economic performance of smallholder farming practices employing whole-farm linear programming (Woubshet and Anderson 1985). Other applications have attempted to simulate household decision making with a view of determining research priorities for smallholder farmers (Leithman-Fruh 1985, Mela 1985).

The contribution of livestock to farm incomes and the use of oxen in the Ethiopian highlands has been investigated to understand the constraints to and opportunities for improving farm resource use and productivity (Gryseels 1988). Analysis of six-year data using gross margin analysis and linear programming revealed that livestock account for a significant share of farm incomes. Results indicate a positive correlation between farm cash income and grain yields on mixed farms. Moreover, increased cash income from livestock farming has synergistic effects on crop production through facilitating the purchase and utilisation of improved technologies (e.g., fertiliser). Results suggest the possibility of improving farm incomes through changes in farming practices, especially, in animal traction practices.

The role of livestock as a risk management strategy for subsistence smallholder farmers in the Ethiopian highlands has been investigated by varying risk aversion parameters and herd sizes. Using a stochastic linear programming model, the effects of ploughing using a single ox-plough, paired oxen and crossbred dairy cows on farm incomes and risk portfolios were compared (Rodriguez and Anderson 1988). The results indicated that single ox-traction is more efficient than the traditional oxen-pair but will require some changes in livestock management. Sale of small ruminants (e.g., sheep) stabilises farm incomes. Use of crossbred cows for animal traction would improve income earnings by nullifying the necessity of keeping oxen for draught power.

The economic viability of producer co-operatives in the Ethiopian highlands has been explored using linear programming and budgeting techniques (Assefa 1989). Results indicated that producer co-operatives could improve incomes by reducing the number of crops grown and also by integrating crops with livestock. However, there will be increased need for financial assistance if agricultural investments and production levels are to be improved and sustained.

The efficiency of smallholder farmers has been investigated using linear programming and linear risk (MOTAD) programming models, by parameterisation of income variability and risk aversion levels to derive estimates of smallholder allocative efficiency levels in the central Ethiopian highlands (Belete 1989). Analysis of alternative modes of traditional farming practices (e.g., different oxen traction arrangements) indicated considerable divergence between actual and optimal farm plans. It was suggested that smallholders appeared to operate at relatively higher risk levels than would be optimal assuming that the risk aversion coefficients were appropriately elicited.

Issues related to farmers' risk perceptions in the use of chemical fertilisers are discussed (Belete et al., 1992) and relate well to other fertiliser studies under weather uncertainty (e.g., Babu et al., 1991). To minimise risk, optimal farm plans suggest that changes in existing farm plans and animal traction technologies would improve household cash incomes and resource productivity if accompanied by supportive policy and technological interventions (Belete et al., 1993).

The potential contribution of livestock to the sustainability of agricultural systems in the Ethiopian highlands was examined through assessment of cropping patterns, scale and intensity of cultivation (Emana and Storck 1992). Improvement strategies through high yielding crop and forage varieties were investigated for the mixed farming systems in the eastern highlands of Ethiopia. The use and contribution of improved inputs to increased farm cash income was examined too. Using a linear programming approach, levels of use of inorganic fertilisers (DAP and Urea) by farmers has been compared with recommended application levels as suggested by extension packages. Results show that farmers use far less of the inorganic fertilisers than advised by extension agents.

Previous modelling efforts on Ethiopia's smallholder agriculture have tended to ignore institutional constraints affecting farm production and the consequent imperfections created, partly, by the socialist agrarian structure. Price controls on farm produce, among other items, discouraged entrepreneurial farming under the former semi-socialist agrarian structure. However, following the ousting of the socialist military regime in 1991, the transitional new economic policy (NEP (Appendix 1)) is shifting towards free markets and is generally aimed at promoting efficient resource management. Adjustments in the farming systems under liberalised price structures will (or is expected to) affect enterprise practices, farm resource portfolios and incomes.

