Chapter Six

Economic Outcomes of Crop-Livestock Integration

This chapter presents results of the linear programming model that is applied to the analysis of farm-level resource allocation in Baso and Worana sub-district of the central Ethiopian highlands. The analysis presents the economic outcomes of timeliness of oxen availability, land productivity differences and integration of crops and livestock on small farms that, on average, have the same land, labour and draught oxen resources. These settings ensure that `like' is being compared with `like'. Results of alternative model specifications, hypothesis testing and implications for farm cash incomes and opportunities for agricultural intensification are discussed.

6.1 Recapitulating on the Resource Constraints

From farm surveys, land fertility and oxen availability pose important resource allocation problems to many small farmers in the study area. Relative acreage shares change as either farm size or livestock herd (or both) increase, especially oxen. The model allows farm inputs to be acquired at their market price. Farm resource endowment, labour and traction input relationships are derived from survey results. The per-hectare labour and traction requirements for each crop activity are specified in chapter four (Table 4.9). Minimum subsistence consumption for wheat and barley are, respectively, specified at 280 and 300 kilograms per household while consumption of field peas and horse beans are each set at 125 kilograms. Crop yields, livestock productivity and other technical parameters are also presented and discussed in chapter four (Tables 4.10 and 4.11). Average values of the model parameters are used, for each variable (from the cluster of crop farms), as obtained from the farm survey data.

Since linear programming is sensitive the type of data that are used, some caution is urged in the interpretation of the results. While this is not radically different from previous studies, it is important to appreciate differences in results arising from alternative model assumptions, constraint specification and input-output coefficients on the outcome of any linear programming exercise, and extensive sensitivity analysis was employed. The whole-farm linear programming model permitted open-ended technology choices (i.e. all modelled enterprise choices) for the analytical scenarios.

Conditional on satisfying the various constraints, an open-ended linear programming formulation permits the solution procedure to discriminate between enterprises based on their relative contribution to farm cash income.

6.2 Baseline Farm Plan

On crop farms, cereal crops account for about 40 percent of the cultivated area (1.6 ha) while pulses and oil crops account for 50 percent and 10 percent, respectively. Land that is left fallow or under pasture is about 0.80 ha or one third of the farm. During the survey period, crop farmers were observed to devote, on average, 0.22 ha to wheat, 0.25 ha to barley, 0.18 ha to oats, 0.36 ha field peas, 0.27 ha to lentils, 0.18 ha to horse beans and 0.14 ha to linseed (Table 6.1, column 1)[1]. To derive the baseline enterprise combinations, acreage combinations that farmers allocate to different crops were specified, as minimum constraints, as was empirically observed during the survey period.

As the best organisation of farm enterprises to satisfy the various resource, subsistence, crop rotational and other constraints, the baseline plan would devote 0.45 ha to wheat, 0.50 ha to barley, 0.20 ha field peas, 0.25 ha to lentils and 0.20 ha to horse beans (Table 6.1, column 2). Crop farms earn, on average, about 425 birr (US $70) in farm income during the main rains (*meher*) cropping season. Work oxen are hired at prevailing oxen rental rates. This farm plan satisfies minimum subsistence food requirements.

However, this farm plan does not change even by reducing oxen rental rates from the current 0.65 birr per oxen-hour to as low as 0.25 birr per oxen-hour. For resource-limited households, the ability to hire oxen, *a priori*, is a major limiting factor and is the rationale behind this sensitivity analysis on rental rates for work oxen. If levels of subsistence food requirements are reduced, these households will, perhaps, be on near-starvation diets, but will then earn some income to purchase other basic household needs.

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[1] For all subsequent tables of results in this chapter, a sample of the original linear programming matrix and a sample of LP results are contained in Appendix 7.

Table 6.1 Baseline and Alternative Farm Plans

Scenario / Enterprise	(1) Actual Farm*	(2) Baseline	(3) Late ox hire No land classes	(4) Timely ox hire No land classes	(5) Late ox hire Land classes	(6) Timely ox hire Land classes
Wheat (ha)	0.22	0.45	0.50	0.44	0.45	0.36
Barley (ha)	0.25	0.50	0.49	0.43	0.53	0.42
Field Pea (ha)	0.36	0.20	0.34	0.19	0.19	0.17
Lentil (ha)	0.27	0.25	0.74	1.14	1.01	1.28
Horse bean (ha)	0.18	0.20	0.22	0.19	0.19	0.17
Linseed (ha)	0.14	0.00	0.12	0.00	0.00	0.00
Fallow Land (ha)	0.80	0.80	0.00	0.00	0.00	0.00
Farm Size (ha)	2.40	2.40	2.41	2.41	2.41	2.41
Labour (Hrs)	-**	630	880	860	870	845
Hired Oxen (Hrs)	-**	388	530	520	535	515
Income (Birr)	-**	425	520	770	540	825

Source: Author's survey (1993-94) results and Appendix 7

* This farm plan includes 0.18 ha for the production of oats

** Not determined

During the short rains (*belg*) season, which is not modelled, they cultivate between 15 to 40 percent of their arable land, depending on weather conditions and availability of necessary resources (chapter four). This implies that they earn an extra 150 birr to generate total annual farm income in the range of 600 birr to 700 birr (US $120). Per capita GNP in Ethiopia is estimated at about US $120, implying that farmers in the study area are approximately representative of the average income distribution in the country. Households in the high potential livestock-perennial crop zone (e.g., coffee-growing areas) would represent higher income profiles while households in the lowland pastoral systems would represent families in the lower income percentiles in the total population of Ethiopia.

The crop rotation constraint appeared usually restrictive when applied on specific types of land categories. Errors in the LP solutions suggested enterprise combinations far removed from empirical farm practices. To overcome this difficulty, the crop rotation was applied at the whole-farm level. This approach is more plausible and permits relatively more realistic farm plans. In some cases, the crop rotation constraint is marginally violated (up to a maximum of about 18-20 percent) in order to satisfy the constraint on minimum subsistence requirements.

6.3 Land Productivity and Timeliness of Land Preparation

Income effects of differences in land productivity to the household economy are explored in association with timeliness of land preparation. The motivation of the analysis is to explore ways and means of improving the observed farm plan, considering both land quality differences and differential access to work oxen. From the farm surveys, it was observed that resource-poor households are often unable to obtain services of rental oxen in time for land preparation, despite enormous efforts to do so. As explained in chapter four, due to the small parcels of arable land, they are not able to prepare different fields at different periods. Since they cannot treat different types of land differently, the land ends up being treated as though it was of uniform quality. Sometimes, because of the vested interests of the oxen owner, such households may even lose the choice of which crop to plant.

Indeed, not to recognise differences in land productivity may impede motivations to maintain land in its most productive state. Using data and other available information about land productivity could serve to advance the benefits of keeping land in a productive state (in terms of food production and income generation) for farm households. However, if households can and do obtain rental oxen in time for land preparation, they often plant different fields with different crops at different periods in the cropping season.

This analysis presents results where land productivity differences are considered and where they are not. These analyses are conducted with minimum subsistence food constraints on cereal grains and pulses. The following sequence of analyses are conducted and discussed: (1) effects of delayed and timely availability of rental oxen on food production and farm income (ignoring differences land productivity); and (2) effects of delayed and timely availability of rental oxen on food production and farm cash income (considering differences land productivity).

When crop farmers are forced to ignore differences in land productivity due to delayed rental acquisition of oxen, derived optimal farm plans suggest that land allocation will be in the magnitude of 0.50 ha to wheat, 0.49 ha to barley, 0.34 ha field peas, 0.74 ha to lentils, 0.22 ha to horse beans and about 0.12 ha to linseed. This farm plan would generate farm income of about 520 birr (Table 6.1, column 3). Recognising differences in land productivity despite late availability of rental oxen, households would devote 0.45 ha to wheat, 0.53 ha to barley, 0.19 ha field peas, 1.01 ha to lentils and 0.19 ha to horse beans. This plan would improve income to 540 birr (Table 6.1, column 5). This is achieved by increasing land devoted to cultivation of high-value crops (e.g., lentils and barley) and marginal reduction in acreage devoted to the production of wheat, field peas and linseed.

Ignoring differences in land productivity, timely availability of rental oxen would improve farm income to 770 birr (Table 6.1, columns 3 and 4). If land productivity differences are accounted for, there is a further increase in farm income to about 825 birr. Timely availability of rental animal traction will allow family labour use to decrease from 870 hours to 845 hours which perhaps represents a 2 percent reduction in drudgery or 2 percent improvement in leisure (Table 6.1, columns 5 and 6, respectively). Timely availability of work oxen permits diversification of household food production, enhancement of household income and involves less labour-intensive employment of family labour.

Timely access to rental oxen permits households to achieve improvement in food production, farm income and leisure without even having to face the indignity of generating extra cash income by offering surplus family labour for rural wage labour. Timeliness in access to work oxen is specified through imposing a 20 percent and 15 percent yield penalty on cereals and pulses, respectively, when oxen are hired late. The optimal plan suggests an overall reduction in cereal production, an increase in lentil production and complete abstinence from production of oil crops. Under this plan, farmers would devote all extra land to additional lentil production. Lentils are high value crops and dominate household meals during the fasting period when Coptic Christians refrain from consumption of meat and dairy products for 56 consecutive days and 2 days every week.

