ECONOMICS OF INTEGRATED CROP AND LIVESTOCK SYSTEMS IN ETHIOPIA

Proceedings of the 3rd Conference of the Agricultural Economics Society of Ethiopia.


Edited by Mulat Demeke and Wolday Amha

Agricultural Economics Society of Ethiopia (AESE)
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Mulat Demeke
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Wolday Amha

Agricultural Economics Society of Ethiopia (AESE)
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Mixed farming is one of the distinctive features of the Ethiopian agriculture. Animal traction has been an integral part of most farming systems of the country for several centuries. It is estimated that 9 to 10 million heads of cattle (of the estimated 30 million) are currently used for draught purposes. Transport in rural areas is carried out with some seven million equines and one million camels.

With expansion of cultivated area into range and pasture land and high population growth, crop residues have emerged as the most important source of livestock feed. Cultivation of more productive fodder crops is largely unknown and commercial feed production is not well developed. Not surprisingly, the very large livestock population has never resulted in an increased supply of animal products and work input that is crucial to keep up a sustainable agriculture. The theme of the Third conference was chosen to contribute on this under-researched aspect of Ethiopian agriculture, the integration of crop and livestock systems.

Shortage of fund delayed the printing of the proceedings. The Executive Committee and the Editors would like to apologize for the delay.

The editors
THE CROP-LIVESTOCK SYSTEMS AND CONTRIBUTIONS TO THE ECONOMY: A REVIEW OF THE EMPIRICAL EVIDENCE

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**Assistant Lecturer, Department of Economics, AAU

ABSTRACT

At the micro-level, households' farming strategies have received limited attention. At the macro-level, trends in the livestock population and relative contributions of the sub-sectors have received little attention. As a result, a number of important questions have remained unanswered: Do landless households abandon livestock population? What happens to cropping patterns as the holding size declines? How do the demographic characteristics of a household relate to farming strategies? What are the trends in the livestock population? This review has attempted to address these and similar questions using the wealth of data accumulated by CSA over years. Different approaches are employed to simultaneously discuss both the crop and livestock sub-sectors. Micro-level analysis has been combined with macro-level analysis and inter-regional investigations with time series analysis. The study has generated interesting findings and hypotheses relevant to policy formulation and to further research into mixed farming system in Ethiopia.

1. INTRODUCTION

It is well known that Ethiopian agriculture consists of two major components: the crop and livestock sub-sectors. But a number of questions remain unanswered concerning the relative contributions of these sub-sectors, how they are combined at the household level, trends in livestock and crop production, herd size and etc. The existing literature treats the sub-sectors separately and little attempt is made to
simultaneously treat household level analysis of farming strategy with the macro-level contributions of these sectors.

The purpose of this paper is to undertake a comprehensive review of the livestock-crop system on the basis of CSA surveys and other sources. The rest of the paper is organized as follows. The second section reviews land availability, crop-livestock combination strategy of households, and herd size. The third section surveys the livestock population and growth rate. The fourth section examines the utilization of cattle and productivity of cows. The fifth section looks at the relative contributions of the sub-sector to the economy. The last section provides concluding remarks.

2. LAND USE AND FARMING STRATEGY

Landlessness

At the country-level, the degree of landlessness is nearly 5 % (or 336,570 holders) of the total holders. Both nomadic/pastoral regions, like Afar and Ethiopian Somali have relatively very high number of landless holders. It may be because, in these regions, land (i.e., grazing land) is communally owned. The degree of landlessness is least in SNNPR (1.7 % of the total holders are without land) (see Table 1).

1Under conditions of traditional agriculture, a holder may be regarded as a person who decides on what, when, where and how to grow crops or raise livestock and has the right to determine the utilization of the products.
Crop Land Area

The size of operational holding in Ethiopia is quite small. In 1995/96, it averaged 1.02 hectares per household. About 8% of the households cultivate an area less than 0.01 hectare. Thirty-eight % cultivate holding of 0.5 hectare or less. Sixty-three % cultivate one hectare or less. Only 0.1 % of the total households cultivate holding of more than 10 hectares. Ethiopian agriculture is dominated by small-holders (Table 2).

Average household size increases systematically with the size of holding. Land is most often distributed on the basis of household size. In addition, large households have adequate capacity to cultivate large traces of land in areas where land is not a constraint (e.g. Illubabor zone).

The cropped land is unevenly distributed between the regions. Most of the cropped land is found in the two giant regions, i.e., Oromia (46%) and Amhara (35%). The third important region, SNNPR, has only 11 % of the total crop land.

Surprisingly enough, crop land availability per household is not the highest in the relatively land abundant regions like Gamballa (only 0.6 ha/hh) but in the environs of Addis Ababa (2.2 ha/hh). What factors then, explain this puzzle? Is it the productive capacity (e.g. availability of labour) of the household? On the other hand, the smallest crop...
area per household (about 0.5 ha) is reported in the largely ‘enset-’ growing region (i.e., SNNPR) and Harari region (Table 3).

Household size (which averaged 5.15 persons at the national level) ranged from 4.82 in Tigrai to 6.35 in the environs of Addis Ababa. Is Tigrai experiencing fertility decline (or out migration)? What factors explain the large household size in the environs of Addis Ababa?

**Permanent and Temporary Crops**

A declining land size is associated with progressive switch to permanent crops like enset, fruits, vegetables, etc. Of the total holders operating land area under 0.10 hectares, 58% grow permanent crops, while only 9% grow temporary crops. This ratio (% growing permanent crops within the range of 0.10 ha.) is highly pronounced in the teff producing zones like Gojjam and Shewa. The proportion of holders growing permanent crops (in the total number of holders, for all sizes of holding) is quite large in the southern regions where crops like coffee, enset, fruits, etc. are important. For example in the Hadiya, kembata and Gurage zones, 47% of the holders grow permanent crops. At the national level, 34% of the total holders grow permanent crops.

The average size of land under permanent crops is very small. At the country level, area under permanent crops averaged 0.14 hectare per household as against 1.01 hectares for temporary crops.
Increased population density on agricultural land induces farmers to switch to land-saving crops like 'enset', fruits, chat and etc (see Table 4).

**Grazing Land**

One important consequence of growing land scarcity is shortage of grazing land, which, in turn, can cause a decline in the number of animals a household can keep. Individually owned grazing land for various villages in Ethiopia averaged less than 0.04 hectares per household [Mulat and Adugna, 1995].

In the absence of quality improvements, this will mean reduced draft power, shortages of animal products, and reduced availability of manure. This also strongly suggests that herd size has been declining due to shortage of grazing land.

A result of integrated household survey (conducted by department of Economics, AAU in collaboration with Oxford University) reveals, herders have stopped the traditional practice of transhumance i.e., seasonal movement of animals to distant grazing places in search of pasture. The quality of the grazing land has also deteriorated. The size of grazing land also restricted herd size. For instance, horses and mules are less needed as feeding problems become more and more acute and also as modern transportation systems replaced them and spread in some parts of the country [Dejene, 1997].
Crop-Livestock Combination

Mixed farming is an important farming strategy of households in the Ethiopian highlands, in particular. Eighty-one % of the farmers practice both crop cultivation and livestock rearing. It is only in the lowlands that the importance of mixed farming system declines. For example, in Gambella, 41 % of the total farmers are engaged in crop production only. In the nomadic areas, crop production is less important than in other areas(table 5).

The two sub-sectors are interdependent and are well integrated through input-output relations. The livestock sub-sector produces traction power, transport services, and manure which are vital to the crop production sub-sector. The latter, in turn produces crop residues and important by-products (e.g. chiod) for use as animal feed. Cash earnings from sales of surplus crops could be saved in the form of livestock. Proceeds from the sales of livestock could be used for the expansion of crop production. Crop failure can lead to sale of animals. A loss of draft can cause a decline in crop production.

It can be, therefore, argued that the Ethiopian peasant has made a rational choice by adopting a mixed farming strategy instead of specializing in either of the sub-sectors. Possible risk of starvation can be minimized by combining crop cultivation with livestock production.
The extent of mixed farming practice is almost closely and positively associated with the age of the household head. The very young household heads (below 18 years) tend to concentrate on either crop cultivation or livestock production. Only 42% of the very young household heads practice mixed farming. Of those who are within the age bracket of 18 to 20 years, 28% produce crop only, while about 10% are engaged in livestock production only. It is, however, difficult to explain the relationship between age of household head and the extent to which crop cultivation is combined with livestock production. Perhaps, it could be explained partly by shortages of complimentary inputs. The younger generation has limited access to productive assets like land and draft power. Another possible reason is, perhaps, the tendency to specialize in either of the sub-sectors by young farmers, who are relatively educated. Still another possible explanatory factor is labour availability. Young households are small in size and often run short of adult male labour required for farm activities (Table 6).

Mixed farming practice is also influenced by sex of the household head. Of the total holders headed by female, 28% produce crops only as against 15% for male-headed households. This pattern is highly pronounced in Wello, Benishangul-Gumuz and Gambella. The latter two regions represent areas where shifting cultivation is practised and where women play an important role in food production. Relatively few households are engaged in livestock production only. In the enset-growing south and in the lowlands (e.g. Gambella and Somalia)
no female headed households specialize in livestock production (Table 7).

The extent to which women combine crop cultivation with livestock production depends on such factors as the prevailing farming system, cultural factors, the degree to which women access to productive resources, and etc.

**Size of Holding and Herd Size**

The average number of livestock per household amounted to 4.6 for cattle, 4.4 for small ruminants, 1.5 for horses, 1.4 for asses, 1.1 for mules, 3.5 for camels, and 6.6 for chicken.

Interestingly enough, landless households tend to keep a larger number of small ruminants (e.g. 4.6 sheep/hh) than the national average (e.g. 4.4 sheep/hh). They also keep quite large heads of cattle (4.5/hh) and poultry (6.6/hh). This leads to an important research hypothesis: land shortage does not necessarily constrain livestock production since stall-feeding can be adopted (see Table 8).

**Animal Sex choice strategy**

Households, consistent with their risk-aversion behaviour, have higher preferences for female animals than for male ones. The strategy of
keeping more females than males is influenced likely by the productive capacity of females, which is needed to maintain the asset levels of households. In the case of small ruminants and poultry, the female/male ratio, in general, is more than 2:1. An interesting exception is the case of camels in which the ratio is one with respect to certain sizes of holding. It is not clear why people in the lowlands have so much preferences for male camels.

Household choices of the sex of an animal can partly be influenced by the particular purpose for which an animal is required. That is, perhaps, why animals which can provide traction and transportation services (pack animals and cattle) have lower ratios than those who do not give similar services (i.e. small ruminants & poultry). On the other hand reproductive capacity is important for small ruminants.

Sex preferences are somewhat associated with the size of holding. Almost invariably higher ratios are reported for the most essential livestock (i.e. cattle and small ruminants within the range of 0.50 hectare and below). Does this suggest that increased population on land induces households to keep more female animals than males? Is this not consistent with the risk-aversion behaviour of farmers? The farming strategy of keeping more females than males is in broad agreement with the fact that households in urban areas (where land area per animal is very small and where stall-feeding is practised) keep virtually only cows and no bulls.
With increased diminution of the land size it can be hypothesised that households tend to abandon plough cultivation (i.e. abandon Oxen) and concentrate on dairy farming (see Table 9).

3. LIVESTOCK POPULATION AND GROWTH RATE

Ethiopia has the largest livestock population in Africa. In 1995/96 there were 31.8 million head of cattle, 12.8 million sheep, 10 million goats, 1 million horses, 2.8 million asses, 0.2 million mules 0.25 million camels, and 33.3 million chickens.

The livestock population is unevenly distributed among the regions of the country. Oromia alone accounts for nearly half of the total cattle population, a little less than half of the sheep population, about one-third of the goats, more than half of the horses, more than one-third of the asses and the chickens and etc. On the other hand, there is Gambella where only two types of livestock (i.e., cattle and chicken) are reported. But Gambella has the highest number of chicken per holder (i.e., 12.4 against 6.6 at the national level). The absence of small ruminants and equine in Gambella has, perhaps, been dictated by climatic factors.

The number of animals per holder is large for chicken (a national average of 6.6 per holder), cattle (4.6), sheep (4.4), and goat (4.4). But the number of equine a household keeps is very small (i.e., an average of 1.5 for horses, 1.4 for asses, and 1 for mule). Naturally
household keeps more of the more essential animals than the less essential ones. But inter-regional variations in the number of livestock per holder is evident from Table 10. For example, camels, which are reported for only three regions, amount to 8.5 per holder in Afar but only 2 in Somalia.

Herd size is not as large as many people think. The largest herd size is (7.9 animals per holder) in Afar, followed by Somalia (6.7). Of course, CSA survey has excluded the nomadic areas (see Table 10).

At the zonal level (see Table 11 which refers the 1994/95 survey), the top producing zones are: North Gondar, Arsi, and West Wellega for cattle (together accounting for more than one-fifth of the total), South Wello for sheep (8.5%), North Gondar for goat (12%), West Wellega for goat (16%, and followed by Agewawi= 6%), East Shewa, Arssi, and North Gondar for asses (7% each but Tigrai as region has 8.7% of the total), South Wello for mules (16%, followed by North Omo=11%), Afar, Borena, and Bale (together 89%), and North Gondar for poultry (9%).