As one of the building blocks to the long-term synthesis of agrarian organisation and performance, linear programming is applied in the current study to evaluate outcomes of crop-livestock integration. It will also make suggestions that would contribute towards improvement in agricultural performance.

5.5 The Empirical Linear Programming Model

A whole-farm linear programming model is applied to evaluate technology and policy options for crop-livestock integration. The model is a non-stochastic multi-input, multi-output representation of a farm household in the Ethiopian highlands. Interactions between crop and livestock are captured through use of intermediate or final products such as manure and straw.

Despite intensive effort, it was extremely difficult to get sufficient and reliable data on farm (crop and livestock) production and household resource allocation schedules during the minor crop (*belg*) season. The *belg* season accounts for, on average, about 20 percent of annual farm output. Since enough reliable data would not be obtained for the *belg season*, the model is run for the main cropping season (*meher*) only. The belg season is not modelled in the current analysis.

5.5.1 The objective function

The model seeks to empirically represent the farmer's dilemma about resource allocation decisions including: (1) how many hectares to devote to which crop(s) ? (2) what combination(s) of crops and animals would make best use of available labour and land? (3) would further intensification increase the employment of family labour?

The objective function in the whole-farm linear programming model is specified as:

$$\max Z = \sum_{k}\sum_{j} P_{jk} X_k - \sum_{f}\sum_{k} P_{fk} X_k + \sum_{m}\sum_{y} P_{my} X_y - \sum_{g}\sum_{y} P_{gy} X_y + P_{air} A_{ir} + P_{hlt} L_{ht} + P_{hht} H_{ht}$$

where **Z** is net cash income, $\mathbf{P_{jk}}$ is price of crop produce type **j** from crop **k**, $\mathbf{X_k}$ are crop activities for crop type **k**, $\mathbf{P_{fk}}$ is the unit cost of crop input type **f** for crop **k**, $\mathbf{P_{my}}$ is the price of livestock product **m** from livestock type **y**, X_y are livestock activities for livestock type **y**, $\mathbf{P_{gy}}$ is unit cost the of livestock input type **g** for livestock type **y**, $\mathbf{P_{air}}$ is the rental rate for leasing out land of type ($\mathbf{A_{ir}}$), $\mathbf{P_{hlt}}$ is the wage rate for offering out wage labour during period **t** ($\mathbf{L_{ht}}$) and P_{hht} is the rental rate for renting out oxen during period **t** ($\mathbf{Hh_t}$).

Household net cash income is thus a summation of net income of individual enterprises from the optimal quantities of marketed production valued at respective market prices. It also includes income from off-farm wage employment and renting out surplus draught oxen. The objective function is attained through selection of optimal levels of crop and livestock activities under the specified input-output coefficients and subject to the resource constraints and other restrictions. The model does not permit households to acquire or hire in additional land, labour or draught oxen, when they do not already have them. Preliminary model simulations indicated an unbounded LP solution without this restriction.

5.5.2 Activities in the model

Activities are representative of the several possible enterprises that can be included in the farm plan. To produce outputs or generate cash income, there are often numerous ways of undertaking and managing these enterprises (Anderson et al., 1977). For crop-farms, the farm model is represented by a crop sector only. Then a livestock sector is introduced into the model to explore effects of crop-livestock integration on resource allocation, enterprise mix and net cash income.

Activities included in the crop sector are production, marketing and consumption. Storage is subsumed in the consumption activity, for purposes of simplicity. Storage losses and costs are negligible and are excluded from the LP model. The livestock sector includes production activities, feeding activities and marketing activities. The specification of the crop and livestock sector activities is constructed to reflect the farmer's conditions, and not experimental results from research trials, using data obtained from farm surveys that were conducted during the study period (1993/94). The farm household is thus linked to markets through its various selling and purchasing activities.