For new farmers who have not had sufficient time to appraise land productivity, delayed acquisition of animal traction would make them incur a substantial income penalty of about 230 birr (Table 6.1, columns 4 and 5). However, if they recognise differences in land productivity over time, they would improve their farm income by about 4 percent by allocating high-value crops to the best land even if they acquired rental oxen late (Table 6.1, columns 3 and 6). Ignoring land productivity differences, timeliness of cultivation improves farm income from 520 birr to 770 birr (about 48 percent). Moreover, recognising the contribution of allocating the best land to the most valuable crops, timely availability of oxen would improve farm income from 540 birr to 825 birr (about 53 percent).

The linear programming analysis reveals quantitative evidence supporting the use of the observed resource exchange contracts between households without oxen and those with surplus draught animals. In entering various animal traction exchange arrangements, farmers have developed many, often complex and invisible, mechanisms of assessing land productivity and the likely yield effects (of course, in relation to expected weather). On relatively better land, households tend to demand more equitable crop-sharing arrangements (e.g., 50-50 share (*yekul*)). On less productive land, households share less equitably because of perceived risk of crop failure (*e.g*, 25-75 in favour of oxen owner (*karate ande*)).

The various resource exchange mechanisms seem to be relatively efficient and serve to optimise household food production and income objectives subject to resource productivity. Intuitively, there is a motive to keep land productive in order to guarantee a steady flow of returns from the land or other productive resources. Work oxen are often grazed on good pastures and supplemented with hay to maximise draught output and permit cultivation of more land (own or exchanged).

As a summary of all these model solutions that are shown in Table 6.1, there is an increase in acreage devoted to high-value crops (e.g., wheat, lentils) and reduction in acreage devoted to low-value crops such as linseed and field peas. Oats is not selected in any of the model solutions. The shadow prices for each resource and activity in the derived farm plans indicate that growing oats would reduce cash income most. High value crops are grown on the most productive land and permit the household to meet household subsistence and income goals least expensively. Effects of changes in land productivity are not as of severe consequence as delays in land preparation due to differential access to oxen (Appendix 7, Table 6.1).

The analysis above presents results from a continuum of strategies involving different farming practices and resource allocation decisions that would impact on farm income and productivity. There is considerable social differentiation in resource endowment and, consequently, resource allocation strategies amongst farmers vary in the study area. In the worst circumstances, households that do not possess work oxen may be unable to produce enough food and thus can hardly keep enough grain stocks. From the field surveys, this category of farmers represents those who were either former tenants and are locked in a vicious cycle of poverty, or those who have lost their animals, or are relatively new into the farming business. The new entrants into farming are either young couples (who have been given land through subdivision of family land), former low-cadre civil servants or new immigrants. Many of these households aspire to improve their livelihood based on agriculture (chapter four), a topic for the next section.

6.4 Agricultural Intensification without Livestock

It is often reported that resource-poor agricultural households have limited access to agricultural credit. In the study area, agricultural credit is provided by a number of different sources. When crop farmers, who are regarded as the resource-poor group in the current analysis, obtain loans at prevailing loan interest rates (12 and 15 percent), the optimal farm plan shifts depending on the volume of the loan and repayment conditions. If the purpose of the loan is to make large input purchases at the beginning of the crop season, farm income in that season is reduced considerably.

In the study area, farmers apply only 20 per cent of the recommended fertiliser rates and only 20 per cent of improved seed. Model simulations reduced farm income from 425 birr to about 200 birr when the purpose of the loan was to rent oxen, and purchase seed and fertiliser at the beginning of the cropping calendar. As a consequence, renting oxen (on cash payment terms) seemed particularly unprofitable. In contrast, when the purpose of the loan is to purchase fertiliser and seed, the pattern of enterprise combinations does not change much. By borrowing 68 birr to purchase seed and fertiliser, farm income increases from 425 birr to 750 birr and to 745 birr at 12 and 15 percent interest rates, respectively (Table 6.1, column 2 and Table 6.2, columns 1 and 2).

Households without livestock offer surplus family labour to work in the rural agricultural labour markets. When surplus[2] family labour is available to the model, about 345 adult-person hours can be gainfully engaged in the seasonal off-farm agricultural labour. During the peak season (for ploughing and other land preparation activities), the average wage rate is about 0.65 birr per hour compared with 0.35 birr in the other periods of the cropping season. Hiring of labour is common for ploughing, harvesting crops or herding livestock. Such a household strategy of offering surplus family labour for seasonal farm hired labour would improve farm income. This model result represents the emerging practice of seasonal hiring of labour in performing different farming activities.

Off-farm wage income employment will enhance farm income from 825 birr to 1168 birr (Table 6.1, column 6 and Table 6.2, column 3) due to wage employment. This scenario represents the labour market for specialised work such as repairing farm tools, rural infrastructural works, laying out irrigation canals, etc.

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2 Literature on labour-use in Ethiopian agriculture, *perhaps like in most countries in the developing world*, is not only fragmentary but also devoid of detailed social and economic analysis (Aredo 1994, pg. 34). (Italicised segment is the author's insertion). The contribution of women and children is perhaps undervalued and insufficiently accounted for (especially in performing household domestic chores). Therefore, estimates of household surplus labour may not fully account for such deficiencies but, nevertheless, indicate the general value of total family labour.

Table 6.2 Enterprise Intensification on Crop Farms (without Livestock)

Scenario / Enterprise	(1) Credit at 12% interest rate	(2) Credit at 15 % Interest rate	(3) Wage labour (labour market)	(4) Keep own Oxen Raise Sheep
Wheat (ha)	0.36	0.36	0.36	0.36
Barley (ha)	0.42	0.42	0.42	0.42
Field Pea (ha)	0.17	0.17	0.17	0.24
Lentil (ha)	1.28	1.28	1.28	0.56
Horse bean (ha)	0.17	0.17	0.17	0.20
Pasture (ha)	0.00	0.00	0.00	0.62
Farm Size (ha)	2.41	2.41	2.41	2.40
Hired ox-hrs (No.)	515	515	515	own one ox**
Sheep (No.)	none	none	none	2 sheep**
credit (Birr)	68	68	nil	nil
Labour used (Hrs)	844	844	844 (+ 345)	844
Income (Birr)	750	745	1 168	803

Source: Author's survey (1993-94) results and Appendix 7

** The solution to own sheep and oxen is building on the introduction of livestock on crop-farms.

6.5 Integrating Crops and Livestock on Crop Farms

From the field surveys, it was observed that households without livestock usually buy and build up their flock of sheep before they endeavour to invest in large animals (cattle and equines). To evaluate the effects of integrating crop and livestock production in the farming system, different livestock enterprises are introduced into the crop farm model. These livestock enterprises differ in productivity and are raised (under different input requirements) on either unimproved pasture or improved pasture.

As higher levels of productivity are introduced with higher input requirements, the option of keeping livestock of lower input requirements is permitted in the successive runs of the models. These solutions are compared with a base run in which the input-output coefficients for crops and related arguments are maintained as in the above models where farm households are assumed to have timely access to draught oxen. Differences in land productivity are thus maintained. Resource constraints on land and family labour are maintained as in the previous models for an average crop farm in the central Ethiopian highlands.

Introduction of livestock into the crop farm model shifts enterprise combinations and income earning opportunities, as shown in Table 6.3. In general, when sheep and cattle are raised on the farm, sale of straw does not enter the optimal plan as all the crop residues are consumed by livestock on the farm. Given the relative profitability of sale of cow dung cakes over and above household fuel needs, manure is sold and increases farm cash income by about 4 percent.

The model first was applied to examine the introduction of a local cow with indigenous unimproved pasture (Table 6.3, column 1). The model permits one zebu cow to be kept on 0.41 ha of pasture. This plan involves reduction in acreage committed to less profitable crops. At these low levels of livestock and pasture productivity, cattle are a preferred integration strategy to local sheep. Farmers adopting this crop-livestock integration strategy would earn income of the magnitude of 983 birr from this farm plan.

Table 6.3 Enterprise Combinations when Livestock are introduced on Crop Farms

Scenario / Enterprise	(1) Local cow Local pasture	(2) Local cow Improved pasture	(3) Crossbred cow Improved pasture	(4) Hire-out oxen Improved Sheep	(5) Improved sheep Improved pasture
Wheat (ha)	0.51	0.70	0.40	0.40	0.36
Barley (ha)	0.68	0.60	0.80	0.52	0.36
Field Pea (ha)	0.20	0.20	0.24	0.20	0.20
Lentil (ha)	0.40	0.40	0.00	0.46	0.68
Horse bean (ha)	0.20	0.20	0.56	0.20	0.18
Pasture (ha)	0.41	0.30	0.40	0.62	0.62
Farm Size (ha)	2.40	2.40	2.40	2.40	2.40
Sheep (No.)	none	none	none	6	8
Cows (No.)	1	1	1	nil	nil
Sell milk (kg)	237	237	942	nil	nil
Labour used (Hrs)	892	948	912	844	1025
Income (Birr)	983	1072	1175	1 220	1195

Source: Author's survey (1993-94) results and Appendix 7

An alternative model is run to represent farmers who consciously attempt to improve the yield of pasture. Current pasture yields can be increased by, approximately, an additional 1000 kg/ha to a production range between 3500 and 5000 kg/ha. Pasture yields of up to about 6000 kg/ha are technically feasible at the farm-level (Gebrehiwot 1988). This usually involves either the application of manure on pasture fields or, on rare instances, intercropping legumes with sown grasses. Such a plan would lead to reduction in pasture area (from 0.41 ha to 0.30 ha), employ more family labour and generate more farm income (1072 birr) and the farmer will keep one zebu cow (Table 6.3, columns 1 and 2). The reduction in land committed to pasture permits the household to cultivate more cereal crops, which also provide straw to serve as animal feed and thus contribute to higher milk yield.