Livestock population growth rates have widely varied among different categories of animals. Cattle and small ruminants have experienced positive growth rates (cattle 2.9%, sheep 2%, goat 1.2%) over the period 1980-1995, while equine, camels, and poultry experienced negative growth rates (horses and asses -13%, mules -28 % camel -18%, poultry -3.7 %) over the same period. Such a differential growth
rate can be explained by various factors. Farmers respond to a declining size of grazing partly by reducing the number of less essential animals like pack animals (horses and mules). Such animals can be afforded only by better off peasants. The expansion of modern transportation networks, albeit slow, has contributed to a decline in the demand for animal transport. Also, the feed requirements of these animals is extremely high. Recent drought in the pastoral areas has contributed to the decline of the camel population (see Table 12).

4. CATTLE UTILIZATION AND PRODUCTIVITY

The Uses of Cattle

Households raise cattle for several purposes. The two major purposes are milk production (44% of the total cattle population are milking cows) and the provision of draft power (39%). Beef cattle accounted for only 2% of the cattle population suggesting that agri-business is highly limited in rural Ethiopia.

The importance of draft cattle is pronounced in the grain-producing zones (e.g. East and West Gojjam, North Shewa) where plough cultivation is ubiquitous. On the other hand, draft cattle are found to be unimportant in the enset growing zones like Sidamo, Gurage, Gedeo, etc. For example in Gedeo only 7% of the cattle (age two and above) are kept for draft purposes. Similarly, in the pastoral areas a small proportion of the cattle population is kept for draft purposes (e.g.
20% in Borena). The purpose to which animal is to be put is partly determined by the particular farming system of an area. This suggests that cropping patterns of an area influences household decision as to which type of animal to keep. In turn, availability and the composition of livestock influences choices of crops to be grown in an area. For example the cultivation of tef in the Metekel area is ruled out by a lack of draft oxen.

The proportion of milking cow is quite large in the enset growing zones (e.g. 61% in Sidamo, 56% in Gurage) and in the pastoral areas (e.g. 53% in Borena against a national average of 44 %). In the enset-growing areas, milk and butter are consumed along with Kocho as necessary food items. On the other hand, milking cows account for a proportion of the cattle population in the tef growing zones (e.g 31% in Gojjam (Table 13).

Productivity of Cows (Milk Yield)

Milk yields have remained extremely low because of feed shortage, poor veterinary services, and limited attempt at introducing improved breeds. Modern breeds of animals are very few in number. According to CSA surveys, indigenous breeds account for 99.74 % of the cattle population. Only 0.26 % are hybrid. Similarly, out of the total sheep population only 0.21 % are hybrid. Other animals are perhaps 100 % indigenous, with the exception of poultry (Table 14). The national average milk yield is as low as 1.09 litres per cow, with an average
lactation period of 6.5 months. A considerable portion of the milk (39%) is converted into butter using traditional processing techniques. The marketing of surplus milk in rural area has been constrained by factors such as limited effective demand and inadequacy of infrastructure. The lowest conversion rate (i.e., 8%) has been recorded in East Hararge, a zone characterized by relatively high degree of commercialization of agriculture and by large-scale consumption of fresh milk by households (Table 15).

At the zonal level, milk yields have varied from as low as 0.87 litres per cow in West Gojjam to 1.47 litres in Bench zone. The longest lactation period is recorded in Bale zone (7.8 month, followed by Agewawi=7.7 months). The shortest lactation period (5.5 months) has been recorded in the Afar region. Such a wide inter-zonal variation in milk yields suggest that there is a scope for improving productivity and breeding of indigenous cows.

5. CONTRIBUTIONS OF CROPS AND LIVESTOCK TO THE ECONOMY

Taking into account all crops ("major and non-major"), the share of the livestock in GDP is about 25 % (Table 16). The share of the sub-sector would be greater than what is indicated in the table, if non-major crops are dropped, the share comes to 32.7 %.
Contributions to Export Earnings

It is well known that agriculture dominates Ethiopia's exports. But evidence from National Bank contradicts the common belief that agriculture accounts for 90% of the total exports. During the period 1979/80-1994/95, it averaged 84% of the total exports. Another point to note is that so far little attempt is made to isolate the contribution of livestock sub-sector relative to the crop sub-sector. In what follows, we will attempt to briefly address these and similar problems. Over the period 1979/80-1994/95, the contribution of the crop sub-sector to total exports averaged 70% while that of the livestock sub-sector accounted to 16% [NBE]. The export of livestock is dominated by hides and skins, which amounted to 97% of the total livestock exports in 1994/95. Similarly, Coffee alone accounted for 84% of the total crop exports in 1994/95. Ethiopia's export has a long way to go towards diversification.

Commercial import of food is limited, while non-commercial imports of food (i.e., food aid) is quite high. Over the period 1979/80-1994/95 food import amounted to 11.3% of the value of total imports. Of this imports, livestock products accounted for 3.1% of the total imports, while imports of grain amounted to 8.2% of the total (see Table 17).

We have also attempted to investigate whether Ethiopia is a net exporter of livestock products or not. With the exception of 1985/86, Ethiopia has remained a net exporter of livestock products and live animals. Over the period 1979/80-1994/95, the ratio of livestock
exports to livestock imports averaged 2.4. As to food grains, it is well known that Ethiopia is significantly a net importer. The recent attempt at boosting exports of maize could not be sustained as the country is once more threatened by imminent famine.

**Contribution to Household consumption**

The contribution of the livestock sub-sector to household consumption is limited due to limited per capita income of the population. Livestock products (which are rich in protein) are luxury items for most Ethiopians. It is only during the important holidays that the broad masses consume meat and butter. Thus, according to CSA's revised consumer price index (see CSA, 1996), the country-level weight attached to livestock products (i.e., meat, milk, eggs, cheese, and butter) amounted to 5.58%. That is, at the country-level, household allocated 5.58% of their total expenditure to animal products.

On the other hand, households allocate the bulk of their income to crops, i.e., cereals, pulses, and vegetables (potatoes, in particular). According to the revised consumer price index, households allocate 41% of their total expenditure to the output of the crop sub-sector. Total food itself accounted for 56.78% of the total household expenditure. This rate is much greater than the 49% which has been in use in the Addis Ababa consumer price index since 1960s.

The relative prices of crops and livestock products have changed
differently over the last decades. The Addis Ababa consumer price Index (1963=100) for crops (mainly cereals) reached 6294.3 points in 1995 as compared to 2720.2 points for livestock products (see Table 18).

Faster growth of prices of starch food can be partly explained in terms of: 1) stagnation of agricultural productivity, 2) extremely low price elasticity of starch food (i.e., cereals, pulses, potatoes, etc.) and 3) stagnating or declining real per capita income.

6. CONCLUDING REMARKS

The literature about Ethiopian agriculture neglected certain important aspects of the mixed farming system in Ethiopia. At the micro-level, households' farming strategies have received limited attention. At the macro-level, trends in the livestock population and relative contributions of the livestock sub-sector have received little attention. As a result, a number of important questions have remained unanswered. Do landless households abandon livestock population? What happens to cropping patterns as the holding size declines? How do the demographic characteristics of a household relate to farming strategies? What are the trends in the livestock population?

This review has attempted to address these and similar questions using wealth of data accumulated by CSA over years. Different approaches are employed to simultaneously discuss both the crop and livestock
sub-sectors. Micro-level analysis has been combined with macro-level analysis and inter-regional investigations with time series analysis.

The findings of this study have important implications for policy and for further research into mixed farming system in Ethiopia. For example, the fact that female-headed households tend to adopt different farming strategies from male-headed households calls for a careful reconsideration of the existing extension policies, which have paid little attention to the needs of women farmers.

REFERENCES


### Table 1: The Extent of Landlessness in Ethiopia

<table>
<thead>
<tr>
<th>Region</th>
<th>Total number of holders ('000)</th>
<th>holders without land ('000)</th>
<th>% without land</th>
<th>population per cropped land ('000)</th>
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Source: Agricultural Sample Survey, Livestock, Poultry and Beehives CSA Bulletin No. 152 Vol VI page 12

Table 2: Size of Holding and Cropped Land

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<th>Size of holding (ha)</th>
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<tr>
<td>2.01-5.00</td>
<td>1060.84</td>
<td>2985.59</td>
<td>2.81</td>
<td>12.45633</td>
<td>99.2</td>
<td>6.23</td>
</tr>
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<td>5.01-10.00</td>
<td>62.28</td>
<td>372.13</td>
<td>5.98</td>
<td>0.731289</td>
<td>99.93</td>
<td>6.79</td>
</tr>
<tr>
<td>10.01 &amp; above</td>
<td>5.94</td>
<td>72.08</td>
<td>12.13</td>
<td>0.069747</td>
<td>100 **</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8516.47</td>
<td>8687.15</td>
<td>1.02</td>
<td>100</td>
<td></td>
<td>4.87</td>
</tr>
</tbody>
</table>

Table 3: Number of Households, Total Crop Land Area and Household Size in 1995/96

<table>
<thead>
<tr>
<th>Region</th>
<th>No. ('000)</th>
<th>%</th>
<th>Area ('000 ha)</th>
<th>Percent</th>
<th>Average crop land area/hh (ha)</th>
<th>HH size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tigray</td>
<td>571.34</td>
<td>6.708648</td>
<td>483.82</td>
<td>5.569375</td>
<td>0.846816</td>
<td>4.82</td>
</tr>
<tr>
<td>Afar</td>
<td>27.96</td>
<td>0.328305</td>
<td>24.6</td>
<td>0.283177</td>
<td>0.879828</td>
<td>4.93</td>
</tr>
<tr>
<td>Amhara</td>
<td>2543.03</td>
<td>29.86014</td>
<td>3010.68</td>
<td>34.65671</td>
<td>1.183895</td>
<td>4.87</td>
</tr>
<tr>
<td>Oromia</td>
<td>3196.85</td>
<td>37.53727</td>
<td>3958</td>
<td>45.56155</td>
<td>1.238094</td>
<td>5.44</td>
</tr>
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<td>1.248522</td>
<td>69.32</td>
<td>0.79796</td>
<td>0.651933</td>
<td>6.16</td>
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<td>Ben.-Gumuz</td>
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<td>0.968829</td>
<td>98.72</td>
<td>1.136391</td>
<td>1.196461</td>
<td>4.92</td>
</tr>
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<td>1935.01</td>
<td>22.7208</td>
<td>1003.05</td>
<td>11.54636</td>
<td>0.518369</td>
<td>5.1</td>
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<td>0.273822</td>
<td>14.11</td>
<td>0.162424</td>
<td>0.60506</td>
<td>4.45</td>
</tr>
<tr>
<td>Harari</td>
<td>11.37</td>
<td>0.133506</td>
<td>5.93</td>
<td>0.068262</td>
<td>0.521548</td>
<td>5.66</td>
</tr>
<tr>
<td>Addis Ababa</td>
<td>4.5</td>
<td>0.052839</td>
<td>10</td>
<td>0.115113</td>
<td>2.222222</td>
<td>6.35</td>
</tr>
<tr>
<td>Diredawa</td>
<td>14.25</td>
<td>0.167323</td>
<td>8.92</td>
<td>0.10268</td>
<td>0.625965</td>
<td>6.14</td>
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<tr>
<td>Total</td>
<td>8516.47</td>
<td>100</td>
<td>8687.15</td>
<td>100</td>
<td>1.020041</td>
<td>5.15</td>
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</table>

Source: CSA, Agricultural Sample Survey, Crop Land Utilization Vol. IV bulletin No. 152 page 11 & 40
### Table 4: Crop Type and Size of Holding 1995/96