5.5.2.1 Crop sector activities

Crop sector activities are developed according to crop type, crop husbandry practices and land type. Each husbandry practice has its own characteristics in terms of resources required (e.g., labour, animal traction) and physical output in terms of grain and/or straw yield. Four broad categories of crops are chosen namely, cereals, legumes, oil crops, pasture and a rotational fallow. The cereal crops in the model are wheat, barley and oats. The legume crops in the model are field peas, horse beans and fenugreek. Linseed is the only oil crop that is grown in the study area.

Pasture (native and improved pastures) and fallow activities complete the set of crop sector activities. However, planned fallows, that fit into specific crop rotation systems, are rarely practised in the study area. Pasture and other crops often grow on land under fallow and easily fit into the general land use management systems that individual farmers may elect to pursue. Fallow activities are subsumed in the pasture production activity. Since pasture production activities are specified in the farm model, excluding the fallow activity helps to keep the model simple and manageable.

5.5.2.2 Livestock sector activities

Four livestock sector activities are introduced in the crop farm model and are differentiated by technology in terms of livestock and pasture productivity. The livestock sector activities in the model are keeping oxen, or local zebu cows, or (indigenous or improved) sheep, or raising crossbred dairy cows. The model permits these activities to be undertaken either with native unimproved pasture or improved legume pastures. Production activities (including feeding activities) and marketing activities are developed for each of the four livestock activities.

Like crop sector activities, livestock production activities each have an objective function coefficient, a set of input requirements and a vector of outputs. Input requirements are included for each livestock activity for labour, straw and hay. These requirements and other livestock production parameters are shown on Table 4.11. Having specified nutritional requirements for livestock, livestock feed rations are determined exogenously to the model and there is not a need for a least-cost feed ration formulation problem to be solved within the empirical net income maximisation model. Animals are assumed to depend, mainly, on pasture and other feed resources that are available on the farm.

5.5.2.3 Subsistence consumption activities

The model is constructed to include household subsistence requirements of cereals, pulses, milk and cooking fuel. These constraints implement the notion of safety-first household consumption strategy.

Subsistence food requirements are specified using the data that were obtained from sample farmers regarding the consumption of cereals, dairy products and legume grains (pulses). For crop farms with an average number of 3.65 persons, minimum level of cereal, pulse and milk requirements for the *meher* season are scaled to 580 kg, 250 kg and 150 litres, respectively. A minimum of 1000 kg of cow dung cakes are specified for household use during the *meher* season.

With appropriate adjustments for household size and length of the planning period modelled, other studies in the central Ethiopian highlands (e.g., Rodriguez and Anderson 1988, Belete 1989) have also pegged cereal and pulse requirements at similar levels. Similar subsistence requirements are applied by the Ethiopian Nutrition Institute (ENI) and World Food Programme (WFP) in various food distribution programmes (Webb et al., 1992). The model can be made to accommodate annual food requirements by either including the requirements for the minor (belg) season or numerically scaling the meher season requirements accordingly. But neither of these two accommodations were made.

5.5.2.4 Marketing activities

For each of the crop and livestock sector activities, the model permits selling of each product (over and above subsistence consumption requirements). The model also permits households to offer, for cash income, any surplus farm resources such as family labour, draught oxen or agricultural land during any of the four periods of the cropping season.

5.5.3 Model constraints

The model is constrained by a number of factors including the availability of land, family labour, work oxen, crop rotation requirements, subsistence (food and fuel) requirements and livestock nutritional requirements. Constraints reflect the competition between activities for limited resources and the interrelationships between activities. The various resource and accounting constraints are discussed hereafter.

5.5.3.1 Land constraint

The farm family can use all of its land with a possibility for renting or exchanging land. Available land is divided into three categories; as was observed during farm field surveys in the study area. The first category (*areda* land - LAND1) is nearest to the homestead and often the most fertile. The second category (*areda nonproductive* - LAND2) is modestly fertile land and within reasonable distance (within 0.50 kilometres) from the homestead. The third category is the least productive (*yemeda* - LAND3) land and is often exchanged with other farm families for pasture production or is left under fallow. Total farm size is held constant (2.4 ha) but variations in acreage of individual types of land (including pasture land) are permitted.