Compared with keeping local zebu cow, the opportunity to keep crossbred cows presents another opportunity for generating farm income in the rural areas. Even though pasture yields are high, keeping a crossbred cow would involve devoting, at least, 0.40 ha to improved pasture area due to the higher feed requirements of crossbred dairy cattle. The farm plan has relatively more land under legume production, whose residues (haulms) are used in improving the feed mix for crossbred cattle that are raised on the farm. Compared with keeping a local zebu cow, the farmer will be able to sell more milk (942 kg instead of 237 kg). With this farm plan, farmers would earn cash income of about 1175 birr (Table 6.3, columns 2 and 3).

Other households would opt to keep improved local sheep instead of cows. The model has assumed that ewes can produce about 1.6 lambs per year instead of the current estimated prolificacy of about 1.2 lambs per ewe per year. At this level of sheep prolificacy, the model does not select keeping cows in the optimal plan. The derived optimal plan permits about 6 local sheep to be raised and about 8 fattened lambs to be sold while maintaining a stable flock structure in terms of prolificacy, mortality and flock replacement requirements. The model also permits the farmer to keep one work ox. This farm plan involves more land to be devoted to pasture production, more employment of family labour. The farmer would earn more income of about 1195 birr (Table 6.2, column 4 and Table 6.3, columns 3 and 5). However, keeping about 8 sheep and leasing out work oxen could, instead, increase farm cash income to 1 220 birr (Table 6.3, column 4).

6.6 Shadow Prices and Alternative Model Solutions

Derived optimal farm plans indicate that arable land and animal traction had positive marginal value product (shadow prices). This indicates that farm income would be increased if additional land and animal traction could be acquired. Subsistence consumption and growing of oats have negative marginal value products, indicating the magnitude that farm income is depressed in the optimal farm plan in achieving nutritional requirements. Some of the shadow prices for various activities are shown in Table 6.4.

Various farm plans unconstrained by nutritional and soil fertility restrictions suggested a reduction in the number of crops grown. Such constraints were included and as a consequence the model farm suffers an income penalty. Nevertheless this is considered to be a more realistic representation of the actual farm situation in the study area for a number of reasons. First, under rainfed conditions, the risks of crop failure would ordinarily not allow `safety-first' households to grow just a few crops.

Second, growing few crops may not satisfy household food preferences. Third, growing a few crops may not serve soil fertility and conservation goals. Fourth, for social and cultural reasons, households prefer to grow their own food than depend on grain markets. There is dignity and social prestige if a family does not go around begging for food using such excuses as lack of food to buy in the rural markets.

Despite this justification for multiple crop enterprise combinations, some high-value crops (e.g., oil crops) do not enter the optimal farm plans. These crops have generally high relative prices but due to their low yield levels, they can only enter the model through substantial price increases or improvement in their yield. Higher prices are neither likely nor politically attractive. Moreover, relative prices are likely to show approximately similar trends over time. An increase in yields, especially of high-value crops, seems a more important research and policy aspect in addressing food security and farm incomes in the rural sector than an increase in producer prices *per se*.

Table 6.4 Marginal Value Product of Some Resources and Activities

Farm Plan	Baseline Plan	Family Wage Labour	Keeping Local Cattle	Keeping Crossbred Cow	Keeping Sheep
Farm Income	425	825	1072	1168	1195
Farm Resource or Activity	Marginal Value Product (MVP)				
Best Land (LAND1)	702	973	1432	1081	1063
Average Land (LAND2)	562	798	1130	858	842
Growing Oats	-752	-862	-158	-846	-97
Growing Fenu Greek	-171	-22.82	-205	-145	-34.9
Wheat Consumption (CONSWHT)	-1.64	-1.43	-1.35	-1.35	-1.41
Barley Consumption (CONSBRL)	-1.49	-1.31	-0.95	-1.04	-1.26
Consume Horse Beans (CONSHRSBN)	-1.52	-1.46	-1.24	-1.23	-1.39
Consume Field Peas (CONSFPEA)	-1.49	-1.43	-1.43	-1.35	-1.39

Source: Tables 6.1, ..., 6.3 and Appendix 7

Without livestock, growing oats could heavily reduce farm income. However, when livestock enter the farm plan, the opportunity cost of growing oats decreases, largely due to the production of straw that can be fed to livestock. At low levels of pasture and livestock productivity, land has a low opportunity cost. However, at higher levels of livestock and pasture productivity, acquiring additional land will make highest contribution to farm income (Table 6.4, rows LAND1 and LAND2). This implies that with existing static technology, farmers may not make any substantial efforts to maintain land fertility and are likely to ignore processes (e.g., soil erosion, de-vegetation) that reduce land productivity.

In the linear programming model solutions, specialisation in crops alone is not the most efficient way of increasing farm income and employment of family labour. Although crop farmers may increase cash income to the level of modest mixed farms, farms with livestock have more opportunity to increase farm output through exploiting beneficial interactions between crops and livestock such use of straw and manure. Farm re-organisation in resource allocation, hiring-out of surplus farm resources and integrating crops with livestock will improve the agricultural performance of small farmers in the study area. There is potential to increase cash income and labour utilisation through rearing of high-yielding livestock breeds, better feed and pasture management and use of improved technology.

6.7 Potential Deviations from Empirical Farm Situation

The derived optimal solutions approximate empirical farm resource allocation practices. However, there may be some departure of the derived solutions from actual farm situation. The reasons for such a departure could include presence of risk-aversion, market or policy failure, sociological and cultural factors, variations in input usage with respect to differential resource endowments and differential access to common pool resources (see Table 6.1, columns 1 and 2).

Risk-aversion influences household decisions and strategies in order to protect household food security and income stability which are important goals of many peasant farmers. Evidence of risk-aversion is indicated by cultivation of many different varieties of crops and ownership, when possible, of various breeds of animals. The multiplicity of household adaptations to coping with various agricultural problems (chapter 4) demonstrates the socio-economic diversity of rural households. Some marginal deviation of model solutions from actual farm situations may thus not be a gross violation of empirical reality. However, it is important to appreciate the influence of differences in resource endowment and farming strategies between and within categories of households on farm income and land use practices.

Socio-cultural factors that may lead to deviation(s) from optimal model plans include role of religion and social relationships surrounding resource exchange contracts. Most of the farmers in the central highlands are members of the Coptic orthodox church who customarily abstain from consumption of dairy and meat products regularly (twice or thrice a week) and for about 56 days before Easter. During such fasting periods, milk and meat are not consumed. Farmers in the remote areas deliberately schedule their herd breeding and management practices in such a way that milk production is lowest during the fasting period. Apart from milk devoted to calf rearing, milk is processed into cheese and butter for sale after the fasting period.

Another reason for divergence from reality is the cultural importance attached to ownership of work oxen. Even the poorest farmers subscribed to wishing to own at least one ox for land preparation. Many farmers are engaged in many and varied resource exchange contracts that hinder them from making the most profitable use of their available resources. For example, farmers exchanging oxen for cultivation (*mekanajo* arrangement) would not singly decide to sell or acquire additional oxen without jeopardising the social and economic relations between (and may be within) farm households. Poor rural infrastructure makes input supplies unreliable, expensive and non-profitable. Under rainfed farming, markets are highly seasonal. Farmers have to accept lower price for their output and pay relatively more for purchased inputs, consumer goods and services.

Variations in input endowment between households can be a substantial reason for model divergence. With skewed distribution of resources and capital (e.g., skills, livestock, etc), there is a tendency to own as many animals as possible. Grazing land is largely communal. Farmers with livestock often feel they would be disgraced and left poor if they lost their livestock. Livestock are valued in the numerical size and not necessarily in terms of productivity per animal.

6.8 Hypotheses Testing

Four hypotheses are posited in this study. The first hypothesis was set to test if integrated crop-livestock production improves income more than crop production alone. First, timely availability of rental oxen improves cash income (by 48 percent) from 520 birr to 770 birr (Table 6.1, columns 3 and 4) although the yield penalty for late oxen availability is about 15 and 20 per cent for legumes and cereals, respectively. When land productivity differences are considered, timely availability of rental oxen improves cash income (by 52 percent) from 540 birr to 825 birr (Table 6.1, columns 5 and 6). Second, if the household introduces six sheep and keep one ox (on improved pasture), household income increases from 825 birr to 1195 birr (45 per cent increase). These results would support the null hypothesis that integration of crops and livestock does increase farm cash income.