<table>
<thead>
<tr>
<th>Region/Zone</th>
<th>% of holders operating size under 0.10 ha</th>
<th>Average crop land per hh</th>
<th>% of holders growing perm. crops</th>
<th>Total hh no producing both</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>temp. crops</td>
<td>perm. crops</td>
<td>temp. crops</td>
<td>perm. crops</td>
</tr>
<tr>
<td>National</td>
<td>9.12</td>
<td>57.83</td>
<td>1.01</td>
<td>0.14</td>
</tr>
<tr>
<td>Tigray</td>
<td>3.26</td>
<td>95.4</td>
<td>0.88</td>
<td>0.03</td>
</tr>
<tr>
<td>Afar</td>
<td>4.08</td>
<td>71.43</td>
<td>0.94</td>
<td>0.07</td>
</tr>
<tr>
<td>E&amp;W Gojam &amp; Apeawawi</td>
<td>5.15</td>
<td>95.74</td>
<td>1.53</td>
<td>0.03</td>
</tr>
<tr>
<td>N&amp;S Gondar</td>
<td>5.72</td>
<td>88.46</td>
<td>1.38</td>
<td>0.06</td>
</tr>
<tr>
<td>N. Wello &amp; Waghaunra</td>
<td>3.33</td>
<td>86.52</td>
<td>0.88</td>
<td>0</td>
</tr>
<tr>
<td>S. Wello, Oroma &amp; N Shewa</td>
<td>2.61</td>
<td>90.27</td>
<td>0.92</td>
<td>0.04</td>
</tr>
<tr>
<td>East &amp; West Wellega</td>
<td>3.26</td>
<td>51.26</td>
<td>1.31</td>
<td>0.18</td>
</tr>
<tr>
<td>Illubabor &amp; Jimma</td>
<td>6.41</td>
<td>60.63</td>
<td>0.94</td>
<td>0.19</td>
</tr>
<tr>
<td>North &amp; West Shewa</td>
<td>3.11</td>
<td>77.92</td>
<td>1.56</td>
<td>0</td>
</tr>
<tr>
<td>East Shewa, Arsi, Bale &amp; Borena</td>
<td>7.05</td>
<td>38.28</td>
<td>1.42</td>
<td>0.28</td>
</tr>
<tr>
<td>East &amp; West Haraqhe</td>
<td>8.4</td>
<td>54.49</td>
<td>0.56</td>
<td>0.14</td>
</tr>
<tr>
<td>Eth. Somali</td>
<td>14.65</td>
<td>33.49</td>
<td>0.61</td>
<td>0.22</td>
</tr>
<tr>
<td>Benishangul-Gumz</td>
<td>2.81</td>
<td>69.37</td>
<td>1.18</td>
<td>0.09</td>
</tr>
<tr>
<td>Yem, Keficho, Maji, Shkicho &amp; Bench</td>
<td>13.88</td>
<td>59.28</td>
<td>0.52</td>
<td>0.13</td>
</tr>
<tr>
<td>N&amp;S Omo, Gardula &amp; Konso</td>
<td>14.76</td>
<td>57.25</td>
<td>0.48</td>
<td>0.12</td>
</tr>
<tr>
<td>Hadiya, Kembata &amp; Gurage</td>
<td>15.99</td>
<td>47.57</td>
<td>0.57</td>
<td>0.13</td>
</tr>
<tr>
<td>Sidama, Gedo, Burji &amp; Amaro</td>
<td>48.86</td>
<td>32.96</td>
<td>0.19</td>
<td>0.2</td>
</tr>
<tr>
<td>Gambela</td>
<td>16.4</td>
<td>62.93</td>
<td>0.55</td>
<td>0.17</td>
</tr>
<tr>
<td>Haran</td>
<td>6.38</td>
<td>44.59</td>
<td>0.4</td>
<td>0.14</td>
</tr>
<tr>
<td>Addis Ababa</td>
<td>2.38</td>
<td>100</td>
<td>2.38</td>
<td>0</td>
</tr>
<tr>
<td>Diredawa</td>
<td>9.55</td>
<td>15.23</td>
<td>0.6</td>
<td>0.39</td>
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Source: CSA, Land Utilization Bulletin No.152 pp113-1
Table 5. Mixed Farming System: Percent of Holders with Crop only, Livestock only and with Crop and Livestock by Zone

<table>
<thead>
<tr>
<th>Region/zone</th>
<th>with crop only</th>
<th>with livestock only</th>
<th>With crop and livestock</th>
<th>all types of holdings</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>17.27</td>
<td>2.06</td>
<td>80.68</td>
<td>100.01</td>
</tr>
<tr>
<td>Tigray</td>
<td>18.47</td>
<td>3.29</td>
<td>78.24</td>
<td>100</td>
</tr>
<tr>
<td>Afar</td>
<td>14.05</td>
<td>7.11</td>
<td>78.95</td>
<td>100.11</td>
</tr>
<tr>
<td>E &amp; W Gojam &amp; Agewawi</td>
<td>22.16</td>
<td>4.54</td>
<td>73.3</td>
<td>100</td>
</tr>
<tr>
<td>N &amp; S Gonder</td>
<td>16.14</td>
<td>3.71</td>
<td>80.15</td>
<td>100</td>
</tr>
<tr>
<td>N. Wello &amp; Waghemra</td>
<td>23.83</td>
<td>0.83</td>
<td>75.34</td>
<td>100</td>
</tr>
<tr>
<td>S Wello, Oromia &amp; N Shewa</td>
<td>22.54</td>
<td>1.55</td>
<td>75.91</td>
<td>100</td>
</tr>
<tr>
<td>East &amp; West Welleaga</td>
<td>23.07</td>
<td>1.19</td>
<td>75.74</td>
<td>100</td>
</tr>
<tr>
<td>Illubabor &amp; Jima</td>
<td>19.4</td>
<td>1.98</td>
<td>78.63</td>
<td>100.01</td>
</tr>
<tr>
<td>North &amp; west Shewa</td>
<td>13.8</td>
<td>1.25</td>
<td>84.95</td>
<td>100</td>
</tr>
<tr>
<td>East Shewa, Arsi Bale &amp; Borena</td>
<td>11.39</td>
<td>2.83</td>
<td>85.77</td>
<td>99.99</td>
</tr>
<tr>
<td>East &amp; West Hararghe</td>
<td>10.46</td>
<td>0.96</td>
<td>88.58</td>
<td>100</td>
</tr>
<tr>
<td>Eth. Somali</td>
<td>12.71</td>
<td>5.26</td>
<td>82.01</td>
<td>99.98</td>
</tr>
<tr>
<td>Benishangul-Gumz</td>
<td>27.73</td>
<td>0</td>
<td>72.3</td>
<td>100.03</td>
</tr>
<tr>
<td>Yem, Keficho, Maji, Shekicho &amp; Bench</td>
<td>15.29</td>
<td>0.6</td>
<td>84.11</td>
<td>100</td>
</tr>
<tr>
<td>N &amp; S Omo, Gardula and Konso</td>
<td>21.06</td>
<td>1.32</td>
<td>77.62</td>
<td>100</td>
</tr>
<tr>
<td>Hadhaya, Kembata &amp; Gurage</td>
<td>6.66</td>
<td>0</td>
<td>93.11</td>
<td>99.77</td>
</tr>
<tr>
<td>Sidama, Gedio, Burji &amp; Amaro</td>
<td>20.97</td>
<td>0</td>
<td>78.39</td>
<td>99.36</td>
</tr>
<tr>
<td>Gambela</td>
<td>40.89</td>
<td>0</td>
<td>56.93</td>
<td>97.82</td>
</tr>
<tr>
<td>Harari</td>
<td>10.98</td>
<td>0</td>
<td>87.96</td>
<td>98.94</td>
</tr>
<tr>
<td>Addis Ababa</td>
<td>14.44</td>
<td>0</td>
<td>79.19</td>
<td>93.63</td>
</tr>
<tr>
<td>Dire Dawa</td>
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<td>1.13</td>
<td>85.74</td>
<td>97.12</td>
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<tr>
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<td>17.42318</td>
<td>2.266364</td>
<td>79.70909</td>
<td>99.39864</td>
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</table>

Source: CSA, Crop Land Utilization, Vol IV Bulletin No 152 PP70-96

Table 6. The Relationship Between Age and Livestock-Crop Combination

<table>
<thead>
<tr>
<th>Age of Holders</th>
<th>% with livestock only</th>
<th>with crop only</th>
<th>with crop and livestock</th>
<th>All types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 18</td>
<td>30.2</td>
<td>27.6</td>
<td>42.2</td>
<td>100</td>
</tr>
<tr>
<td>18-20</td>
<td>9.6</td>
<td>27.86</td>
<td>62.54</td>
<td>100</td>
</tr>
<tr>
<td>21-24</td>
<td>5.13</td>
<td>21.89</td>
<td>72.98</td>
<td>100</td>
</tr>
<tr>
<td>25-29</td>
<td>2.54</td>
<td>20.72</td>
<td>76.74</td>
<td>100</td>
</tr>
<tr>
<td>30-39</td>
<td>0.94</td>
<td>17.43</td>
<td>81.63</td>
<td>100</td>
</tr>
<tr>
<td>40-49</td>
<td>1.12</td>
<td>14.03</td>
<td>84.96</td>
<td>100</td>
</tr>
<tr>
<td>50-59</td>
<td>1.13</td>
<td>14.85</td>
<td>84.01</td>
<td>100</td>
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<tr>
<td>60 &amp; above</td>
<td>2.68</td>
<td>17.56</td>
<td>79.76</td>
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</tbody>
</table>

Source: CSA, Agricultural Sample Survey, Crop Land Utilization Bulletin No 152 Vol IV page 70
Table 7: Holders by Sex in 1995/96

<table>
<thead>
<tr>
<th>Region/zone</th>
<th>with crop only</th>
<th>with livestock only</th>
<th>with crop and livestock</th>
<th>all types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>male</td>
<td>female</td>
<td>male</td>
<td>female</td>
</tr>
<tr>
<td>National</td>
<td>15.06</td>
<td>27.62</td>
<td>1.29</td>
<td>5.65</td>
</tr>
<tr>
<td>Tigray</td>
<td>14.57</td>
<td>30.61</td>
<td>1.41</td>
<td>9.16</td>
</tr>
<tr>
<td>Afar</td>
<td>14.32</td>
<td>0</td>
<td>0</td>
<td>16.29</td>
</tr>
<tr>
<td>E &amp; W Gojam &amp; Agewawi</td>
<td>17.62</td>
<td>47.37</td>
<td>4.14</td>
<td>6.75</td>
</tr>
<tr>
<td>N &amp; S Gonder</td>
<td>11.96</td>
<td>35.64</td>
<td>2.15</td>
<td>11.05</td>
</tr>
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<td>55.17</td>
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<td>0</td>
</tr>
<tr>
<td>S Wello, Oromiya &amp; N Shewa</td>
<td>19.78</td>
<td>34.68</td>
<td>0.55</td>
<td>5.96</td>
</tr>
<tr>
<td>E &amp; W Wellega</td>
<td>21.13</td>
<td>30.78</td>
<td>0.69</td>
<td>3.19</td>
</tr>
<tr>
<td>Illubabor &amp; Jima</td>
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<td>23.7</td>
<td>0</td>
<td>5.22</td>
</tr>
<tr>
<td>N &amp; W Shewa</td>
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<td>17.16</td>
<td>0.92</td>
<td>0</td>
</tr>
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<td>E Shewa, Arssi, Bale &amp; Borena</td>
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<td>11.3</td>
<td>1.16</td>
<td>9.81</td>
</tr>
<tr>
<td>E &amp; W Hararghe</td>
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<td>20.61</td>
<td>0</td>
<td>6.52</td>
</tr>
<tr>
<td>Eth Somali</td>
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<td>23.6</td>
<td>4.13</td>
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</tr>
<tr>
<td>Benishangul-Gumz</td>
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<td>52.51</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yem, Keicho, Maji, Shekicho &amp; Bench</td>
<td>13.2</td>
<td>24.65</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N &amp; S Omo, Gardula and Konso</td>
<td>17.6</td>
<td>37.37</td>
<td>1.49</td>
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</tr>
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<td>Hadiya, Kembata &amp; Gurage</td>
<td>6.56</td>
<td>7.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sidama, Omo, Gardula &amp; Konso</td>
<td>19.92</td>
<td>27</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gambela</td>
<td>38.9</td>
<td>48.36</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Harari</td>
<td>11.18</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Addis Ababa</td>
<td>10.63</td>
<td>27.89</td>
<td>5.99</td>
<td>8.65</td>
</tr>
<tr>
<td>Diredawa</td>
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<td>0</td>
<td>7.89</td>
<td>36.47</td>
</tr>
<tr>
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<td>1.445909</td>
<td>5.669091</td>
</tr>
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</table>

Source: CSA, Crop Land Utilization Bulletin No 152 pp98-111
## Table 8: The Relationship Between Number of Livestock and Land Size at The Household Level (Average Number of Animals per Holder)

<table>
<thead>
<tr>
<th>Size of holding (ha)</th>
<th>cattle</th>
<th>sheep</th>
<th>goats</th>
<th>horses</th>
<th>asses</th>
<th>mules</th>
<th>camels</th>
<th>poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without land</td>
<td>4.54</td>
<td>4.61</td>
<td>5.23</td>
<td>1.41</td>
<td>1.37</td>
<td>1</td>
<td>**</td>
<td>6.63</td>
</tr>
<tr>
<td>under 0.01</td>
<td>3.31</td>
<td>3.23</td>
<td>4.26</td>
<td>1.23</td>
<td>1.21</td>
<td>**</td>
<td>**</td>
<td>5.94</td>
</tr>
<tr>
<td>0.1-0.5</td>
<td>3.37</td>
<td>3.56</td>
<td>3.75</td>
<td>1.26</td>
<td>1.22</td>
<td>1.1</td>
<td>2.16</td>
<td>5.76</td>
</tr>
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<td>0.51-1.00</td>
<td>3.92</td>
<td>4.12</td>
<td>4.04</td>
<td>1.49</td>
<td>1.31</td>
<td>1.12</td>
<td>2.06</td>
<td>6.3</td>
</tr>
<tr>
<td>1.01-2.00</td>
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<td>4.74</td>
<td>4.66</td>
<td>1.54</td>
<td>1.36</td>
<td>1.06</td>
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<td>7.04</td>
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Source: Agricultural Sample Survey, Livestock, Poultry and Beehives CSA Bulletin No. 152 Vol VI page 10
Those estimates designated by "**" in all tables could not be reported
Table 9: The Relationship Between Female/Male Ratio of Livestock and Size of Holding