The allocation of each category of land among different crops and forage crops is represented by the following relationship:

$$\sum_k \mu_k X_k + \sum_y \mu_y X_y + A_{ir} \leq A_{i,} \quad \forall_i$$

where μ_k is the land requirement by crop **k**, X_k is a matrix for crop production for crop type **k** (ha), μ_y is land requirement for livestock type **y** for pasture and fodder (ha), X_y is a matrix for livestock type **y,** A_{ir} is size (ha) of rented ('leased out') land of category type **i** and A_i is the maximum area (ha) of own farm of productivity category **i.** Each crop land category has a different production potential which affects crop and pasture yields, labour and animal traction requirements. Land productivity differences are reflected in the linear programming model by adjusting the respective input-output coefficients.

5.5.3.2 Labour constraint

Different crops have different labour requirements for different production activities depending on the productive potential of the land category. To avoid different interpretations of available labour time, labour is expressed in adult person-hours. There are usually many household members spending varying amounts of time for various farm activities. To reduce the data requirements and inconsistencies, average number of hours spent on each farming activity during the *meher* cropping season are used in the LP model. An average household has an effective labour force of 2.75 adult persons providing 6 hours of labour time daily for 186 working days in a year.

Allocation of labour time in different farming activities is described by the following relationship:

$$\sum_{k} \alpha_{kt} X_{kt} + \sum_{y} \alpha_{yt} X_{yt} + L_{ht} \leq L_{t}, \forall_{t}$$

where α_{kt} is the labour requirement (hours/ha) by crop **k** during period **t,** α_{yt} is the labour requirement (hours/herd unit) by livestock type **y** during period **t**, $\mathbf{L_{ht}}$ is family labour hired out for wage labour in period **t**, $\mathbf{L_t}$ describes availability of family labour in period **t.**

Labour requirements are presented on a per-hectare basis for each period representing ploughing (**t=1**), weeding (**t=2**), harvesting (**t=3**), threshing and other crop production (**t=4**) activities. (See Table 4.6 for the timing of these operations). For the same time periods, labour requirements for herding, watering, milking and barn cleaning are shown for livestock husbandry activities on a per herd-unit basis. During peak labour demand periods, opportunities for hiring or `selling' extra labour are included in the model. Estimates of rural wage rates were obtained from rural farm surveys (chapter four). Although there are wage differentials based on the age and gender of hired labour and task performed, average wage rates are used in the model to maintain consistency and tractability.

5.5.3.3 Animal traction constraint

Different crops have different traction requirements depending on the land type, yield potential and the threshing bulk. Availability of draught power varies with livestock herd size and structure across households. Requirements of animal traction are expressed on a per-hectare basis, in oxen-hours, for each of ploughing, harvesting and threshing periods for crop activities, during the *meher* season. Oxen are not required during weeding, an activity that is performed manually.

Allocation of animal draught power for various farm activities is specified as:

$$\sum_{k} \beta_{kt} X_{kt} + H_{ht} \leq H_{t}, \quad \forall_{t}$$

where β_{kt} is the number of oxen-pair hours (per hectare) required by crop type **k** during period **t**, $\mathbf{H_{ht}}$ is hired out draught power and $\mathbf{H_t}$ is available animal draught power in period **t**. The rental market for oxen is employed as a surrogate for any of the sources of, or arrangements involving, animal traction. These alternatives include the situation where farmers who own one ox arrange to obtain another ox either from farmers with more than two oxen or among themselves in order to have the traditional pair of work oxen for ploughing and planting.

5.5.3.4 Crop rotation constraint

A crop rotation constraint is imposed on the model in order to reflect the observed farmer practise of a cereal-legume-fallow rotation. Although different rotations have different crop and pasture yields arising from differences in management skills of individual farmers, average crop yields are used in the model assuming average performance levels from the skills and management practices by crop farmers.