The second hypothesis was set to test if employment of family labour is higher in integrated crop-livestock production systems than crop enterprises alone. From results presented in Table 6.1, between 845 hours and 880 hours of family labour are used depending on land productivity and timeliness of draught power. When animals are not available in time for land preparation, households have to work for longer periods of time to compensate for late and sub-optimal land preparation. Timely availability of rental oxen permits a 3-5 percent increase in household leisure time. Such additional labour would be traded for gainful employment and hence improve farm income. From results that are presented in Tables 6.2 and 6.3, keeping about 6 sheep will increase use of family labour from 844 hours to 1024 hours (21 per cent increase). Keeping crossbred cows would also involve increased employment of family labour to the range between 740 hrs and 912 hrs (Table 6.3). With these results, the hypothesis that family labour time is higher in integrated crop-livestock systems is thus maintained.

The third hypothesis was set to test if improving livestock productivity is beneficial for farmers with limited resources especially the amount of arable land. Several scenarios of livestock productivity indices were submitted in the linear programming solution algorithms. These indices are based on input-output relationships regarding prolificacy, weaning and survival rates, feed and labour requirements for local and improved sheep, local and crossbred cattle. At low levels of cattle and sheep productivity, the model selects keeping of zebu cow and ox since their input requirements are also low. The model improves the income from 425 birr to 983 birr. However, at high levels of livestock productivity, the farmer can profitably replace local zebu cow by a crossbred cow. Despite meeting the higher input requirements for crossbred cow, cash income would increase from 983 birr to 1175 birr. Instead of keeping cows, farmers can profitably keep sheep under improved breeding and feeding systems. By keeping about six improved sheep and one work ox, the model indicates that the farmer would earn about 1195 birr. Considering these results, improving the productivity of livestock through various breeding programs and management practices is highly profitably. The hypothesis that improving livestock productivity will be profitable especially for resource-limited farms is thus not rejected.

The fourth hypothesis was set to explore whether increasing forage production will lead to increased animal production, employment and income. At low levels of herd productivity, pasture is not a constraint to increasing farm output. None of the programming solutions selected growing of forage crops in the derived optimal farm plans. At low levels of herd productivity, crop residues produce enough feed to supplement natural pastures. However, increasing pasture yield levels will permit forage production and the keeping of livestock on resource-limited farms. By improving pasture yields, farm cash income will increase from 983 birr to 1072 birr, labour use changes from 892 adult-person hours to 948 hours and land area devoted to forage production decreases from 0.41 ha to 0.30 ha (Table 6.3, columns 1 and 2). The hypothesis that increasing forage production will lead to increased animal production, employment and income is thus maintained.

6.9 Alternative Livestock Improvement Strategies

Farmers in the study area face multiple constraints in managing the available resources to meet various, often mutually reinforcing, household goals. Investing in livestock contributes to the most important goal of household food security although it may involve devoting some land to pasture production away from crop production. However, there is considerable complementarity between crops and livestock in the use of crop residues, animal traction and manure. Increasing crop and livestock production is often feasible with the existing farm resource endowment.

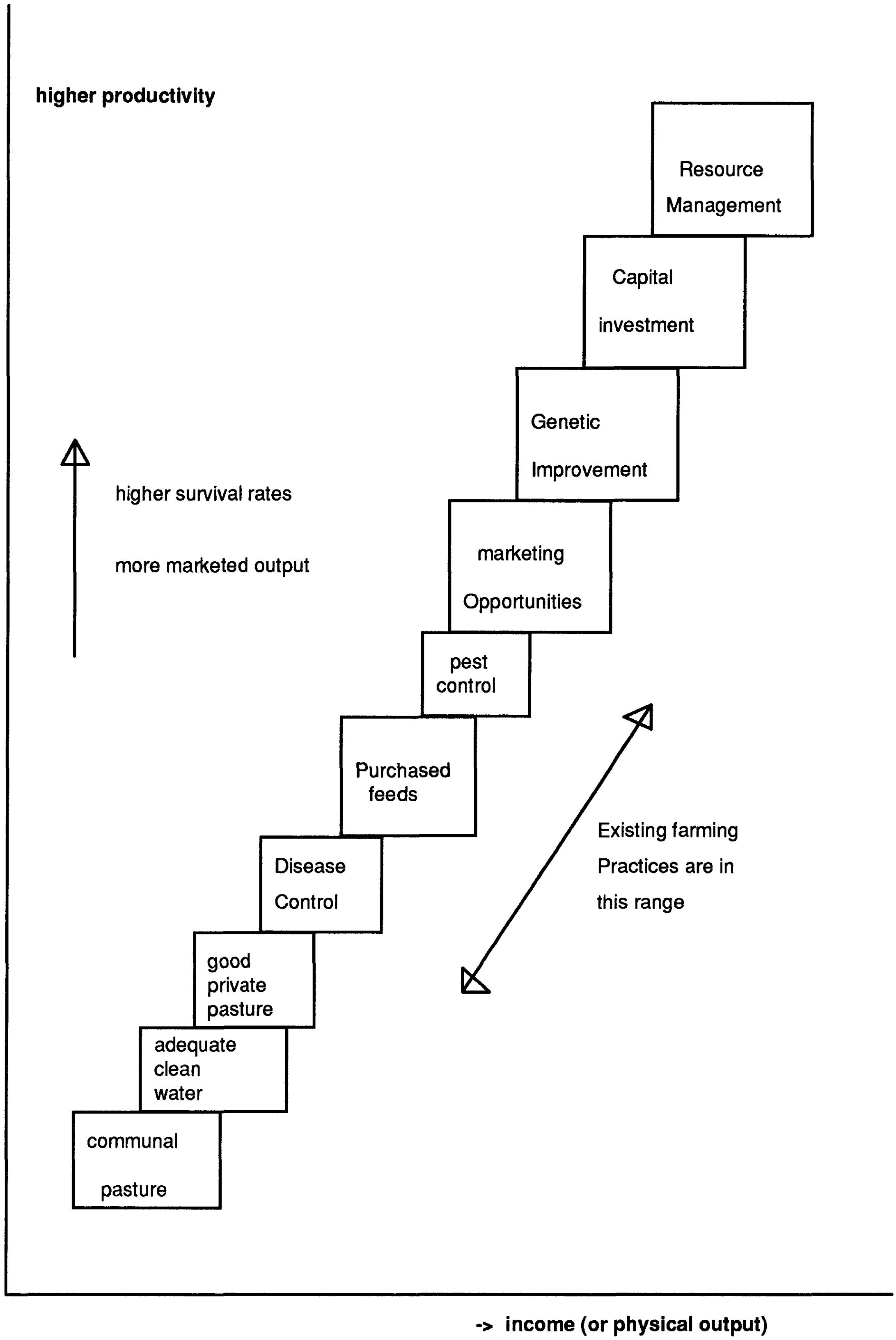
Farmers use various nutritional resources, genetic improvement practices, health management techniques, resource exchange contracts and different marketing strategies in livestock husbandry management. Each improvement option adopted by farmers represents the perceived superiority of a specific response over the other available alternatives. Alternative agricultural improvement strategies that farmers in the study area are adopting are illustrated in Figure 6.1 and some of them are discussed in chapter seven.

Farmers do not raise high-yielding livestock breeds. Neither do they grow improved pasture nor employ improved techniques of livestock management such as anti-helminthics. Considerable dependence on communal pasture exposes animals to endoparasites (e.g., liver flukes) which reduce animal productivity. While few farmers use commercial drugs to treat animals, it is not beneficial unless such animals are separately grazed and managed, an option that would be labour intensive and perhaps not very rewarding. The demand for milk is quite seasonal (due to religious and other factors) and milk surplus may not be disposed and thus reducing returns to labour and capital devoted to exclusive herding and management of high-yielding crossbred animals.

Different strategies employing a different mix of enterprises and resources by different groups of farmers can often achieve the same results (income or food production). For example, owning one crossbred cow could result in earning almost same income compared with keeping 6 sheep on improved pasture. Further improvement of agricultural productivity will involve increasing pasture and livestock productivity. There is need to adapt livestock technologies to farmer circumstances consumerate with resource use pressure necessitated by agricultural intensification.

Technical improvement strategies will include intervention in breeding, nutrition and disease management. Other improvement approaches will include market development, capital investment (e.g., training, fencing) and better resource management (e.g., communal grazing). Improvement strategies should recognise the multiplicity of farmer adaptations to their different resource endowments, needs and limitations of resource-limited farmers.

Figure 6.1 Alternative Livestock Improvement Strategies



Source : After Ghirotti (1991)

6.10 Summary

The linear programming model demonstrates that crop-livestock integration generates more income and higher employment of labour and other farm resources. Opportunities for seasonal employment of family labour and hiring out of surplus draught oxen could substantially increase farm cash income.

Farm households would increase cash income by devoting as little land to low-value crops such as linseed and more to high-yield crops such as wheat and barley. Although some crops attract high prices, such crops (e.g. linseed) are a burden to the household economy due to their low yields. Improvements in crop yields could be necessary for low-yield crops to be profitably grown. There are several opportunities of integrating crops with livestock which would not compromise household subsistence goals. These include the introduction of either crossbred dairy cows or sheep. With improved pasture productivity, sheep are the most profitable livestock activity. However, crossbred cows offer profitable returns to farm resources and high milk output.