<table>
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<th>Size of holding (ha)</th>
<th>Cattle</th>
<th>sheep</th>
<th>goats</th>
<th>horses</th>
<th>asses</th>
<th>mules</th>
<th>camels</th>
<th>poultry</th>
</tr>
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<td>**</td>
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<td>**</td>
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Source: Agricultural Sample Survey, Livestock, Poultry and Beehives CSA Bulletin No. 152 Vol VI page 85
## Table 10: Livestock Population and Number of Livestock Per Holder by Region

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<th>Region</th>
<th>Cattle</th>
<th>Sheep</th>
<th>goats</th>
<th>horses</th>
<th>asses</th>
<th>mules</th>
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<th>poultry</th>
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<td>No ('000)</td>
<td>No ('000)</td>
<td>No ('000)</td>
<td>No ('000)</td>
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<td>5189 74</td>
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<td>1621 65</td>
<td>4.18</td>
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<td>**</td>
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Source: Agricultural Sample Survey, Livestock, poultry and Beelives CSA Bulletin No. 152 Vol VI pp12-19
Table 11: Number and Percentage Distribution of Livestock by Zone (1994/95)

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<th>%</th>
<th>Goat No. (000)</th>
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Total 29592.38 100 11457.9 100 9350.46 100 1121.15 100
Economics o f Integrated Crop and Livestock Systems in Ethiopia

No
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Regioiv'zone
T IRfKV
Afar
■\gew»wi
East Gouam
West Gouam
North Gondcr
South Gondcr
Amhara
N She\*a
Amhara
Oromia
Wanhamra
North Wello
South Wello

Asses
No
COOO)
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27 3

190 11
118 65
184 03

4 609611
7 149656

26 3

1 021768

0 69

135 76
98 54

29 63
88 59
173 83
200
111
63
122
95

lllubabor
Jima
East Shewa
Oromia
N shewa
West Wellei*a
East Wellega
West wellcua
Bench

5 56
22 09
192 03
108 65

Shekicho •
Sidamo
Amaro
Bur]i
Derashe
Konso
Yem
Total

8 657832
0 679884

Mule
No
COOO)
9 22
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1 76
2 53
7 92
10 28
II 36
6 66

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Borena
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West Harari<hc

Gedio
Guraite
Hadiva
kem bau
Keficho
Maji
N oah Omo
South Omo

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81
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131 36
36 41
42 62
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5 274343
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7 385867

Camel
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4 293964

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5 963264
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3 688525
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Poultry
No
COOO)
2258 98
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1 091295

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803 17
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658 4
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906 45
685 99
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21023
537 93
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V.

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16 19784
3 590723
4 31725
2 82228
0 796386
1 206222
1 248137

0
3 42
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61 28
64 93
0
5 23
0

4 633942
2 887481
2 021237

0 53
0
0

1 15114
3 441765
6 753381
7 801567
4 34465
2 452632
4 742091
3 708279
0 216009
0 858207
7 46046
4 221106

4 02
3 85
34 78
771
9 27
606
1 71
2 59
2 68
9 95
62
4 34

5 103401
1 414546
1 655808
0

7 11
8 11
1 77
0 49

3
3
0
0

0 064103
0 954557
0 808867
0 921922
0 020979
0 001166
0933189
0 035742

2 23

1 038562
2 482303
5 146237
2 3519
0419151
0
11 6291
0 158346
0 21889
0 409836
0 591468
0 065201
0 172317
0
0 060544

0012432
0 934743
0
0 02603
0 246701
0 046621
0
100

5 33
11 05
5 05
09
0
24 97
0 34
0 47
0 88
1 27
0 14
0 37
0
0 13
214 72

V,

-

31 1289
777012
824329
228204

100

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236 28

Percent
8 95822
0 400962
1 360-14
2 151006
4 783153
9 I2 9 H 8
4 926866
3 633088

366 23

0
0
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0
0
100

62 35
906 94
207 25
91 5
608 89
78 42
47 96
23 29
24 84
12 41
25216 84

4 241332
1 555746
2 610054
3 604 33 7
2 928757
2 967739

3 594622
2 720365
4 007957
0 591549
0 833689
2 133217
2 47*846
1 9354 53
1 969874
0 247255
3 596565
0 821871
0362853
2 414617
0
0
0
0
0

310983
187811
092359
098506
049213
100

Source: Agricultural sam ple survey,livesto ck,p oultry and beehives CSA__

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Note:

1) No. 3-12 represent Amhara region
2) No. 13-24 represent Oromia region
3) No. 25-40 represent SNNPR

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<table>
<thead>
<tr>
<th>Year</th>
<th>Cattle ('000)</th>
<th>Sheep ('000)</th>
<th>Goat ('000)</th>
<th>Horse ('000)</th>
<th>Asses ('000)</th>
<th>Camel ('000)</th>
<th>Mule ('000)</th>
<th>Poultry ('000)</th>
<th>Total ('000)</th>
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<td>10061.61</td>
<td>6322.93</td>
<td>1153.78</td>
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<td>37905.35</td>
<td>82006.33</td>
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<td>21547.64</td>
<td>8605.805</td>
<td>5881.203</td>
<td>1328.79</td>
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<td>2490873</td>
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<td>9255.752</td>
<td>7029.012</td>
<td>1211.66</td>
<td>237196</td>
<td>4391283</td>
<td>2554402</td>
<td>22188.83</td>
<td>65462.94</td>
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<td>1983</td>
<td>23995.07</td>
<td>10095.73</td>
<td>7304.55</td>
<td>1180</td>
<td>2466268</td>
<td>2918225</td>
<td>3070179</td>
<td>20167.87</td>
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<td>1984</td>
<td>23145.72</td>
<td>10855.72</td>
<td>6985.726</td>
<td>1162.59</td>
<td>2237972</td>
<td>32926</td>
<td>230886</td>
<td>21777.58</td>
<td>66429.13</td>
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<tr>
<td>1985</td>
<td>24173.18</td>
<td>11291.47</td>
<td>7254.789</td>
<td>1210.69</td>
<td>2326264</td>
<td>404505</td>
<td>2355118</td>
<td>19771.71</td>
<td>66304.07</td>
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<td>1986</td>
<td>24441.08</td>
<td>10182.98</td>
<td>5880.063</td>
<td>1349.61</td>
<td>2432866</td>
<td>39678</td>
<td>2965038</td>
<td>17611.96</td>
<td>62234.75</td>
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<tr>
<td>1987</td>
<td>25048.87</td>
<td>9405.122</td>
<td>5597.845</td>
<td>1260.14</td>
<td>225723</td>
<td>58752</td>
<td>2392818</td>
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<td>63829.23</td>
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<td>1988</td>
<td>24355.17</td>
<td>10218.66</td>
<td>5789.444</td>
<td>1215.91</td>
<td>2162541</td>
<td>179214</td>
<td>2448714</td>
<td>24943.65</td>
<td>68948.17</td>
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<td>1989</td>
<td>23479.71</td>
<td>9510.161</td>
<td>5809.862</td>
<td>1084.87</td>
<td>2093268</td>
<td>386172</td>
<td>2111808</td>
<td>19523.57</td>
<td>61751.23</td>
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<td>1990</td>
<td>23720.3</td>
<td>10194.45</td>
<td>6481.766</td>
<td>1099.13</td>
<td>1943995</td>
<td>320382</td>
<td>1900056</td>
<td>22135.4</td>
<td>65797.09</td>
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<td>1991</td>
<td>23438.01</td>
<td>9578.079</td>
<td>5803.706</td>
<td>993.37</td>
<td>1869946</td>
<td>433194</td>
<td>1457880</td>
<td>17731.26</td>
<td>59603.48</td>
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<td>1992</td>
<td>23222.57</td>
<td>10253.21</td>
<td>5808.494</td>
<td>1030.59</td>
<td>1911953</td>
<td>1473058</td>
<td>1547021</td>
<td>18843.46</td>
<td>61239.72</td>
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<tr>
<td>1993</td>
<td>23673.89</td>
<td>10180.04</td>
<td>6064.458</td>
<td>1054.6</td>
<td>1905197</td>
<td>4306577</td>
<td>1699182</td>
<td>23786.03</td>
<td>66877.2</td>
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<td>1994</td>
<td>23827.78</td>
<td>10156.9</td>
<td>6195.672</td>
<td>1070.9</td>
<td>1899322</td>
<td>3547243</td>
<td>1826084</td>
<td>21426.92</td>
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<td>1995</td>
<td>29825.03</td>
<td>11545.85</td>
<td>9611.63</td>
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<td>2601.9</td>
<td>2416</td>
<td>215.09</td>
<td>25776.28</td>
<td>80721.23</td>
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Source: Compiled from CSA, Agricultural Sample Survey, Livestock, Poultry and Beehives, Various Issues

Note: 1) CSA's Surveys were interrupted in 1993 and 1994. Data for these years were generated by making projection on the basis of the historic rates of growth

2) Growth rate over the period 1980-1995 is computed by taking average livestock population for 1980-1988 and 1989-1995 and then computing the growth rate between the two period

Growth rate 1980-1995: 2.934141
### Table 13. Percent of Cattle Used for Different Purposes by Zone, Private Holdings, 1994/95

<table>
<thead>
<tr>
<th>No.</th>
<th>Region/zone</th>
<th>Milking cow</th>
<th>Draught cattle</th>
<th>Beef cattle</th>
<th>Cattle for other purposes</th>
<th>All purposes</th>
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<tbody>
<tr>
<td>1</td>
<td>Tigray</td>
<td>37,996,65</td>
<td>48,240.5</td>
<td>1,105,286</td>
<td>12,657,57</td>
<td>100</td>
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<td>2</td>
<td>Afar</td>
<td>49,312,02</td>
<td>16,262.16</td>
<td>10,450,79</td>
<td>23,974,58</td>
<td>100</td>
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<td>3</td>
<td>Agewawi</td>
<td>39,657,67</td>
<td>38,796.17</td>
<td>0,761,991</td>
<td>20,784,17</td>
<td>100</td>
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<td>4</td>
<td>East Gojam</td>
<td>31,6134</td>
<td>53,944.12</td>
<td>0,482,336</td>
<td>13,960,15</td>
<td>100</td>
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<td>5</td>
<td>West Gojam</td>
<td>31,496,35</td>
<td>50,570.87</td>
<td>0,704,709</td>
<td>17,228,07</td>
<td>100</td>
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<td>6</td>
<td>North Gonder</td>
<td>44,6108</td>
<td>39,856.19</td>
<td>3,945,579</td>
<td>11,587,43</td>
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<td>7</td>
<td>South Gonder</td>
<td>34,450,38</td>
<td>50,076.72</td>
<td>0,299,515</td>
<td>15,173,39</td>
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<td>8</td>
<td>Amhara N. Shewa</td>
<td>26,965,75</td>
<td>62,899.34</td>
<td>1,207,538</td>
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<td>Amhara Oromia</td>
<td>35,698,69</td>
<td>52,525.47</td>
<td>1,251,82</td>
<td>10,524,02</td>
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<td>10</td>
<td>Waghama</td>
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<td>54,351.05</td>
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<td>6,859,903</td>
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<td>11</td>
<td>North Wello</td>
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<td>49,394.78</td>
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<td>12</td>
<td>South Wello</td>
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<td>East Hararghe</td>
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<td>17</td>
<td>West Hararghe</td>
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<td>Illubabor</td>
<td>41,545,33</td>
<td>45,448.54</td>
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<td>Jima</td>
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<td>East Shewa</td>
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<td>41,058.39</td>
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<td>16,320,15</td>
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<td>21</td>
<td>Oromia N. Shewa</td>
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<td>22</td>
<td>West Wellega</td>
<td>38,816,19</td>
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<td>39,069,57</td>
<td>1,804,721</td>
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Source: Agricultural Sample Survey, Livestock, Poultry and Beehives CSA Bulletin No. 132 Vol II pp44-45
Table 14: Breed of Livestock, National, 1994/95: Percent of Indigenous and Hybrid

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<th>Livestock</th>
<th>Indigenous</th>
<th>Hybrid</th>
<th>Total</th>
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<td>0.26</td>
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<td>Sheep</td>
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<td>0.21</td>
<td>100</td>
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<tr>
<td>Goat</td>
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<td>100</td>
</tr>
</tbody>
</table>

Source: Agricultural Sample Survey, Livestock, Poultry and Beehives CSA Bulletin No. 132 Vol II pp37

Table 15: Average Milk Yield Per Cow Per Day, Lactation Period and Percentage of Milk Converted into Butter by Zone for Private Holdings (1994/95)