The crop rotation constraint affects enterprise acreage combinations between cereals (**cl**) and legumes (**lg**) and is specified as follows:

$$0.5 \sum_{k} X_k^{cl} - \sum_{k} X_k^{lg} \leq 0, \quad \forall_k$$

The crop rotation constraint is expressed as a ratio of `one of legumes' to `two of cereals'. Crop rotation (including rotational fallow) is important for both agronomic and economic reasons. First, crop rotation between cereals and legumes helps to reduce pest and disease problems. Second, legumes help to improve soil fertility through nitrogen fixation. Third, for crop-livestock farmers, legume residues help improve the feeding quality of cereal straw.

5.5.3.5 Livestock nutrition constraint

For each livestock breed, estimates of requirements for pasture, grass hay and crop residue (kg) are specified on per herd-unit basis considering requirements for production, maintenance and growth of each livestock type. Although sheep are not commonly supplemented with large amounts of good quality hay or straw, feed rations of lambs and breeding rams that are targeted for the prime market are often supplemented for quick fattening or high mating performance, respectively. These nutritional estimates take herd prolificacy, mortality, replacement and culling processes into consideration.

The livestock feed requirements are specified by the following relationship:

$$\sum_{y} \eta_y X_y \pm X_{gy} \leq \sum_{j} \sum_{k} \eta_{jk} X_k$$

Where η_y is the per herd requirement of straw (or hay) by livestock type **y**, $\mathbf{X_{gy}}$ is the amount of livestock input type **g** (e.g., purchased crop residue) and η_{jk} is the amount of crop residue type **j** from crop type **k**.

Data were not available for the determination of the content of minerals, total digestible nutrients (TDN) and trace elements in the various straw and hay types. Mineral restrictions were thus excluded from the model and this substantially reduced the analytical complexity of the model. Many farmers in the study area do not use mineral supplements and the exclusion of such livestock feed constraints is a good approximation of the empirical situation.

5.5.3.6 Accounting identities

Accounting identity constraints necessitate that production, consumption, selling and purchase activities for each crop and livestock product balance. Accounting constraints also help to balance the demand and supply of farm inputs (own and purchased). Storage of crop and livestock products is subsumed in the consumption component. The various accounting constraints are specified as follows:

Crop production balance

The crop production restriction is intended to balance the crop sector activities in the model and ensures that subsistence requirements must be first fulfilled before any crop selling activity enters into the model. It is specified as follows:

$$\sum_{k} \gamma_{jki} X_k - X^s_{jk} \geq M^c_{jk}, \quad \forall_{jk}$$

where γ_{jki} is the yield of produce type **j** from crop type **k** from land **i**, X^s_{jk} is the amount of crop produce that is offered for sale and M^c_{jk} is the subsistence requirement for crop produce type **j** from crop **k**.

Crop input balance

The crop input restriction ensures that supply of farm inputs meets their demand by crop sector activities. It balances resource requirements for crops through their supply from livestock sector activities (e.g., manure and traction when animals are introduced in the model) and from purchased sources. This accounting constraint captures some of the features of resource use linkages between crops and livestock in crop-livestock systems. It is specified as follows:

$$\sum_{k} \theta_{fk} X_k + \sum_{f}\sum_{k} X_{fk} - \sum_{m}\sum_{y} \theta_{fmy} X_y \geq 0, \quad \forall_f$$

where θ_{fk} is the per hectare requirement of input type **f** by crop type **k,** $\mathbf{X_{fk}}$ is the amount of input type **f** for crop **k** and θ_{fmy} is the amount of crop input type **f** available from livestock product **m** (i.e., manure) of livestock type **y**.