Some of the main conclusions and implications of this study are taken up in the next chapter.

Chapter Seven

Conclusions and Policy Suggestions

This study has applied both statistical and linear programming methods to evaluate effects of crop-livestock integration. Stratified sampling procedures were used to select the crop farmers and mixed farmers who provided the data used in this study. There are substantial income benefits from integrating crop and livestock production, especially through more productive use of farm resources and intermediate inputs such as crop residues. The discussions and conclusions that emerge from the analysis presented in chapters four and six are discussed below.

7.1 Household Resource Endowment

There are considerable differences in family size, resource endowment and enterprise allocation between crop farmers and crop-livestock farmers in the densely populated central Ethiopian highlands. Crop farmers have smaller household membership, smaller area of arable land and do not possess any livestock (except some poultry) compared with crop-livestock farmers. Within the last three years (1992-1994), there has been considerable transition from collectivist agrarian structure towards market-driven agricultural production. Crop farmers have experienced more land scarcity than crop-livestock farmers, through various land exchange processes. More than 40 percent of the crop farmers and 20 percent of the crop-livestock farmers claim that they cannot satisfy their food requirements from existing farm size (chapter 4: sections 4.1, 4.2 and 4.3). While these model results suggest that farmers can satisfy subsistence food requirements, this result applied to an average farm from which there is a group of some households who cannot satisfy such food requirements (assuming normal distribution of population parameters with respect to resource endowments).

In attempting to address the food production problem, proportionately more crop farmers offer household labour as hired wage labour than crop-livestock farmers. However, proportionately more crop-livestock farmers exchange family labour with other households than crop farmers. Proportionately more crop farmers rent or lease land for farming purposes than crop-livestock farmers. The egalitarian land ownership in Ethiopia is changing. Livestock ownership will change as farm size changes, partly, in response to population pressure. Different technical innovations and a conducive policy environment will be required to influence farming decisions for different categories of households. Farmers adopt different strategies to achieve subsistence needs considering differential ownership of or access to land, oxen, agricultural labour and other productive resources (chapter 4: sections 4.1, 4.2 and 4.3).

7.1.1 Strengthening labour markets

There is room to improve farm income and labour productivity through re-allocation of existing farm resources even without introduction of livestock on crop farms. This will enhance use of surplus family labour in non-farming activities that would broaden opportunities of increasing cash income. Existence of surplus family labour, even accounting for various social activities, suggests that labour will not be an immediate constraint to the introduction of labour intensive technologies. Considering the historical importance attached to land tenure (Wolde-Mariam 1991), family farms will remain a way of life and perhaps contribute to social security and welfare. Rural farms usually have large labour absorptive capacities to productively employ family and hired labour.

Following the end of a protracted 30-year civil war (de Waal 1991), there were a number of non-agricultural employment opportunities especially in the construction or rehabilitation of various types of infrastructure. Given the poor state of transport infrastructure in most of the rural areas (Appendix 1, chapter 4: section 4.8), the surplus labour in the rural areas could be mobilised at attractive (though low) wage rates to be involved in various community development projects such as agroforestry and watershed protection. This could result in substantial gains in social welfare (e.g., employment, poverty alleviation). Increased off-farm income could improve the purchasing power of the rural poor (Braun and Pandya-Lorch 1991) and thus contribute to enhanced household food security.

There is considerable opportunity to increase cash income through development of stable and transparent markets for rural labour (and rental markets for animal traction and agricultural land). However, various institutional and infrastructural constraints must be addressed. In the past, imperfections in the land, labour and animal traction markets have been blamed for inefficient organisation of farm-level production (McCann 1987, Omiti et al., 1994b). However, government policy must recognise and promote policies aimed at alleviation of rural unemployment and poverty.

Development of small-scale rural industries (e.g., agro-based processing plants, artisans, retailing) may go a long way in promoting the efficient use of rural resources, developing human capital and diversifying the rural economy. Such a diversified rural economy is capable of substantially absorbing periodic shocks such as drought-induced famines.

Failure to provide incentives for rural households to work more efficiently in the use of farm resources will stifle opportunities for agricultural intensification. The capacity of farm households to produce above subsistence requirements might remain difficult to realise. The opportunity to confront both household and country-wide structural food deficits will remain a distant (and receding) hope (Cloutier 1984). At the moment, Ethiopia meets only 75 percent of her domestic food requirements (Negussie and Lemma 1992). The development and implementation of agricultural policy need to consider how to influence the functioning of rural factor markets to permit efficient agrarian organisation. Improvements in labour markets may in the long-run lessen the pain of rural poverty and also serve to diversify the rural economy.

7.1.2 Oxen rental market

Addressing the scarcity of oxen has been central in many of the socio-economic research studies undertaken in the Ethiopian highlands. The rather skewed distribution of work oxen has important implications on food production, farm incomes and utilisation of agricultural land and farm labour. Many suggestions have been offered including rental oxen pools, single-ox traction, cow traction, hand cultivation, equine traction and small tractors (Goe 1987, Panin 1989, Belete et al., 1993). The results of the current study support the contention that there are substantial income and productivity gains from either timely acquisition of rental oxen, owning work oxen or other sources of traction (chapter 6: section 6.3). The rental market for animal traction is employed as a surrogate for any of the mentioned alternatives without excluding use of equines or small tractors.

A number of studies on animal traction in the Ethiopian highlands are focussing on some of these alternative sources of draught power. For households without oxen, encouraging oxen rentals would permit timely, effective land preparation (they do not have to incur an income penalty due to late cultivation). If cash for renting or purchasing oxen is a serious constraint, designing appropriate institutional mechanisms of availing agricultural credit, and bearing in mind the difficulties that subsistence-oriented farmers experience in repaying loans, would help to solve the cash liquidity problem, especially for households without oxen. Credit for renting, as opposed to purchasing, oxen seems a more plausible approach because (i) credit is acquired on a short-term basis and is easier to repay, (ii) there is increasing land scarcity to permit devoting some to pasture (for oxen), and (iii) oxen are often idle for a larger part of the year when cultivation is not required. Purchasing oxen could impose a high opportunity cost of devoting some scarce arable land to pasture production. However, care must be taken not to make such credit too cheap (Adams and Graham 1981, Adams et al., 1984) as this may stifle the development and functioning of rural financial markets.

With increasing population, the increasing household and urban demand for food will require expansion of the area of arable land under crop cultivation. This may necessitate reduction in pasture land (including constriction of communal grazing land). Many resource-limited households in the highlands may lose the capacity to keep a stable herd (i.e., capable of replacing itself) due to such pressure on agricultural land. For these households, recourse to rental oxen arrangements may eventuate the need for an efficient and dependable market for rental oxen.

Given the increasing scarcity of oxen, appropriate, acceptable and profitable alternative sources of draught power need be explored. Each alternative bears its own benefits and costs in relation to timely and effective land preparation. From disappointing experiences with tractor hire services from previous governments schemes, the economics of tractor services will have to be reassessed in the current changing economic context of Ethiopia's Agriculture. Agricultural policy practitioners need to conduct multi-disciplinary research including comparative cost-benefit analyses of these traction alternatives. For instance, equine traction should be considered since there is a large population of donkeys, horses and mules in the Ethiopian highlands. Policy analyses are needed to examine the relative profitability, efficiency gains and income effects of each of these alternative sources of draught power in the highland farming systems.

7.1.3 Land rental market

Land being one of the most important inputs in the agricultural sector, improvements in agricultural performance will depend, to a considerable extent, on how constraints of land pressure and uncertainty in land tenure are addressed. There are fears of increased encroachment upon and cultivation of communal grazing land (to individuate occupational rights) that would lead to increased land degradation and grazing pressure. This would reduce the productive capacity of land resources and place livestock under increasing feed scarcity, even at low levels of productivity. Uncertainty about emerging land tenure policies would discourage efficient and sustainable allocation of land resources (FAO 1993, pg. 4).

As with oxen and labour, farmers in the study area engage in different mechanisms of owning and exchanging land through many, often complex and invisible, inter-household arrangements (chapter 4: section 4.2). The fact that many households engage in various land exchange mechanisms indicates that there are welfare gains to both the land owner and lessee. There are some important implications of encouraging land rentals. First, if the rental rate is tied to the productive capacity of land, then landowners will strive to maintain land in its most productive state over space and time (King and Sinden 1988). Second, land rentals will increase total productive capacity of other resources such as family labour. Low transactions costs and security of land tenure will encourage such rentals.

Third, land rentals would permit less efficient farmers to rent land to more efficient farmers. Interrelated with this assertion, more informed people (e.g., retired extension agents) would stand a chance of renting land and this would serve to demonstrate better farming methods. Fourth, land rentals may permit temporary or long-term amalgamation of the fragmented non-contiguous land parcels and thus attain economies of size in performing various farming operations. Fifth, since they are temporary, land rentals permit households to rent out land without having to resort to the distress sale of land or other farm capital (e.g., cattle). Sixth, land rentals may encourage intensifying use of agricultural land through reduction in fallow periods, modification of cropping patterns and combinations, and development of irrigation systems (in itself a risk-reduction strategy).