<table>
<thead>
<tr>
<th>No.</th>
<th>Region/zone</th>
<th>Average milk yield per cow (litre per day)</th>
<th>Average lactation period (months)</th>
<th>Percentage of milk converted into butter per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tigray</td>
<td>0.97</td>
<td>6.19</td>
<td>40.6</td>
</tr>
<tr>
<td>2</td>
<td>Afar</td>
<td>0.9</td>
<td>6.5</td>
<td>22.28</td>
</tr>
<tr>
<td>3</td>
<td>Agewawi</td>
<td>0.9</td>
<td>7.7</td>
<td>45.5</td>
</tr>
<tr>
<td>4</td>
<td>East Gojam</td>
<td>0.96</td>
<td>6.1</td>
<td>34.9</td>
</tr>
<tr>
<td>5</td>
<td>West Gojam</td>
<td>0.87</td>
<td>6.6</td>
<td>38.23</td>
</tr>
<tr>
<td>6</td>
<td>North Gonder</td>
<td>1.12</td>
<td>7.5</td>
<td>45.95</td>
</tr>
<tr>
<td>7</td>
<td>South Gonder</td>
<td>0.92</td>
<td>6.8</td>
<td>43.82</td>
</tr>
<tr>
<td>8</td>
<td>Amhara N Shewa</td>
<td>0.96</td>
<td>6.1</td>
<td>30.62</td>
</tr>
<tr>
<td>9</td>
<td>Amhara Oromia</td>
<td>1.31</td>
<td>6.7</td>
<td>38.1</td>
</tr>
<tr>
<td>10</td>
<td>Waghamra</td>
<td>1.14</td>
<td>5.7</td>
<td>35.4</td>
</tr>
<tr>
<td>11</td>
<td>North Wello</td>
<td>1.18</td>
<td>5.9</td>
<td>46.64</td>
</tr>
<tr>
<td>12</td>
<td>South Wello</td>
<td>1.13</td>
<td>6.1</td>
<td>42.07</td>
</tr>
<tr>
<td>13</td>
<td>Arsi</td>
<td>1.02</td>
<td>7.5</td>
<td>40.67</td>
</tr>
<tr>
<td>14</td>
<td>Bale</td>
<td>1.21</td>
<td>7.8</td>
<td>27.44</td>
</tr>
<tr>
<td>15</td>
<td>Borena</td>
<td>1.34</td>
<td>6.7</td>
<td>27.72</td>
</tr>
<tr>
<td>16</td>
<td>East Hararghe</td>
<td>1.44</td>
<td>6.1</td>
<td>8.24</td>
</tr>
<tr>
<td>17</td>
<td>West Hararghe</td>
<td>1.28</td>
<td>6.5</td>
<td>14.02</td>
</tr>
<tr>
<td>18</td>
<td>Illubabor</td>
<td>1.12</td>
<td>6.5</td>
<td>37.07</td>
</tr>
<tr>
<td>19</td>
<td>Jima</td>
<td>1.0</td>
<td>5.9</td>
<td>39.76</td>
</tr>
<tr>
<td>20</td>
<td>East Shewa</td>
<td>0.99</td>
<td>7.15</td>
<td>48.41</td>
</tr>
<tr>
<td>21</td>
<td>Oromia N Shewa</td>
<td>1.03</td>
<td>6.87</td>
<td>52.07</td>
</tr>
<tr>
<td>22</td>
<td>West Wellega</td>
<td>1.02</td>
<td>6.45</td>
<td>37.1</td>
</tr>
<tr>
<td>23</td>
<td>East Wellega</td>
<td>0.97</td>
<td>6.8</td>
<td>49.47</td>
</tr>
<tr>
<td>24</td>
<td>West Wellega</td>
<td>0.99</td>
<td>6.59</td>
<td>42.91</td>
</tr>
<tr>
<td>25</td>
<td>Bench</td>
<td>1.47</td>
<td>6.35</td>
<td>31.09</td>
</tr>
<tr>
<td>26</td>
<td>Gedio</td>
<td>1.12</td>
<td>6.35</td>
<td>26.71</td>
</tr>
</tbody>
</table>
### Table 16. Relative Contributions of the Crop and Livestock Sub-sectors to Agricultural GDP in 1995

<table>
<thead>
<tr>
<th>Items</th>
<th>Amount (in Birr)</th>
<th>% of Agr GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Major Crops&quot;</td>
<td>8929581660</td>
<td>51.770368219</td>
</tr>
<tr>
<td>&quot;Non-Major Crops&quot;</td>
<td>3977682150</td>
<td>23.061110521</td>
</tr>
<tr>
<td>Livestock</td>
<td>4341177658</td>
<td>25.168521261</td>
</tr>
<tr>
<td>Agricultural GDP</td>
<td>17248441468</td>
<td>100</td>
</tr>
</tbody>
</table>

**Note:**
1. "Major Crops," as defined by CSA, stands for cereals, pulses, and (mostly) Oilseeds.
2. "Non-Major Crops" stands for fruits, vegetables, spices, enset, coffee, and chat.
3. The share of livestock sub-sector would be raised to 32.7% if we consider "major crops only.

Source: [Dejene, 1997a]
Table 17: Export and Import of Livestock Products and Crops: Percentage Share and Ratio of Livestock Export to Livestock Import.

<table>
<thead>
<tr>
<th>Year</th>
<th>Value of export</th>
<th>Value of import</th>
<th>Livestock export as a ratio of livestock import</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>crop Livestock others total</td>
<td>livestock crop others total</td>
<td></td>
</tr>
<tr>
<td>1979/80</td>
<td>73.1 16 10.9 100</td>
<td>2.2 2.8 95 100</td>
<td>4.75</td>
</tr>
<tr>
<td>1980/81</td>
<td>70.7 12.8 16.5 100</td>
<td>3.2 3.2 93.6 100</td>
<td>2.44</td>
</tr>
<tr>
<td>1981/82</td>
<td>71.6 14.4 14 100</td>
<td>3.6 4.7 91.7 100</td>
<td>1.91</td>
</tr>
<tr>
<td>1982/83</td>
<td>71.7 12.8 15.5 100</td>
<td>3.2 6.8 90 100</td>
<td>1.87</td>
</tr>
<tr>
<td>1983/84</td>
<td>72.3 12.3 15.4 100</td>
<td>2.7 5.5 91.8 100</td>
<td>2.12</td>
</tr>
<tr>
<td>1984/85</td>
<td>69.9 15.9 14.2 100</td>
<td>4.9 14.6 80.5 100</td>
<td>1.36</td>
</tr>
<tr>
<td>1985/86</td>
<td>74.2 15.1 10.7 100</td>
<td>6.7 17.3 76 100</td>
<td>0.96</td>
</tr>
<tr>
<td>1986/87</td>
<td>72.1 16 11.9 100</td>
<td>5.0 12.5 82.5 100</td>
<td>1.17</td>
</tr>
<tr>
<td>1987/88</td>
<td>64.3 21.6 14.1 100</td>
<td>3.0 7.8 89.2 100</td>
<td>2.47</td>
</tr>
<tr>
<td>1988/89</td>
<td>73.1 16.2 10.7 100</td>
<td>2.0 10.8 87.2 100</td>
<td>3.63</td>
</tr>
<tr>
<td>1989/90</td>
<td>62.7 19.2 18.1 100</td>
<td>1.8 4 94.2 100</td>
<td>4.34</td>
</tr>
<tr>
<td>1990/91</td>
<td>56 17.2 26.8 100</td>
<td>2.9 9.5 87.6 100</td>
<td>1.61</td>
</tr>
<tr>
<td>1991/92</td>
<td>56.7 18.6 24.7 100</td>
<td>0.7 0.1 99.2 100</td>
<td>4.45</td>
</tr>
<tr>
<td>1992/93</td>
<td>64.3 14.4 21.3 100</td>
<td>2.1 11.6 86.3 100</td>
<td>1.72</td>
</tr>
<tr>
<td>1993/94</td>
<td>66.6 15.8 17.6 100</td>
<td>1.9 10.2 87.9 100</td>
<td>2.38</td>
</tr>
<tr>
<td>1994/95</td>
<td>75.8 13.6 10.6 100</td>
<td>4.9 9 86.1 100</td>
<td>1.20</td>
</tr>
<tr>
<td>Average</td>
<td>68.4 15.7 15.9 100</td>
<td>3.1 8.2 88.7 100</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Source: Computed from National Bank of Ethiopia's Annual Report, various issues

Notes: 1). Value of crop exports include coffee, oilseeds & pulses, fruits and vegetables and chat.
2). The value of crop import is approximated by the value of commercially imported grain.
3). Livestock export is the summation of values of hides and skins, meat products and live animals.
4). Livestock import is obtained by deducting the value of grain from the value of food & live animals imported in the given year.
5). Other export value column is the value of sugar, oilcakes, gold petroleum products, bee's wax, and re-export. 6). Other imports included value of raw materials, semi-finished goods, fuel, capital goods, consumer goods, and miscellaneous
### Table 18. Addis Ababa Consumer Price Index (1963=100)

<table>
<thead>
<tr>
<th>Year</th>
<th>General</th>
<th>Food</th>
<th>Crop</th>
<th>Livestock</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>353.5</td>
<td>421.6</td>
<td>2388.3</td>
<td>832.1</td>
<td>976.3</td>
</tr>
<tr>
<td>1981</td>
<td>375.2</td>
<td>441.2</td>
<td>2576.9</td>
<td>805.9</td>
<td>849.2</td>
</tr>
<tr>
<td>1982</td>
<td>396.1</td>
<td>471.0</td>
<td>2811.1</td>
<td>841.2</td>
<td>1341</td>
</tr>
<tr>
<td>1983</td>
<td>407.8</td>
<td>522.8</td>
<td>3186.1</td>
<td>935.9</td>
<td>1351</td>
</tr>
<tr>
<td>1984</td>
<td>509.4</td>
<td>654.7</td>
<td>3812.9</td>
<td>900.8</td>
<td>1709.8</td>
</tr>
<tr>
<td>1985</td>
<td>459.4</td>
<td>554.9</td>
<td>3254.4</td>
<td>903.6</td>
<td>1552.8</td>
</tr>
<tr>
<td>1986</td>
<td>448.3</td>
<td>521.3</td>
<td>3030.3</td>
<td>951.4</td>
<td>1342.4</td>
</tr>
<tr>
<td>1987</td>
<td>480.0</td>
<td>562.4</td>
<td>3308.4</td>
<td>1039.8</td>
<td>1539.5</td>
</tr>
<tr>
<td>1988</td>
<td>517.6</td>
<td>599</td>
<td>3609.2</td>
<td>1168</td>
<td>1812.1</td>
</tr>
<tr>
<td>1989</td>
<td>544.2</td>
<td>630.1</td>
<td>3488.2</td>
<td>1178.10</td>
<td>1859.4</td>
</tr>
<tr>
<td>1990</td>
<td>738.7</td>
<td>890.6</td>
<td>5122.5</td>
<td>1845.60</td>
<td>2558.8</td>
</tr>
<tr>
<td>1991</td>
<td>771.9</td>
<td>941.1</td>
<td>5248.7</td>
<td>1989.2</td>
<td>2429.9</td>
</tr>
<tr>
<td>1992</td>
<td>849.9</td>
<td>1027.6</td>
<td>5746.5</td>
<td>2361.7</td>
<td>2777.4</td>
</tr>
<tr>
<td>1993</td>
<td>858.9</td>
<td>1029.4</td>
<td>5332.8</td>
<td>2541</td>
<td>2963</td>
</tr>
<tr>
<td>1994</td>
<td>973.6</td>
<td>1217.4</td>
<td>6294.3</td>
<td>2720.2</td>
<td>4114.4</td>
</tr>
</tbody>
</table>

Source: National Bank of Ethiopia, Annual Report, various issues

Notes:
1). Crop includes indices for cereals, fruits and vegetables, pulses and spices
2). Others includes indices for fish, other food items and drinks
THE CONTRIBUTION OF LIVESTOCK TO THE SUSTAINABILITY OF AGRICULTURAL INCOME IN ETHIOPIA: REVIEW OF TECHNOLOGY AND POLICY ISSUES

Simeon k. Ehui and Nega Gebreselassie

ABSTRACT

Despite the rapidly growing population and the enormous constraints to production, the country has potential to attain food security. Empirical evidences indicate that intensification of agriculture though integration of livestock into cropping systems and much greater use of modern technologies can significantly increase food production and farm income. Not only can farmers mitigate risks by producing multitude of commodities, but they can also increase the productivity of both corps and animals in a more profitable and sustainable way. Livestock can make a major contribution to the efficient use of available natural resources.

The results of this study has shown that there is a potential to increase cash income and labor utilization through rearing of high-yielding livestock breeds, better feed and pasture management and use of improved technology and that farmers can further increase their household incomes by keeping crossbred cows (ETB 1175 as opposed to ETB 954 from keeping local Zabu cows only).

Policy-makers can assist the integration of livestock into the cropping system and adoption of modern technologies by designing favorable price and trade policies, provisions of credit facilities, generation of new technologies through research, dissemination of new technologies through extension services, and improving education.

1. INTRODUCTION

Poverty and food insecurity are two major problems in Ethiopia. Population pressure has increased the demand for food, however,
agricultural productivity has not kept up with population growth. The average growth of population during 1980-90 was 3.1%, while the growth of agricultural production during the same period was only 1.1% (World Bank, 1996). The per capita food and agricultural production have been consistently declining for the past two decades. The index of per capita food production in 1992 was 84.67 (FAO, 1994). Projections show that the population will continue to grow at a faster pace and, hence contribute immensely to the severity of food deficit, unless remedial actions are taken.

Recurrent drought and famine are common phenomena. All in all, 39 periods of food shortage and excess mortality or both have been identified. The underlying factor that makes famine possible is poverty - absolute poverty at both national and household levels (IFPRI, 1992). The per capita Gross National Product of US$ 120 is one of the lowest in the world (World Bank, 1996). Studies indicate that from 0.6 to 4.4 million urban and 12.6 to 33 million rural Ethiopians do not have the means of the normal diet (USAID, 1995; World Bank, 1992). Imports and international aid often fill the gap between food production and consumption. In 1992/93 about 833,400 tons of cereals, 4,023 tons of skimmed milk, and 41,522 tons of vegetable and butter oil were donated to Ethiopia as food aid (FAO, 1993).