Livestock production (e.g., milk) balance

This accounting restriction ensures that there is a balance between production, consumption and marketing activities for each livestock enterprise that enters in the farm model. It is specified as follows:

$$X^{s}_{my} + \gamma_{my} X_y \geq M^{c}_{m}, \quad \forall_{my}$$

where γ_{my} is the yield of livestock product **m** from livestock type **y**, X^{s}_{my} is the amount of livestock output type **m** from livestock type **y** that is sold and M^{c}_{m} is the subsistence requirement for livestock product **m**.

Livestock input balance

The livestock sector input constraint balances resource requirements for livestock enterprises through their supply from crop sector activities (e.g., straw, stubble) and from purchased sources. This accounting constraint captures some of the features of resource use linkages between crops and livestock in mixed farming systems. It is specified as:

$$\sum_{y} \eta_{gy} X_y - \sum_{g}\sum_{y} X_{gy} - \sum_{j}\sum_{k} \eta_{gjk} X_k \geq 0, \quad \forall_g$$

where η_{gy} is the per herd requirement of input type g for livestock type **y** , X_{gy} is the amount of livestock input type **g** for livestock type **y** and η_{gjk} is the amount of livestock type **g** available from crop produce type **j** of crop **k**.

5.6 Model Assumptions

The model rests on the following assumptions.

1. Households cannot acquire or lease-out extra land and hire labour, when they already have them. This prevents unboundedness in the linear programming modelling process.
2. Mixed crop-livestock farming is a means to achieve increased farm output and employment.
3. Households strive to satisfy subsistence food requirements before selling any surpluses.
4. All the livestock are bred on the farm. This assumption removes the necessity of livestock purchases for a steady-state herd structure. Since herd-building is a long-term investment (like land purchases), the model ignores the investment and capital costs of building a livestock herd.
5. Households with livestock depend on natural pastures, crop residues and some cultivated fodder and there is no need for concentrates to be purchased and fed to animals.
6. There will be adequate infrastructure and markets to absorb the increased marketable surplus from improved crop and livestock production.
7. All farm inputs and outputs are valued at market prices.
8. The specified resource endowment and constraint levels approximate the representative category of households in the study area.
9. Households without livestock satisfy their daily fuel needs by collecting either firewood or manure (or both) from communal grazing land and public forests.

5.7 Derivation of Model Parameters and Constraint Levels

Estimating the appropriate input-output coefficients is problematic for the farm sector because of data inconsistencies in published statistics. A survey conducted as part of this study provided the input-output relationships for crop and livestock production specified in the empirical linear programming model. The coefficients and parameters in the model include: input requirements (per hectare) by different crops and per herd unit for different livestock activities; yields of different crop and livestock products; household endowments of land, labour and livestock; market prices and costs of different inputs and farm products. Prices and cost of different inputs and farm produce were obtained from farmers, local input suppliers and local markets during the survey period. After considering transportation costs, seasonal variations in prices were negligible to the farmers.

Grain and straw yields varied depending on soil types, management practices, delays in production practices (delayed planting or weeding or harvesting) and measurement methods. Households were grouped according to family structure, resource endowment, combinations of crops and livestock. For each cluster of households, average values of each parameter were used. Within cluster differences were small and the magnitude of bias is therefore small. These estimates of input-output parameters compare relatively well with the coefficients used in other studies conducted in the study area (e.g., Gryseels 1988, Rodriguez and Anderson 1988, Belete 1989, Wolde-Mariam 1991). Any differences in parameter values between these data sets is assumed to reflect effects of institutional and socio-economic changes that has taken place over time and the effects of sampling and data collection techniques employed by different research studies.

5.8 Analytical Scenarios for Crop-Livestock Integration

In applying the linear programming model for the resource allocation analysis, different scenarios can be selected to represent different farming practices and operating conditions in the Ethiopian highlands. Any such scenarios are likely to have different data demands, model complexity or tractability and research outcomes. Some of the immediate data implications relate to the quantification of availability of family labour (in the performance of the numerous and varied crop and livestock activities), animal traction (for production and marketing activities as well as rental services) and profiling the acquisition of various external inputs (e.g., fertiliser).