However, institutional mechanisms promoting land rental must guard against encouraging rural landlessness. Wealthier households often have better access to information and other agricultural services (e.g., extension, credit, etc) that would enable them to exploit and marginalise poor households (Umbeck 1981). Nonetheless, over time, land markets will encourage land to be put to its most valued use.

7.1.4 Improved technologies

With increasing demand for off-farm goods and services, an increasing number of farmers will depend on the development and stability of factor and commodity markets to meet their income requirements. Many recommendation domains directed at improving Ethiopia's agricultural sector stress the need for technological improvements (Nair 1983, Kidane and Abler 1994). Even if endowed with same resource portfolios, some farmers will utilise resources sub-optimally, partly due to differences in technical know-how or access to information, which would result in inefficient production schedules.

The first strategy in improving peasant farming would involve intensifying resource use without necessarily introducing new inputs or techniques (Figure 2.2). After eliminating inefficient agrarian organisation, opportunities for improving resource allocation through the adoption of more productive and efficient technologies and better land use practices (chapter 6: sections 6.3 and 6.4) can be explored.

In order to address problems of increasing scarcity of grazing land, several attempts to develop sing-ox plough technology, among others, have borne disappointing results. Farmers have not adopted single-ox technology because of the excessively heavy soils, weak oxen (due to nutritional and feeding regimes) and high cost of alternative tools (Gryseels et al., 1989). The single-ox plough technology was, and is, aimed at replacing the traditional oxen-pair ploughing practice.

Research on the possibility of using crossbred dairy cows for traction (instead of oxen) is underway on a pilot scale, as a joint venture between the International Livestock Centre for Africa (ILCA) and the Institute of Agricultural Research (IAR) in Ethiopia. If adopted on a wide scale, cow traction would improve the productivity of dairy farms as well as improving the household nutrition, especially for malnourished children. Markets, if competitive, would probably be the best guide to what farmers need and can profitably engage in, especially in the changing economic context in Ethiopia.

A joint research venture between ILCA and IAR has produced a relatively simple technology to improve drainage of the heavy clay soils (vertisols) in the central highlands. Vertisols occupy more than 7.6 million ha throughout the highlands, of which only about 26 percent are cultivated during the latter part of the season, largely due to waterlogging. It involves modification of the traditional plough to allow mechanical shaping of the broad beds which farmers have traditionally made by hand. The broad bed maker (BBM), as it is known, has proven potential for increasing grain and fodder yields (ILCA 1993). The technology has been widely adopted. It has permitted different varieties of crops to be planted earlier than was possible without improved drainage (FAO 1993). It has also released women and children from the task of making broad beds by hand, permitting them to pursue other welfare-enhancing roles in the household economy.

Such improved technologies will be necessary to meet the increasing demand for food and fibre. Adoption of improved technology is one of the keys to long-term food security through higher agricultural productivity and rural employment (Anthony et al., 1979, Webb et al., 1992). However, under rainfed conditions, the chances of catastrophic outcomes may hinder their widespread adoption. To be adopted, such technologies (e.g., fertilisers, anti-helminthics) have to be economically attractive and fit within the farmers' management capabilities. Technical innovations (e.g., high-yielding varieties) would increase output per unit of input (e.g., land) and thus improve household income (Figure 2.2).

Farmers will need to be provided with more supportive services and conducive policies in order to adopt new technologies or to intensify the production of existing enterprises. An interesting policy question is the determination of the type, timing and amount of incentives necessary for farmers to adopt innovations and more efficient management practices. In addition, such a policy dilemma needs to recognise the various resource, socio-economic, institutional and infrastructural conditions prevailing in most of the rural areas that are likely to affect the farmer's willingness to adopt new techniques.

7.2 Land Use Practices

Proportionately fewer crop farmers leave land under fallow than crop-livestock farmers in attempting to resuscitate soil fertility. Relatively more of the crop farmers practise shorter fallow periods than crop-livestock farmers. Though not considered very appropriate by soil scientists for soil fertility maintenance (Abebe 1982), relatively more of the crop farmers practise soil-burning (guie) more frequently than crop-livestock farmers. Proportionately fewer crop farmers have attempted soil conservation efforts compared with crop-livestock farmers (chapter 4: section 4.7).

7.2.1 Greening rural Ethiopia

Farmers showed strong interest in improving land productivity through such practices as crop rotations, tree planting and soil conservation. Public interventions, to make land conservation remain a desired household goal, will include guaranteeing security of land tenure. This is a subject of on-going (1994-95) debate in the Ethiopian Parliament (*shengo*). Gains from planting trees are multi-faceted and many involve externality effects such as pollination effects, higher honey yields from communal hives, etc. This could have increased social welfare effects especially for the functionally landless households. The most attractive tree species are those with multiple benefits. Agroforestry efforts will go a long way in greening Ethiopia and provide substantial economy-wide benefits. However, mechanisms of encouraging agroforestry could have to recognise how different household characteristics (including how changing farm sizes) affect the motivation to undertake afforestation efforts.

Because of smaller farm size, many crop farmers indicated that they are less likely to plant trees than crop-livestock farmers. For farmers where land is very scarce and risk-aversion plays a substantial role, strategies for improving use of agricultural land should focus on better methods of land cultivation and improvements in resource exchange contracts for hired labour, animal traction and agricultural land.

As trees becomes increasingly scarce due to deforestation, households spend more time to travel longer distances to gather firewood. Increased time spent on collection of firewood has an opportunity cost in terms of foregone farm output or other activity (Pearce and Turner 1990).

Households adapt to scarcity of fuelwood in various ways including changing cooking habits, brewing less beer, using other energy alternatives such as cow dung cakes. Changing cooking habits may affect nutritional standards and human energy input for farming operations. Moreover, diverting cow dung cakes to fuel has an opportunity cost in its alternative uses such as soil fertility amendment (Newcombe 1984) or income generation.

7.2.2 Investing in soil fertility

Crop-livestock farmers apply more manure and inorganic fertiliser (in varying quantities) on their crop fields than crop farmers (chapter 4: section 4.7). A potentially attractive alternative towards improved use of manure as organic fertiliser would be to attempt to introduce biogas digesters and recycle the sludge through the farming system. Previous experiments indicate that capital costs for purchase of biogas digester are high and beyond the reach on most farmers. Moreover, a minimum of three cows is required in order to produce enough cow dung for the currently available types of biogas digesters (Gryseels 1988). There is need to attempt to reduce the initial capital costs and increase the timely availability of affordable agricultural credit to permit purchase of recycling equipment. There is also a need for developing cheaper ways of recycling manure such as reducing the size of biogas digesters to suit farmers with one or two cows.

Mechanisms of amalgamation of the numerous non-contiguous parcels of land in the study area would make manure easier to apply on agricultural land. However, it was beyond the scope of this study to elicit mechanisms that farmers could have preferred *ex hypothesi* during the process of land amalgamation. Perhaps land amalgamation would also make tree planting more appealing by reducing the shading effects of trees on small parcels of land. There may be a need for research for more economically attractive and environmentally sound patterns of soil fertility amendment (e.g., manuring practices, crop rotations). Other considerations may need to focus on vegetative methods of soil conservation and, where applicable, destocking programmes that are sensitive to the social and economic aspirations of farm households. These land use practices have non-marginal effects on crop yields and cash income, and therefore could improve household food security and reduce pressure on land.

7.2.3 Extension and technical advisory services

There is and has been considerable policy pressure to search for appropriate rural development strategies. However, no single package will suit all farmers or all situations considering the diversity of edaphic and socio-economic features in the farming system. First-hand knowledge of rural areas among agricultural policy-planners is often rare, out-dated or insufficient. In many cases, such information is obtained through rapid rural appraisals and often from influential or more easily accessible rural households (e.g., those nearby roads). It is likely to distort agricultural policy formulation, giving wrong signals to the farming community.

From discussions with farmers, a number of non-governmental organisations, extension agents, church organisations, etc disseminate various messages to the farming community. Harmonising the different rural research and agricultural extension activities could minimise the likelihood of giving conflicting messages about improving rural welfare and be responsive to farmers needs. Opportunities of inter-institutional linkages and collaboration would also permit a holistic synthesis of various aspects of the rural economy. Opportunities for sharing or exchanging information between farmers, researchers and policy planners could provide a forum for problem-solving research and design appropriate mechanisms for rural development.

Various economic, cultural, institutional and other public policies must take full recognition of differences in characteristics of different categories of farmers in order that innovations stand a good chance of widespread adoption (Figure 2.1, chapter 4: section 4.9). There will be need to develop appropriate extension messages for farmers to adopt innovations that are suited to farmers' different socio-economic circumstances. Manipulation of various policy variables affecting household decision making would offer a means of promoting efficient low-input farming by affecting the matrix of incentives available to farmers. To this end, continued farming systems research would provide various participants in rural development a means of understanding how farmers adopt to various technology and policy interventions and socio-economic pressure.