Agricultural productivity has to be improved significantly if food deficit problems are to be minimized and ultimately eliminated.
Intensification of agriculture through a closer integration of livestock into the cropping system and use of modern technologies is an important step to increase farm productivity and tackle poverty and food insecurity, while preserving the environmental quality. Livestock can make a major contribution to the efficient use of available resources. In mixed farming, not only can farmers mitigate risks by producing a multitude of commodities, but they can also increase the productivity of both crops and animals in a more profitable and sustainable way. The benefits of crop-livestock interactions are several. Animal traction could improve the quality and timeliness of farming operations, thus raising crop yields and incomes. Farm animals furnish manure to improve soils. Livestock sales would generate cash to buy inputs. Keeping animals on the farm could also provide a use for other resources such as crop residue, which might be wasted in the absence of animals (McIntire et al, 1992).

The objective of this paper is to review available empirical evidence on how closer crop-livestock integration with use of modern inputs and technologies, particularly livestock technologies, could mitigate poverty and food insecurity and assess the problems that constrain the adoption and sustained use of modern livestock technologies in the Ethiopian highlands.

The Ethiopian highlands are considered suitable for both crop and livestock production (McIntire et al, 1992; FAO 1996). The highlands constitute approximately 44% (49 million ha) of the...
total land area in Ethiopia, and more than 88% of Ethiopia’s 53 million people live there (Omiti et al., 1997). Agriculture is the main occupation and livestock breeding is an important component of the Ethiopian highland farming systems. Since it is an area in which the process of integration has reached a high level of complementarity, strategies should focus on development and implementation of improved technologies and the use of modern production inputs. Small-scale farmers’ production account for about 90% of the total agricultural output and 84% of the marketed production in Ethiopia. Any significant change in the agricultural productivity in the small-scale farm sector will substantially affect national income and food security (Belete et al., 1993).

2. THE BENEFITS OF CROP-LIVESTOCK INTEGRATION

Crop-livestock production systems denote land use systems in which livestock husbandry and cropping are practiced in association in a mutually beneficial manner. The benefits of crop-livestock interactions are several. Animal traction could improve the quality and timeliness of farming operations, thus raising crop yields and farm incomes. Farm animals furnish manure to improve soils. Livestock sales would generate cash income to buy inputs. Keeping animals on the farm could also be a use to feed on other resources such as crop residue, which might be wasted in the
absence of animals (McIntire et al., 1992). Cattle and equine are used as sources of draft power for a variety of purposes, such as ploughing, threshing, transport, pulling agricultural implements, and pumping irrigation water. Compared with the use of tractors, animal power is a renewable energy source and is produced in the farm, with almost all the implements required made locally (FAO, 1996).

2.1 Livestock as a Source of Food and Nutrition

Animal products not only represent a source of high quality food, but are also important sources of proteins and essential amino acids and calories, when used as a major constituent of human diet (FAO, 1996). Animals are also used as a buffer to risks of crop failure and to variability in crop production. Cash from the sales of livestock and livestock products is used to purchase grains.

Evidence from research shows that using animals for traction can increase food production by enabling timely and better soil preparation (Assamenew et al., 1993; Gryseels, 1988; Omiti, 1997). Oxen - based farmers have also been found to have a higher price elasticity of supply than hoe -based farmers, indicating that they are more responsive to price incentives. Using draft animals on vertisols for land shaping, where there is a water logging problem, enables the use of improved varieties and fertilizer that can increase grain and fodder production (see Table 1). Vertisols account for 12.7 million hectares in Ethiopia, of which 7.6 million hectares are in the highlands. Only about 2 million hectares (25%)
of the vertisols in the Ethiopian highlands is presently cultivated (Assamenew et al., 1993). The use of animal drawn drainage making has reduced the average labor required per hectare by 67% at Enewari, in the central highlands. At Debrezeit, for a period of five years, there was a 32% average net return from wheat production as a result of using animal drawn broad bed maker (BBM) (Assamenew et al., 1993). The study also reports that in the Ginchi area the average yield of wheat in 1988 and 1989 was 1.8 tons per hectare while it was less than one ton per hectare on traditionally flat and late planted plots. If an increment of 5 quintals per hectare is achieved, by using the BBM, then the total yield increase of wheat in the Ethiopian highlands will be in the order of 1 million tons of wheat (Mussa and Astatke, 1995). The benefits of BBM are more enhanced when in combination with other technological components and hence, the attitude of farmers towards each component has a great bearing on the adoption of the BBM (Assamenew et al., 1993).

2.2 Livestock as a Source of Employment and Income

Animals are source of income for many small farmers in developing countries, which will be used for the purchase of food as well as agricultural inputs, such as seed, fertilizer and pesticides. Gryseels (1988) showed that in the Ethiopian highlands, sale of livestock and livestock products contribute 83% of cash income per year. About 52% of cash income was from trade of live animals and 31% from the sale of livestock products. Manure
alone accounted for 25% of the sale of livestock products and dairy products for just over 50%. Farmers with small livestock holdings derived a proportionally higher fraction of their cash income from livestock than farmers with large livestock holdings. The livestock share in cash income is higher in those villages where total cash income is higher indicating that increased cash income comes primarily from livestock (Gryseels, 1988).

These results are supported by a recent study (Omiti et al, 1997) which examined the economic outcomes of introducing livestock on crop farms to increase food production and cash income in the central highlands of Ethiopia. The key question addressed in the study is whether crop farmer will improve farm income and food security by adopting crop-livestock system instead of sole cropping system. The results (see Table 2) showed that specialization in crops alone is not the most efficient way of increasing farm income. Reorganizing resource allocation practices and integrating crops with livestock improves the agricultural performance of smallholder farmers in the study area. There is potential to increase cash income and labor utilization through rearing of high-yielding livestock breeds, better feed and pasture management and use of improved technology. The study showed the benefit of assuring long term food security with adoption of new technology. Compared with keeping a local Zebu cow (under improved pasture yield), the opportunity to keep a crossbred cow presents another opportunity for generating farm income in the rural areas. With this
farm plan, farmers would earn 1175 Birr as opposed to 954 Birr (Omiti et al, 1997).

Livestock, particularly sheep are efficient in controlling weed. They have been shown to reduce the cost of weeding by as much as half and also provide additional income from meat production. Such systems also safeguard the environment and also avoid chemical pollution while supplying additional organic matter to the soil.

Livestock husbandry, especially dairy farm is a labor intensive activity. As man to land ratio increases due to population growth, it can offer a viable option to absorb the redundant labor and can minimize the rural underemployment problem. Omiti et al (1997) have showed that by keeping cross bred cows in the farm instead of local Zebu cows, the farmer will be able to sell more milk (767 kg instead of 175 kg) and employ more family labor (807 hours instead of 782 hours). This was supported by Buta (1997) in his evaluation of the economic returns of using crossbred cows for both draft and milk production. The study shows that on average, the introduction of crossbred cows increases labor utilization by about 40% compared to the traditional technology (see Table 3).

2.3 Livestock for Sustainable Agriculture
Tropical soils generally require periods of fallowing to restore their capacity to sustain crop yields. However, with population growth,
fallow periods are shortened or are no longer possible. Nutrient cycling is an essential component of any sustainable farming system. The integration of livestock and crops allows for efficient nutrient cycling. Animals use the crop residues, such as cereal straws, as well as maize and sorghum and groundnut haulms as feed. The manure produced can be recycled directly as fertilizer. Manure is among the most important contributions of livestock to the sustainability of agriculture. Although it cannot replace all of the soil minerals removed by harvested crops, it recycles a significant proportion and adds organic matter that contributes to the tilth and water holding capacity of soils (Winrock, 1992).

One ton of cow dung contains about 8 kg N, 4 kg P₂O₅ and 16 kg K₂O. The chemical composition of manure, however, varies according to the animal and also the nature of its diet. In addition to the direct contribution of plant nutrients, manure provides important organic matter to the soil, maintaining its structure, water retention and drainage capacity. Forage legumes and leguminous trees have been shown to have the capacity to increase soil nitrogen and organic matter content and thus the soil caption capacity. They also improve soil conditions for cropping by effects such as improving the workability, reducing soil surface temperatures and erosion and increasing soil moisture penetration. These benefits have justified the inclusion of forage legumes and multi-purpose trees in cropping systems through crop yield enhancement. The benefits of the production of livestock feed can, therefore, be achieved at a very low opportunity cost, provided that
the forage crop interactions and implications for nutrient cycling properties are identified and utilized properly. Seasonal shortages and low nutritional value of feed resources are the most widespread technical constraints for livestock producers in developing countries. Better utilization of crop by-products and the establishment of improved fodder crops, including trees, which have superior energy and protein availability for ruminants are required. Multi-purpose trees serve both as legumes to improve soil productivity through nitrogen fixation and as high quality animal feed. They increase the attainable food and fodder crop yields from the same land unit through a combination of plant species and varieties in different associations. In the crop-livestock systems they provide for the enhancement of animal productivity at low opportunity cost.

The use of crossbred cows for both draft and dairy purposes have shown to have the potential to increase farmers’ cash income from milk production, while relieving stock pressure by reducing the need for oxen. It enables to reduce livestock numbers and increase productivity per head. At the national level, such technology can bring more and quality meat supplies for urban consumption, reduced herd size and can minimize grazing pressure (Gryseels and Goe, 1984). Work oxen provide farm power but are used for only 8-10 weeks within a year. Ethiopia has up to seven million work oxen and there are 3-4 more cattle than this for oxen replacement. All these compete on the same communal feed resource with other
livestock. The use of cows for both milk and draft can potentially reduce the large herd kept for work oxen replacement and reduce overall grazing pressure. On station experiments by the International Livestock Research Institute and the Institute of Agricultural Research have demonstrated that both work and milk output are satisfactory if nutrition is adequate. The on-farm tests conducted later around Holetta (Buta, 1997) show significant increases in household incomes and farm outputs as a result of milk sales, cow traction and reduced numbers of work oxen. As a result of production beyond subsistence level, cash income is raised by 6.2% and 73% over the cash income achieved by the dairy only and the traditional farm plan (Buta, 1997). As crossbred cows are used for both milk and traction, the number of local herd can be reduced by half. Thus, the use of crossbred cows for traction can enable more sustainable development through decreased stock pressure on land. The use of crossbred cows for milk and traction is likely to be more attractive option for small and medium land size farmers. This is so because as land size reduces, feed resources become more limited and the need arises to keep a smaller number of animals to support the farm system (Buta, 1997).

3. CONSTRAINTS TO THE USE OF MODERN LIVESTOCK TECHNOLOGIES

The Ethiopian agriculture is characterized by a low use of modern technologies and inputs (Kidane, 1994; MOA, 1995). This is manifested by the low levels of yields of both crop and livestock
products. For instance, the average yield of maize and wheat for 1992-93 are lower than that of the world average by 50% and 58% respectively (FAO). The productivity of the livestock sector gives a much more dismal picture. Livestock productivity in Ethiopia is below most countries in sub-Saharan Africa. In 1994, the average yield level for beef and veal and cow milk was 105 kg and 209 kg/animal respectively, compared to 123 kg meat/animal and 350 kg milk/animal for Eastern Africa and 140 kg meat/animal and 376 kg milk/animal for sub-Saharan Africa (FAO, 1995). Milk yield of local cows is on average about 2.5 liters/day, and of goats around 0.3 liters per day. Under reasonable management conditions, these can be improved 3-5 times (MOA, 1995).

There are several constraints to the uptake and sustainable use of modern technologies and inputs. Poor linkage between research and extension (reflected in the farmers' limited knowledge of modern technologies), high cost, low returns inappropriateness of technologies, lack of credit facilities, the prevalence of animal diseases, and the absence of transport and marketing infrastructure (to market inputs as well as surplus output) are some of the problems in the diffusion of the technologies.

3.1 Research-extension Linkage
Studies on the adoption rate of some technologies show that farmers' perception of specific technology characteristics is important in the adoption of new technologies. Coverage and
quality of research and extension services in Ethiopia are below acceptable standards (MOA, 1995). Like in many other countries in sub-Saharan Africa, improving the link between research and extension and the education of farmers will be important in this regard. Successful development depends upon improving human capital and establishing the conditions under which knowledge can be used. Appropriately focused education systems, effective means of transferring knowledge to farmers, and properly functioning support services are essential to this process (Winrock, 1992).

3.2 Appropriateness of Technology
An important factor in the adoption of technologies is the appropriateness of the technology in terms of addressing the problems and production objectives, the wealth status and the cultural norms, traditions of the target group, its affordability, profitability, and use of local resources. Involving farmers in the generation of technologies and selecting specific technology characteristics improves the chances of adoption of a particular technology.