Even for a single enterprise (e.g., wheat), several production activities are performed from land preparation through post-harvesting period to adequately represent in a tractable LP model. Family labour may have to be scheduled according to the age-sex structure of both family and wage labourers, varietal differences and husbandry practices (e.g., weed control methods, harvesting methods, storage and marketing strategies) of each crop may need to be distinguished and modelled accordingly, etc. The realism of inclusion of such detail may not justify the extra complications in operationalising the empirical model. It is difficult and expensive to obtain such data from rural households.

Considering these potential limitations, three scenarios are considered for analysis to meet the objectives of this study. Some common features of these scenarios are worthy of brief mention. First, the scenarios deal only with the cluster comprising crop farmers. Scenarios with the other two clusters could also have been considered but were excluded in order not to detract from the planned focus of this study. The key question of this study is not whether a crop farmer is less well off than a crop-livestock farmer, rather it is whether a crop farmer will improve farm income by adopting a crop-livestock system instead of a sole cropping system. Second, the land use constraint is specified in such a way that each land category has different input-output coefficients. Third, minimum subsistence requirements are maintained in all scenarios. Fourth, the resource endowments of crop farmers are maintained throughout (unless otherwise stated). To test the hypotheses posited in this study, the following scenarios were investigated.

First scenario : This scenario investigates the level of farm cash income, enterprise mix and employment of family labour under situations of either late or timely hire of draught oxen by crop farmers. Crop farmers usually hire oxen from farmers with surplus oxen but they may acquire the oxen late in the cropping period. They often obtain about 20 per cent less cereal yield and about 15 per cent less legume yield due to late oxen availability. The yield penalty is due to reduction in cultivated area, inadequate land preparation or late sowing. In some cases, crop farmers may be able to hire oxen in good time for effective land preparation. The yield penalty imposed in the situation of late cultivation is then relaxed. A capital constraint on availability of credit at variable interest rates is imposed on renting work oxen. The household can also offer surplus family labour to work as wage labourers in the rural or urban labour market.

Second scenario : The possibility of introducing livestock on crop farms is investigated. An alternative scenario would have been to evaluate potential income effects of removing livestock from mixed farms. However, introducing livestock on crop farms is a more practical research issue than examining the effects of removing livestock from crop-livestock farms. This scenario represents the path of agricultural intensification from a situation of nil livestock towards crop-livestock production. This scenario permits the analysis of the contribution of livestock to economic viability of the farming systems in the cereal livestock zone of the Ethiopian highlands.

Crop farmers are permitted to own oxen, sheep or cattle. The yield penalty imposed in the above scenario, due to lack of oxen, is relaxed. The livestock herd could be composed of work oxen, indigenous cattle and sheep. The household can also offer surplus family labour to work as wage labourers in the rural or urban areas and sell crop residues in the local straw markets.

Third scenario : On introducing livestock on crop farms, outcomes arising from improvements in either livestock productivity or pasture yield, or both, are investigated. This would occur through increased herd prolificacy and would result in increased marketable progeny, more milk yield and manure production. This scenario examines the possibility that improved pasture yield (either through lower stocking rates or use of manure or fertiliser) could enhance crop-livestock integration.

5.9 Incorporating Riskiness of Rainfed Agriculture

As in most regions practising rainfed agriculture in developing countries, households in the study area face different levels of risk in their farming endeavours. The main sources of risk were associated with fluctuations in weather (especially rainfall and frost); challenges posed by diseases and pests for both crops and livestock; institutional risk in the form of uncertainty about land tenure and legislation regarding the functioning of markets for rental land and agricultural labour; price variability and occasional risk of theft (e.g., livestock). Households in the study area have adopted various social and market responses to cope with variations in farm output resulting from operating under these risky conditions (see chapter four : section 4.8). This study examines outcomes from crop-livestock integration taking the different types and levels of risk as given. However, it is important to appreciate the predominance of risk in peasant agriculture.