7.3 Markets and Rural Infrastructure

7.3.1 Market systems development

Farmers in the central Ethiopian highlands experience important marketing problems symptomised by low and fluctuating prices, high transportation costs and extraction of agricultural surplus (through agricultural pricing and taxation mechanisms) (chapter 4: section 4.8). Efforts to promote agricultural performance ought to consider and allocate funds to evaluate the development and efficiency of factor and output markets. A marketing system can be a source of considerable development leverage or a barrier to rural development depending on how various technologies and incentives are transmitted to the farming community.

Evaluating the structure, conduct and performance of various marketing channels of inputs, commodities and services would be instrumental in identifying constraints to and opportunities for institutional changes aimed at improving agricultural performance. There is thus need to create and mobilise the necessary institutional capacity capable of identifying and addressing problems in rural markets in order to expand the opportunity sets for different segments of the farming community. Integrating `marketing systems research' (Fleming and Hardaker 1993a) with farming systems research would offer considerable research benefits.

7.3.2 Infrastructural development

Inadequate rural infrastructure is a serious constraint to improved crop-livestock farming and a challenge to enhancing household income-generation and employment opportunities (chapter 4: section 4.8). Difficult terrain, civil war and general neglect have led to general deterioration of the rural transport infrastructure. Perhaps less than 15 percent of Ethiopian farmers are reliably and effectively served by the existing road transport network (FAO 1992, pp 4-5). Improvements in infrastructure have important implications on marketing costs and farm incomes. Farmers will subsequently incur less travel time to and from rural markets (Gittinger et al., 1987, Pearce and Turner 1990). Such improvements will reduce human drudgery in marketing farm produce, improve leisure and labour productivity.

For vehicle operators, improvements in transport infrastructure will lead to lower vehicle operating costs, leading to higher cash incomes in the transportation and distribution sectors. Reduced transportation costs for farmers will lead to direct income gains because of lower transport expenses, reduced transportation losses and may result in general improvement in rural incomes. There may be need to complement farming systems research with `infrastructural systems research' (Anderson 1992) to realise substantial gains from crop-livestock integration.

7.4 Alternative Improvement Strategies

Farmers in the central Ethiopian highlands practise multi-crop farming strategies and keep multi-species herds to guarantee subsistence consumption. In addition to increasing income earning potential, the derived optimal plans from the linear programming analysis suggest the possibility of reducing the number of crops grown while households still satisfy food requirements (chapter 6: section 6.6). A long-term agricultural policy challenge is how to influence the subsistence-mentality of rural households to improve management skills to realise more cash income and food production from fewer yet well managed enterprises. Mixed crop-livestock farming could become an increasingly important agricultural feature in the Ethiopian highlands because it will allow more intensive and efficient use of farm resources.

7.4.1 Risk-reduction

Farmers in the study area face multiple constraints in managing the available resources to meet various, mutually reinforcing, household goals. There are different responses to problems caused by unpredictable weather, disease and pest challenge, marketing and infrastructural problems, seasonality of availability of agricultural labour and animal traction, scarcity of land and farm inputs. Farmers have developed multiple adaptations to confronting the various constraints to achieve their basic household survival goals (chapter 4: sections 4.4, 4.5 and 4.8). It is not possible to maximise all household goals simultaneously. Farmers often experience varying degrees of trade-offs in allocating scarce farm resources to meeting various goals.

If it is correct that risk-aversion, at low income levels, hinders technology adoption and agricultural growth (Belete 1989), it may be necessary to introduce some risk-reduction mechanisms. The different types of risks facing the farmers in the study area include diseases, climatic risk, and price variability. In the emerging era of a free-market economy, it may be necessary to provide safeguards to minimise monopsonist merchants stifling development of competitive agricultural commodity markets (Pausewang et al., 1990, E.I.U. 1990-1993). Appropriate institutional support for private sector development towards risk reduction may be necessary. For adoption of improved technologies to proceed, at higher than current rates, research and extension services must develop appropriate and responsive mechanisms associated with agricultural intensification. These strategies must deal with such problems as handling diseases of intensification (e.g., helminths).

There could be substantial gains from risk-reduction schemes. This could involve adoption of better farm-level techniques such as irrigation, pesticides, etc.; strengthening the functioning of retail marketing systems; provision of information on such aspects as climatic forecasts, price information, etc. Such risk-reduction interventions would permit households to engage in opportunistic management strategies (e.g., bad vs good season cropping strategies), purchase of lumpy or high-capital inputs (e.g., land rentals, work oxen, etc).

7.4.2 Keeping small ruminants (sheep)

Driven by population pressure, land scarcity may necessitate reduction in the number of large animals (cattle and equines) that a resource-limited farmer can effectively keep. Small ruminants (especially sheep) pose less competition for available arable land. While suggesting reduction in the number of crops grown, there is ample opportunity to increase livestock production, especially small ruminants, in the highland farming system. However, while the development of the sheep industry remains economically attractive, the possibilities of achieving expanded sheep production remain ambiguous. This is partly attributed to the strong presence of cattle, especially oxen, in the farming system (Jahnke 1982, pg. 181). Introduction of small ruminants (e.g., sheep) with improvements in pasture yield will be more attractive than introducing large ruminants, such as crossbred cows, for farmers with limited land considering rural infrastructural and marketing problems.

The linear programming solutions tended to select work oxen and sheep as the best-bet livestock components for small farms (chapter 6: section 6.5). Sheep have lower nutrition requirements and higher prolificacy than cattle. The demand for milk is quite seasonal to the extent that unless the milk market is developed to induce higher prices, improved dairy production a less attractive enterprise option. Improved technologies involving sheep production and animal traction therefore stand a higher degree of transferability than dairying and forage production. These views are not divergent from earlier research experiences in the farming system in the study area (Gryseels and Anderson 1983, Belete et al., 1993).

7.4.3 Introducing crossbred cows

Where constraints of introducing improved pasture present onerous challenges and there is relatively more land, targeting the introduction of crossbred cows would produce higher research gains than focussing on the introduction sheep improvement programs (chapter 6: section 6.5). However, introduction of crossbred cattle has some important implications. First, Ethiopia has some 27 million head of zebu cattle. If many farmers adopted crossbred dairy cows, there will be a huge demand on the national breeding programs to determine the best breeding plan for different sets of farmer circumstances; such circumstances being determined by land scarcity and feed requirements. Second, even if supply problems are overcome, constraints of disposing surplus milk (especially during fasting periods) will have to be overcome.

For farmers with relatively large farms, introduction of large ruminants will be attractive and may not necessarily involve committing land to improved pasture as long as marketing and infrastructural problems do not hinder disposal of farm marketable surpluses. An alternative complementary intervention could involve developing technologies for on-farm milk processing. Milk processing (e.g., into butter) would generate substantial income gains (estimated at an additional 0.15 birr per litre of fresh milk (Assefa 1989). The national agricultural research and extension systems would also need to provide appropriate and acceptable technical advisory services for farmers about best management practices for crossbred cattle.

7.4.4 Forage production

A wide array of research and policy interventions seems applicable to various forage improvement strategies in the study area. Initially there will be a need for institutional intervention to develop better use of communal pastures (Omiti 1994b, Templet 1995). Research on how to improve the pasture quality and grazing management in communal grazing areas will give a kick-start to improving livestock productivity through improved pasture yield. For various reasons, outlined in chapters 4 and 5, communal grazing would not be modelled in the current analysis. To complement gains from better communal pasture, there will be a need to improve the quality of water to minimise the possibility of animals contracting disease vectors or endoparasites (Figure 6.1).

Improvement in feed availability (both in quality and quantity) could lead to higher livestock output in terms of prolificacy, yield of milk, manure and traction and weight gains of marketed surplus animals. However, there are a number of issues to be addressed in order to improve livestock nutrition in the study area.

First, ways and means have to be developed and tested (on-farm) on how to improve the nutritive value of crop residues. Second, introduction of sown legumes must fit into the farmer's land use management practices. Since annual crops predominate in the farming system, initial efforts should focus on suitable and adapted annual legumes instead of perennial fodder crops (McIntire and Siegfried 1987). Third, introduction of perennial tree forage crops will require testing for adaptability, nutritive value, palatability and compatibility with existing farming practices (*e.g*, effect of crop yields from effects of shading by fodder trees). Given scarcity of labour during peak seasons, fodder trees could also act as live fences and permit rotational grazing; and thus reduce any potential (though unlikely) conflict in seasonal use of family and hired labour (ILCA 1993, Omiti 1994a).

If forage production was adopted on a wide scale, farmers are likely to keep high-yielding animals that produce enough final outputs (e.g., milk). This could serve to eventually influence the household decision making processes to keep few but high-yielding livestock (chapter 6: section 6.5). Peasant farmers often tend to hold to some minimum number of animals (especially oxen) to reduce the risk of being marginalised into wage labourers. Scarcity of land, risk-aversion and imperfect markets may be hindering widespread forage production and there may be need for research on how to overcome these impediments to agricultural intensification.