3.3 Credit Facilities
Many farmers are poor and cannot raise the necessary funds of their own to adopt new technologies, some of which may require substantial initial investment and to purchase the complementary variable inputs that go with these technologies. The availability of credit accelerates the adoption and sustainable use of modern
technologies and increases the commercialization and modernization of farmers. A recent study by Freeman et al (1997) on the impact of credit on milk productivity in Ethiopia showed that providing credit to farmers to fund operations could encourage higher variable input use and substantially increases smallholder dairy productivity. The study also showed that the marginal contribution of crossbred milking cows to milk output is relatively high on credit constrained farms. An additional unit of credit (through investment on a crossbred cow) to liquidity constrained farmers contributes about twice as much to milk output (in liters) per farm as it would on a credit non-constrained farm (Freeman et al, 1997). There is an urgent need to devise rural credit policy, which will be acceptable to both lenders and borrowers.

3.4 Animal Health Services and Feed
The prevalence of broad array of animal diseases coupled with poor delivery systems of animal health services depresses livestock production and retards the introduction of more productive breeding stock and new technologies. Crossbred animals are particularly more susceptible to diseases than local animals and have more feed requirements. As animal agriculture is intensified, diseases will cause greater problems and will have to be controlled to assure farmers that intensification will yield an adequate return on investment (Winrock, 1992). The unavailability of feed at a reasonable cost is often a main limiting factor that determines the adoption of modern livestock technologies. This is especially more
so when milk prices are very low and thus farmers will have a small or negative gross margin. Strengthening of animal health delivery services through appropriate cost and improving the feed market will significantly help reduce risk on animal agriculture and foster diffusion of modern livestock technologies.

3.5 Marketing and Transport Infrastructure
Absence of roads, storage warehouses, milk collection and processing centers are some of the bottlenecks that reduce the incentive to adopt technologies and increase marketable output. This is especially true for livestock and other perishable agricultural products. Investments in rural infrastructure would reduce transportation costs, link rural markets in general, and foster transformation of the agricultural sector while improving the marketing of inputs and outputs.

4. CONCLUSIONS

As a result of poor productivity of the agricultural sector and high population growth rate, poverty and food insecurity are two major problems in Ethiopia. The Ethiopian agricultural sector is characterized by low use of modern technologies and inputs. It is evidenced by the productivity levels, which are low even by African standards.

A closer integration of crop and livestock systems in the Ethiopian highlands with the use of modern technologies can substantially
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increase productivity of crops and livestock and can have significant impact at both the household and national levels on poverty and food security. Studies have showed that the use of modern livestock technologies can improve productivity, increase cash incomes of farmers, and increase the use family labor without adversely affecting the quality of the environment.

Several problems militate, however, against the diffusion and sustained use of available modern technologies, some of which are:

- Poor coverage and lack of coordination between research technologies;
- Lack of resources of farmers and absence of credit facilities;
- Appropriateness of technologies;
- Prevalence of animal diseases, poor animal health delivery and unavailability of adequate feed at affordable prices;
- Lack of transportation and marketing facilities.

Strengthening the link between research and extension, provision of institutional credit facilities especially to the resource poor farmers; involving the target groups in technological development; and improving animal health delivery systems through appropriate private and public sector participation can improve the adoption of the technologies. Socio-economic and policy research is required to better understand factors that hinder the adoption of the
technologies. It is also needed to improve the functioning of input and output markets and institutions.

REFERENCES


Table 1: Drainage Effects on Grain and Straw Yields of Wheat and Horse Bean at Were Ilu

<table>
<thead>
<tr>
<th>Crop</th>
<th>Land preparation</th>
<th>Sample size (n)</th>
<th>Grain yield (kg/ha)</th>
<th>Straw yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durum wheat</td>
<td>BBM</td>
<td>163</td>
<td>759***</td>
<td>1140</td>
</tr>
<tr>
<td></td>
<td>Traditional</td>
<td>167</td>
<td>311</td>
<td>449</td>
</tr>
<tr>
<td>Horse bean</td>
<td>BBM</td>
<td>170</td>
<td>683***</td>
<td>572***</td>
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<tr>
<td></td>
<td>Traditional</td>
<td>166</td>
<td>172</td>
<td>162</td>
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</table>

Source: Assamenew et al, 1993  
*** Significant at p=0.001

Table 2: Farm Level Impact of Improved Pasture and Breeds on Farm Resources

<table>
<thead>
<tr>
<th>Scenario Enterprise</th>
<th>(1) Baseline (2) Local cow local pasture</th>
<th>(3) Local cow improved pasture</th>
<th>(4) Crossbreed cow and improved pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat (ha)</td>
<td>0.31</td>
<td>0.42</td>
<td>0.36</td>
</tr>
<tr>
<td>Barley (ha)</td>
<td>0.34</td>
<td>0.36</td>
<td>0.36</td>
</tr>
<tr>
<td>Field pea (ha)</td>
<td>0.36</td>
<td>0.19</td>
<td>0.18</td>
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<tr>
<td>Lentil (ha)</td>
<td>0.27</td>
<td>0.62</td>
<td>0.45</td>
</tr>
<tr>
<td>Horse bean (ha)</td>
<td>0.18</td>
<td>0.17</td>
<td>0.16</td>
</tr>
<tr>
<td>Linseed (ha)</td>
<td>0.14</td>
<td>0.14</td>
<td>0.81</td>
</tr>
<tr>
<td>Pasture (ha)</td>
<td>Fallow land</td>
<td>0.60</td>
<td>0.31</td>
</tr>
<tr>
<td>Work oxen (no.)</td>
<td>Hired</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sheep (no.)</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Cows (no.)</td>
<td>None</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sell milk (Kg)</td>
<td>Nil</td>
<td>52</td>
<td>175</td>
</tr>
<tr>
<td>Labor used (hrs)</td>
<td>Not estimated</td>
<td>740</td>
<td>782</td>
</tr>
<tr>
<td>Income (Birr)</td>
<td>425</td>
<td>710</td>
<td>954</td>
</tr>
</tbody>
</table>

Source: Omiti et al, 1997
Table 3: Impact of Using Dual Purpose Crossbred Cows on Farm Households

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Traditional</th>
<th>Dual purpose cows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total labor (Hrs)</td>
<td>3348</td>
<td>3538</td>
</tr>
<tr>
<td>Family labor (Hrs.)</td>
<td>2621</td>
<td>3017</td>
</tr>
<tr>
<td>Hired labor (Hrs.)</td>
<td>273</td>
<td>521</td>
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<tr>
<td>Gross margin (Birr)</td>
<td>9379</td>
<td>13843</td>
</tr>
<tr>
<td>Subsistence (Birr)</td>
<td>3302</td>
<td>3302</td>
</tr>
<tr>
<td>Cash income (Birr)</td>
<td>6077</td>
<td>10543</td>
</tr>
<tr>
<td>Gross margin per employed Family labor (Birr)</td>
<td>4</td>
<td>4.9</td>
</tr>
<tr>
<td>Gross margin per hectare (Birr)</td>
<td>1914</td>
<td>2825</td>
</tr>
</tbody>
</table>

Source: Buta, 1997

Table 4: Farming Practices in the Ethiopian Highlands

<table>
<thead>
<tr>
<th>Activity</th>
<th>Crops only farms (n=34)</th>
<th>Mixed farms (n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure fields</td>
<td>61.8%</td>
<td>95.7%</td>
</tr>
<tr>
<td>Use fertilizer</td>
<td>26.5%</td>
<td>100%</td>
</tr>
<tr>
<td>Fallowing</td>
<td>52.9%</td>
<td>87.0%</td>
</tr>
<tr>
<td>Soil burning</td>
<td>69.6%</td>
<td>35.3%</td>
</tr>
</tbody>
</table>

Source: Omiti et al, 1995
USE OF CROSSBRED COWS FOR MILK AND
TRACTION IN THE ETHIOPIAN HIGHLANDS:
A WHOLE-FARM EVALUATION

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ABSTRACT

This study assessed the constraints to the use of crossbred cows for both milk and traction rather than for milk only and investigated the impact on farmers' incomes and resource use. Given these objectives, Mixed Integer Programming (MIP) was employed to model farm practices of traditional farmers who have been testing crossbred cows on-farm.

Crossbred cows were found 19% more efficient than oxen for cultivation. The model results showed that given the average resource endowment of the sampled farmers, use of crossbred cows for both milk and traction improves farm gross margins by about 5% than their use for milk only. An assessment of the sensitivity analysis results showed that farmers with relatively less crop land holdings benefitted more from keeping crossbred cows for both milk and traction. This improvement in gross margins over the dairy-only technology is mainly the effect of more efficient use of the available feed resources.

When crossbred cows are used for both milk and traction the number of local herd can be reduced by half. This can enable more sustainable development through decreased stock pressure on land.

Not until a 50% increase in the price of concentrates occurs, would the substitution of concentrates by oats-vetch hay became feasible. However, the substitution of concentrates by oats-vetch at current prices is only accompanied by a decline in gross margins of 2%, showing that on-farm production of oats-vetch could replace concentrates even at current prices.
1. INTRODUCTION

In most developing countries, motorized mechanization is an exception and animal power remains vital to a large proportion of the population. At least 80% of the world's farmers use hand-tools only, while 15% use animal draft power, and only 5% rely on machine-powered equipment (Bodet, 1987).

In developing countries, where animal traction is essential in the farming system, it can be expected to continue to be the main source of power in the foreseeable future. The small size of farms, together with relatively abundant labor and high capital and operation costs of machines, makes draft power, and not machines, the most viable source of on-farm power.

Animal traction has existed for a long time in the Ethiopian highlands and is also common in the highlands of Kenya, Uganda, Tanzania, and Madagascar. Animal traction is also used in some areas in the semi-arid tropics and is said to be emerging in some parts of the sub-humid zone of West Africa (Jabbar, 1993).

Mixed smallholder farming accounts for all but a small percentage of agricultural land use in the Ethiopian highlands. Draft power is usually the most important product of cattle kept by these highland farmers. The standard method of cultivation involves a pair of oxen drawing a wooden plow of ancient design.
In many highland areas of Ethiopia, population is growing rapidly and resulting in reduced land sizes, less pasture land. It is estimated that a heard of 8-16 cattle are now kept by most farmers at any one time to ensure that they have a pair of working oxen available when needed (Agyemang et al., 1991). In areas where land is becoming a more scanty resource, the provision of feed to this number of cattle is obviously a prime problem. Previous efforts of researchers, directed at the introduction of crossbred dairy cows, that this technology can raise the net cash incomes of adopters. However, their introduction leads to increases in livestock holdings which in turn entail a more acute scarcity of feeds. For this reason, a means of reducing the effective number of draft animals needed to support crop production could help make production more efficient, profitable, and sustainable. One option is the use of crossbred dairy cows as draft animals, in addition to their use for milk production to reduce the need for a follower herd to produce oxen.

Dual-purpose dairy-draft animals are commonly used in some parts of southeast Asia, but in Africa, with the exception of Egypt and to some extent the Sudan, where barren cows are used (Jabbar, 1993).

To improve smallholder incomes the Institute of Agricultural Research (IAR) and the International Livestock Centre for Africa (ILCA) [now the International Livestock Research Institute (ILRI)] began testing and promoting the use of crossbred cows as one option and have been conducting joint dairy-draft research since
1978. To demonstrate that the technology is feasible, various experiments were conducted at research stations on crossbred cows to determine the technical trade-offs between milk production, calving interval, and work output when dairy cows are used also as draft animals.

Farmers in the study area, i.e., Holetta, have exposure to the use of crossbred cows for milk production. However, the use of cows in general and crossbred cows in particular for plowing is unknown. Plowing is at present solely being carried out with oxen. They are used for plowing only for short periods of time each year, but farmers have to feed them throughout the year resulting in high costs.

If cows could be used without significant penalty to their milk production and reproduction performance, farmers could reduce the number of stock required to satisfy their needs for draft power. This could lead to increased animal productivity and income by improving the efficiency of resource use. The objective of this paper is therefore to test the following hypotheses and in relation to the viability of using crossbred cows for milk and traction at the same time.

1. Dual-purpose use of crossbred cows would positively affect farm incomes.
2. As the size of cropland decreases, the necessity to reduce herd size would increase and the profitability of using crossbred cows for draft would increase.

3. An increase in the price of concentrates would significantly affect the profitability of crossbred cows and the adoption of forages grown on-farm, in this case oats-vetch, becomes necessary.

2. SOURCE OF DATA

The data used in this study are based on two years of farm trials in the Holetta area with 14 volunteer farmers, half using the cows for milk production and the rest for both traction and milk production. The Holetta area is located between 40 and 70 km west of Addis Ababa, in the vicinity of two small towns: Holetta and Addis Alem. The altitude of this area is around 2600 m and receives an average annual rainfall of 1100 mm (Hailu et al., 1990). According to the records of Holetta Research Center of IAR, the average minimum and maximum temperatures of the areas, over five years (1986-1972), were 11.6°C and 15.3°C respectively. The main rainy season is from June to September (meher season), where more than 70% of the rainfall occurs. The short rains are from February to May and are mainly used to break and prepare the soil for the main crop season. Farmers of this area exclusively depend on rain-fed agriculture and most crops are grown in the main rainy season.
For data collection, seven enumerators were assigned to reside and work in the survey area. Each enumerator was equipped with questionnaire forms, a measuring tape, a wrist watch, and a spring balance. Data collection included land use, labor allocation, use and source of draft power, input use, output use, and prices. Details on farm labor were recorded, including the number of workers in a family, hired or exchange, adults and children workers of each sex, the crop and type of operation on which they worked, and the length of working hours. Details of animal husbandry such as milking, barn cleaning, feeding, and herding, including use of draft power, were also recorded.