Multi-criteria or risk programming would have been a more appropriate mathematical programming technique to account for the varying degrees of riskiness in rainfed agriculture. However, a number of factors led to the selection of a non-stochastic LP framework. First, lack of credible estimates of time series data about various farm-level production, consumption and marketing practices prevented such an approach. Second, some of the studies (e.g., Holthausan 1981, Rodriguez and Anderson 1988, Belete 1989, Kello 1992) that have attempted to apply risk programming to farming circumstances have had to cope with substantial variations in the nature of risk experienced by farmers.

Third, two studies (Rodriguez and Anderson 1988, Belete et al., 1993) have investigated some aspects of risk in peasant agriculture, in the study area, to greater detail than would have been possible with the nature and volume of research and personnel resources that were available for this study. Some enterprises, such as crossbred dairy cattle, are relatively new and there is no sufficient and consistent set of local data about farm production practices. Prior to the recent liberalisation of the economy (that started in 1991), most of the farm produce was organised under controlled market prices. Moreover, farmers rarely keep records of their production plans and performance (see section 4.6.4). It is therefore rather difficult to obtain the mean and variance of the yields and prices describing these and other enterprises. This study set to examine the contribution of livestock to the economic viability of farming systems in the Ethiopian highlands taking the nature and level of various forms of risk as given. Fourth, there are large gaps in the data sets regarding alternative return distributions (mean and variance) of enterprise yields and costs that are difficult to authenticate and apply in risk modelling. It is implicitly assumed that existing levels of performance and achievement, through yield and price levels realised at whatever levels of risk in the past, are reasonable indicators of predicted performance in the future.

Fifth, from field experiences in eliciting farming goals, it is even more difficult to elicit estimates of risk-aversion from rural households. Similar difficulties have been encountered with rural households in other developing countries such as Kenya (Parton 1993) and Tonga (Delforce 1994). Sixth, as a result of such complexities, alternative assumptions about riskiness of agriculture have a profound influence on the nature of analytical results for policy applications.

Despite the difficulties, accounting for risk in a linear programming framework would improve analytical results in some rudimentary manner.

Due to the lack of adequate and reasonable data sets for describing the nature of riskiness in farming, the empirical LP model uses two surrogate measures to accommodate or account for risk. First, specification of minimum levels of subsistence requirements approximates farmer adaptation to various forms of risk and forces the allocation of farm resources to the production of preferred staple crops and livestock enterprises. Second, the crop rotation constraint permits acreage devoted to cereals and legumes to remain approximately flexible from year to year and perhaps provide a steady supply of subsistence food preferences over time (Hazell and Norton 1986). Specification of minimum food requirements and crop rotation constraints thus incorporate a subsistence consumption insurance in the programming model to hedge against risk and uncertainty in rainfed agricultural systems and imperfections in the functioning of the various components of the rural economy (Kennedy and Francisco 1974, Just 1975). While this is only an approximation method of accounting for downside risk, which is usually handled by minimising the probability of being below some threshold, it is nevertheless a tractable method.

5.10 Summary

Increasing farm cash income, food production and labour usage are major aspects embracing the importance of crop-livestock integration in the farm household economy. Linear programming is selected as the appropriate analytical tool to examine interactions between crops and livestock. The whole-farm linear programming model incorporates various aspects of crop-livestock integration such as animal traction, use of crop residues as animal feeds, use of manure from animals for cooking energy needs as well as organic fertiliser, allocation of land to pasture, forage and for crop production.

The value of livestock to the household economy is modelled to maximise household net cash income conditional to meeting several inequality constraints. These constraints include availability of land, labour, animal traction and livestock nutrition. Estimates of these constraints and other parameter values were obtained from empirical field surveys and secondary sources, as discussed in chapter four. Results of the linear programming model analysis are the subject of the next chapter.