7.5 Contributions of this Study

7.5.1 Outcomes from crop-livestock integration

The objective of this study was to examine the outcomes of integrating crop and livestock production. It has been demonstrated that crop-livestock integration generates more cash income and employment of farm resources than engaging in crop production alone (chapter 6: sections 6.5 and 6.6). The linear programming model has highlighted the differences in resource endowment and how they affect cash income and employment. The contributions of factor rentals (e.g., seasonal labour wage employment) to farm income are shown to be high with crop-livestock integration and improvements in livestock and pasture productivity. (Effects of improvements in crop yields on farm income are discussed by Emana and Storck 1992). There could be substantial income gains from targeting agricultural research to improve livestock and pasture productivity, which will be consistent with the household and economy-wide goal of better food security and poverty alleviation.

There is sufficient capacity to further integrate crop-livestock farming even on small farms especially with improvements in input and produce markets. More livestock and increased cash income are also associated with better land use practices such as longer fallow periods and less soil-burning. From the shadow prices indicated in chapter six, increases in farm size will have a significant influence on cash income and investment in livestock. Differences in farm size and household size have important bearings on ownership of livestock. Naturally, increases in farm size will lead to increased availability of pasture and, perhaps, improve prospects of investing in livestock.

7.5.2 Social differentiation and sampling procedures

Random sampling approaches may obscure social differentiation amongst rural households (Cochran 1960, Omiti et al., 1994d). Moreover, when obscured, it is difficult to tease out the economic outcomes of various policy and technical interventions, because target groups of households are not appropriately defined. Recognising such potential dangers, this study has applied stratified sampling procedures. This is the first application of stratified sampling procedures in the study of crop-livestock interactions in Ethiopia. In distinguishing households on the basis of ownership of livestock, other important differences emerged especially in family size, farm size and land use practices. The differences would have been masked if a random or other sampling procedure was employed in sample selection.

A few other socio-economic and farming systems studies (e.g., Gryseels 1988, Belete 1989) have been conducted in the same geographical location. Because of methodological differences (e.g., sample selection), this study offers different results (e.g., household resource endowments) in comparison with other previous socio-economic studies (see chapter four). These differences would also have arisen from the different political and institutional environments that farmers faced during the period of socialist military rule (1974-1991) when those other studies were conducted in comparison with this study (free and liberalised market economy). For example, evolving changes such as in farm resource exchange mechanisms (e.g., land rentals, labour market, etc), land use practices (e.g., diminishing importance of oats) and alternative farming strategies (preferred investments in farming). Nonetheless, the objectives of these other studies were also different from those of this study (chapter one). As such, there is no common ground for specific comparisons of analytical results of this study with any other specific previous study.

This sampling procedure could be replicated in other highland areas to investigate opportunities for crop-livestock integration. Apart from enriching the agricultural data base, such a farming systems research exercise would improve the quality of information available for agricultural policy analysis. It would permit regional comparisons of the income, employment and resource use effects arising from introducing livestock on crop farms. A beneficial outcome of this sampling approach could be its institutionalisation in conducting socio-economic rural surveys. Applications of this approach could be useful in assessing economic outcomes of adopting the various technology packages, for example, by differentiating households on the basis of gender, and use or non-use of specific technologies (e.g., fertiliser, fodder, etc).

7.5.3 Relevance to highland farming systems

Similar highland farming regions exist in many parts of Kenya, Madagascar, Malawi, Tanzania, Uganda, Zambia and Zimbabwe (although each with its own unique features). There will be greater demand for multi-disciplinary research to evaluate crop and livestock production systems. This will examine the profitability and acceptability of intended interventions related to enterprise combinations, crop residue management and measurement of livestock production. Widespread interactions between various research teams could foster greater multi-disciplinary collaborative research to explore crop-livestock interactions in greater detail and over wider geographical areas.

However, it is important to note that the central Ethiopian highlands has its own unique features. Some of these features include : (1) almost exclusive reliance on oxen for land preparation, (2) lie at very high altitude (an average of 2800 metres above sea-level), (3) very high human and livestock population, and (4) strong adherence to religious faith (mostly Coptic orthodox Christians). Because of these and other features (see chapter four), frost and animal diseases such as pneumonia are often major impediments to crop cultivation and livestock, respectively. However, the cool weather is quite conducive to sheep production and introduction of exotic breeds of livestock (especially temperate dairy animals). Nonetheless, despite the increasing land scarcity, ambitious development projects introducing improved or resource-intensive technologies (e.g., keeping rabbits or pigs) have received general antipathy from the local population. Some of the results described in this study may therefore be relatively location-specific and care must be exercised in extrapolating the results.

The linear programming model applied in this study is more detailed than has appeared in literature for the Ethiopian highlands. It has production, consumption, purchasing and selling activities affecting both crops and livestock enterprises. It has more technical details on livestock nutrition and management than has been attempted before. It has considerable potential to contribute to informed debate about benefits of crop-livestock integration and adoption of improved technologies across professional disciplines (agronomy, economics, nutritionists, veterinarians, etc.).

The context of the linear programming model applied in this study could be applied in other highland farming systems research. It is relatively simple and could be useable by a multi-disciplinary research team to address various aspects of crop-livestock integration in different geographical and socio-economic settings. However, some preliminary caution is urged to ensure that the model is tractable enough to approximate farm-level conditions. This will depend of the research issues to be addressed, quality of data, computational skills and treatment of various aspects of risk (Barry 1984). Nonetheless, it could offer an opportunity to different agricultural research teams to answer different questions regarding crop and livestock interactions such as those affecting animal health, nutrition and marketing strategies. The model could also be useful to address changes in model parameters including such questions as `what if' different land use and enterprise combinations evolve, say, due to changes in prices, yields, etc.

7.5.4 Livestock and pasture productivity

Improvements in pasture and livestock productivity could transform the role of livestock in the household economy. The derived optimal plans suggest raising one crossbred cow can generate nearly the same revenue as keeping six sheep. These livestock numbers approximate the statistical herd size in the study area. It implies that farmers owning more than these livestock numbers may be exploiting communal grazing resources beyond the carrying capacity of much of these pasture resources.

Forage development might reduce pressure on grazing lands and progressively protect marginal lands from erosive and other degradative processes. Keeping fewer livestock will effectively permit households to realise substantial income gains through better management. Different research and advisory services will be required to assist farmers as they adapt to innovations with, perhaps, different managerial requirements.

7.6 Further Socio-Economic Research

Future socio-economic research in Ethiopia's highland agriculture should move away from generalised representation of generalisable farming scenarios and focus more on specific issues affecting agricultural stagnation and rural impoverishment. Further research could focus on some of the following issues.

A number of studies in Ethiopia's highland agriculture have attempted to model farmers' risk aversion by specification of minimum subsistence requirements as a surrogate measure for household food consumption insurance. However, while recognising the modelling complexities that may be envisaged, it is suggested that future household modelling examine the specific types of risk that different types of farmers face and examine the contribution of alternative farming strategies to household food security and risk-reduction.

Another weakness that is not sufficiently dealt with in this study, except through assumptions, is the role of risk in rainfed agriculture. Perhaps, more than any other country in sub-Saharan Africa, Ethiopia has suffered from devastating droughts and famine in the last two decades. Given that risk is not explicitly included, the linear programming model does not address long-term effects of climatic risk on livestock farming, and there may be a need to do so in future research. This may involve more detailed mathematical programming techniques such as stochastic or sequential programming to incorporate and evaluate economic outcomes under risky production and marketing environments.

It is suggested that some future research effort attempt a spatial mathematical programming to link selling and purchasing activities between households in order to establish resource flows either at village level or community level. This will permit a clearer impression to be gained of which households exchange or hire labour, traction and land. This approach will illuminate the perceived inter-household benefits of resource flows on crop-livestock farming between different farm households. It could also serve to minimise illusions about acclaimed gains from factor rental markets.

This study has attempted to delineate the productivity differences between different classes of land as a proxy for environmental quality. It would be useful to examine this scenario further using important environmental variables such as soil depth, erosion risk, vegetation cover and rainfall intensity. This will permit evaluation of cropping patterns, crop rotation and cultivation practices for various crops depending on the risk of land degradation due to either soil erosion or de-vegetation (or both).

A major handicap of modelling mixed farming systems in rural areas lies with data quality. While considerable effort has been made to gather an acceptable and up-to-date data set about livestock for the linear programming model, the extent and importance of communal grazing is not considered directly. There may be a need to test the sensitivity of future modelling efforts on the availability of communal grazing, as an additional resource. It is often the case that as resources become increasingly scarce, common pool resources tend to shrink. There may a need to examine how cropping and livestock feeding systems evolve and adapt to population pressure. For example, how do households adjust the composition of their livestock herds as communal grazing areas shrink or deteriorate due to overgrazing? Do they adopt improved breeds and better pasture species on their own farms?

Another aspect of crop-livestock integration not explored exhaustively in this study relates to estimating the opportunity cost of alternative uses of manure. Since manure is a major beneficial feature of crop-livestock integration, estimating the alternative net present value (NPV) of manure in its different uses would indicate why farmers choose to sell cow dung cakes, or use cow dung cakes as cooking fuel instead of applying it to crop fields. Alternative valuations would help focus appropriate research and extension agenda on the use of manure. There may be a need to complement manure studies with research on inorganic and other fertilisers, agroforestry and soil conservation.