3. THE REPRESENTATIVE FARM MODEL

A Mixed Integer Linear Programming (MIP) model was constructed to represent farm practices of those farmers who got crossbred cows, forming two groups—the dairy-draft (D-D) group that use the cows for milk and traction: and the dairy-only (D-O) group that use the cows for milk only. The model has 62 activities and 59 constraints.

There are many cases in which the LP model can be used. It can be used to determine farm plans that could yield maximum profits, identify resources constraints and formulate government policies that can be helpful in designing strategies for farm development. LP has frequently been employed in farm management analysis.
to determine the merits and demerits of enterprises both within the existing mix and the feasibility of introducing new techniques into the current systems with the aim of maximizing farm income.

However, as is the case with all mathematical tools, LP has some limitations in its application. It assumes additivity of resources and activities, meaning that the sum of the resources used by the different activities equals the total quantity of resources used by each activity for all resources, individually and collectively. This implies that there is no interaction among the activities or resources, which leads to linearity in the calculation of total gross margin and total requirements of any resource for a given plan. One implication is that constant returns to scale and an absence of economies of size are assumed to apply for each activity, which may not always be a reasonable assumption. Where the degree of complementarily between enterprises in insignificant this assumption will practically apply. However, when non-linearities do exist, it may be possible to represent theses adequately as a number of linked linear segments (Dillon and Hardaker, 1993).

Divisibility of activity levels to resources has also been assumed, implying that there exist continuity of resources and output. One can use factors in fractional quantities and produce output in fractions. This may create difficulties in small-scale agriculture using large or small animals since the solution appears in non-integer values. To address this problem, a MIP (Mixed Integer Programming) model has been used in this study.
LP models have the property of being deterministic owing to the assumption of single values for input-output coefficients. However, the impact of varying coefficients such as prices can be tested using sensitivity analysis.

Finite activities and resource restrictions are the other assumptions of LP models. This implies that the method cannot be used if there are an infinite number of alternative activities and resource restrictions.

There are two cases of previous applications of whole-farm mathematical programming techniques to ILCA’s research on the use of milking crossbred cows for draft power. Unlike this study, the data used in one of the previous studies was not generated from on-farm use of the technology (Gryseels and Anderson, 1985). The other study used on-farm data to explore the potential benefits of three alternative traction technologies: traditional, single-ox, and cow-traction (Panin and Brokken, 1992). But still it differs with the current study in that it did not evaluate the relative profitability of crossbred cows for milk only, unlike their use for milk and traction at the same time.

The objective here is to maximize net cash income out of the possible combination of enterprises, subject to fulfilling the
priority of meeting minimum food requirements and other constraints.

Three farm plans have been developed for analysis using LP:

**The D-D plan:** While oxen are dept for draft in all the three models, only in the D-D model distinguished only by the non-use of crossbred cows for traction.

**The T-D plan:** A traditional model (T-D) without crossbred cows was also considered for an initial comparison and validation.

The mathematical structure of the whole-farm integer programming model used in this study is as follows:

\[
\begin{align*}
\text{Max } Z &= \sum_{i=1}^{n} C_i X_i \\
\text{subject to} & \\
\sum a_{ij} X_j &\leq b_j \\
X_i &\geq 0 \text{ for all } i
\end{align*}
\]

where:

- \(Z\) = Total objective function to be optimized
- \(C_i\) = gross margins per unit of the \(i^{th}\) activity
- \(X_i\) = level of \(i^{th}\) activity
- \(b_j\) = availability of the \(j^{th}\) resource
The important categories of activities and constraints that have been identified and used in the model are briefly described below.

### 3.1 CROP PRODUCTION ACTIVITIES

Crop type and form of tenancy on the land from which they are produced are the bases for delimitation of the various crops as separated activities, and thus occupy different columns in the LP model matrix. The activities incur variable costs in the objective function. These variable costs include the imputed cost for seed and fertilizer cost per hectare of each crop type. Crops grown on own land include tef, wheat, barley, horse-beans, fieldpea and oats-vetch. In the model only tef, wheat, and horse bean are specified to be grown on shared croplands. In the area the most common share cropping arrangement known as ‘siso’ takes place based on the agreement that all required inputs other than land are to be provided by the farmer who share crops-in land. For this he retains three-quarters of the total grain yield, and the land owner takes the remaining on quarter. In the matrix of the model the yield indicated for crops grown under such type of arrangement is the part taken by the farmer who shares in the land.

### 3.2 LIVESTOCK PRODUCTION ACTIVITIES

Livestock are kept to meet the various requirements of farmers. The livestock activities are distinguished by type, breed, age and sex. Those included in the model are crossbred cows, local cows, work-oxen, young males and females of both crossbred and local
cows, and sheep. Draft power, fuel dung, milk, and replacement herd are the main outputs from the livestock activities. Crossbred cows were found more efficient than oxen in most of the different cultivation passes and when these passes were aggregated they were more efficient by a total of 19%. Thus, the possibility of substitution of working cows for oxen is reflected in the model by this same rate, demanding an additional 7.6 MJ of metabolizable energy per pair hour work. Livestock production activities require variable costs such as veterinary services, mineral licks, and breeding in the case of crossbred cows. The economic life span of crossbred cows is about 8 years, compared to about 10 years for local zebu cows and oxen (Gryseels, 1988; Panin and Brokken, 1993). The mortality rate of calves and lambs is 20% (Gryseels, 1988 and Woubshet, 1985 respectively). The economic life span of sheep is assumed to be 6 years.

3.3 CONSUMPTION ACTIVITIES
To reflect a greater degree of reality regarding farmers’s concern towards household food security, self-sufficiency was imposed in the model. In this respect minimum consumption restrains, which have been included as separate activities, were made on tef, wheat, barley, horse bean, fieldpea activities, were made on tef, wheat, barley, horse bean, fieldpea, milk, butter, and cheese and fuel dung.
3.4 SALES AND PURCHASE ACTIVITIES

Surplus commodities produced above those needed for consumption by the household are sold after meeting those requirements. Surplus feed, livestock in the follower hards over and above that required for replacement and old culled animals are also sold. Besides food grains, purchase of concentrate, hay, fuel dung, butter, cheese, and hiring of casual labor are also included as purchase activities.

3.5 RESOURCE SUPPLIES OR CONSTRAINTS

The constraints reflect the competition between activities for limited farm resources and the interrelationships between activities. The farm fixed resources, currently available, on the farm were used to derive the restrictions for each plan. These resources that were specified as the basic constraints of the farm include land, labor, and cash.

3.5.1 Crop and Pasture Land

On the average the sampled households have 4.9 ha of land allocated to them by the peasant association. Of this total holding, crop land comprises 69% and the rest in pasture land. In addition, the average household cultivates share-cropped land measuring 0.5 ha. It is also assumed that each household has access to communal grazing land. This land is assumed to produce total roughage amounting to 1500 kg dry matter in the form of grazing feed.
Based on the agroclimate, soil fertility and type of crops grown, farmers of the area classify their crop land into three basic classes, namely kossi, dimile and yemeda. Kossi land is usually found close to the homestead. It is well drained and manure is applied and thus it is comparatively fertile. Horse bean, fieldpea, wheat, and tef are grown on this land. Dimile land, which is less productive than kossi, has occasional waterlogging problems. On this land wheat, tef, barley, horse bean, and fieldpea are grown. Yemeda land is poorly drained and seasonally flooded bottomland. Wheat, tef, and barley are grown on yemeda land.

Based on the baseline survey, the maximum area that can be allotted to a particular crop type has been specified in the model. This restriction has been imposed in recognition that, despite that relative profitability, farmers grow a mix of crops to minimize risk and meet their minimum consumption requirements. The maximum area for a particular crop is based on the sum of its average share in the cropping pattern and rotation of the surveyed farmers under all land classes (Table 1).

Table 1. Average cropping pattern by land class (%)

<table>
<thead>
<tr>
<th>Land type</th>
<th>Wheat</th>
<th>Tef</th>
<th>Barley</th>
<th>Fieldpea</th>
<th>Horse bean</th>
<th>Total area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kossi</td>
<td>25</td>
<td>25</td>
<td>-</td>
<td>25</td>
<td>25</td>
<td>0.34</td>
</tr>
<tr>
<td>Dimile</td>
<td>23</td>
<td>22</td>
<td>17</td>
<td>16</td>
<td>22</td>
<td>1.70</td>
</tr>
<tr>
<td>Yemeda</td>
<td>34</td>
<td>33</td>
<td>33</td>
<td>-</td>
<td>-</td>
<td>1.36</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.40</td>
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</tbody>
</table>
3.5.2 Human Labor and Oxen Power

The farm family is the main source of labor for farming. The potential family labor available depends on the size and composition of the household. It is clear that males and females of different age groups do not have the same work capacity. The labor of household members was converted into adult male equivalents by attaching weights for each age and sex group. The average family size of 7.9 thus translates into 2.7 adult-equivalent active labor force, each working 6 hours per day.

Almost all of the farming population of the area are Christian Orthodox Church followers. Sunday and religious holidays are strictly observed. Consequently cropping activities such as plowing, weeding, harvesting and threshing are not allowed during religious holidays. This limits the farmers for the activities of crop production, including harvesting of hay, the total average working days available are 222 in any crop season.

The labor requirements for the cropping and livestock activities were determined so as to cope with the timeliness of some of the critical farm operations such as land preparation and planting, weeding, harvesting and threshing. Thus, in order to capture the labor constraints, the year is subdivided into four labor periods, starting in March and ending in February.
Availability of oxen hour is determined by the number of oxen employed each day, number of hours worked per day, and the number of working days in the period. In the Ethiopian highlands oxen are commonly engaged for 4 to 9 hours per day, depending on time available for soil preparation (Gryseels and Goe, 1983). In the 1994/95 crop season in the dairy-only group, oxen were worked for about 4.5 hours per day. Thus, the observed 4.5 hours per day has been considered in the model.

3.5.3 Working Capital
The level of available working capital has been determined by adding farm and off-farm income, net of expenses required to purchase food items (other than food grains) clothing, land use taxes, hired labor, and payments for various social obligations. Based on the formal survey, the level of available working capital in the T-D model is ETB 3000 while both the D-O and D-D models have a working capital of ETB 5000.

3.5.4 Minimum Food Requirements
In the Ethiopian highlands farmers are subsistence producers. Most of the farm output is consumed and only the remaining amount from consumption is sold. Hence, household subsistence food requirements for crops, milk, butter and cheese are specified in the model. The subsistence food requirement for the household has been determined based on Gryseels and Anderson (1983). The requirement is 200 kg of cereals, 50 kg of pulses, and 500 kg of fuel dung per adult-equivalent per year. Household preferences for
each crop type have been determined according to production pattern. That is, the quantity of each crop grain type demanded is calculated by multiplying its percentage share in the total production of cereals/pulses by the amount of total cereal/pulse grain required. The subsistence requirement of households for milk, butter and cheese are results of the 1993 and 1994 survey data.

3.5.5 Feed Demand and Supply

The feed requirements for the livestock activities are represented in the model by feed transfer activities. The requirements can be fulfilled from purchase of hay and concentrates, if there is any shortage of farm-produced feed.

The feed requirements of cattle have been calculated based on the Cornell Net Carbohydrate and Protein System (CNCPS) model (Fox et al., 1990). The CNCPS model is used as a management aid for adjusting nutritive requirements and utilization over wide variations in cattle, feed, management, and environmental conditions. The procedure applied by Kearl (1982) was adopted for sheep.

The quality of feeds is specified in terms of metabolizable energy. Natural pasture hay, grazing pasture, straw, and oats-vetch are the feed sources that satisfy the feed requirements of the farm animals. Grazing pasture and hay competed for the same type of land but
the latter required labor for cutting and carrying. The practice of growing fodder crops was not common in the study area. Before the introduction of crossbred cows only one farmer was producing oats as a fodder crop. Since feed requirements of crossbred cows are greater than that of the local cows, much emphasis was put by the project to improving on-farm feed production. To evaluate this option, the oat-vetch production has been included as a new technology activity in the model with the objective of determining the exact level through the optimization process. The nutritive value of the traditional farm-produced roughage is often poor and is not adequate to meet the need for maintenance, work and milk of crossbred cows. Thus, the model assumes that crossbred cows fulfill their minimum metabolizable energy requirement under the constraint of their total dry mater intake capacity.

3.5.6 Number of Livestock

In order to be able to compare the effect of using crossbred cows as dual-purpose animals, rather than for milk only, the number of crossbred cows was fixed at two, in accordance with the requirements of the traditional plowing practice that involves a pair of animals.

4. RESULTS AND CONCLUSIONS

4.1 LAND USE PATTERN

Tef and wheat are the most important crops which together occupied about 44% of the total land and 60% of the arable land. In
all the optimized model, the area under different crops is the same or similar to the cropping pattern before the introduction of crossbred cows (Table 2). This suggests that farmers strive to maximize their income, although they are subject to the constraint of fulfilling household subsistence food requirements.

4.2 NUMBER OF LIVESTOCK

Of all the three farm models, the optimum farm plan of the D-O model consisted of the maximum number of livestock, which added up to about 12 tropical livestock units (TLU). The D-D plan gave only 70% of the D-O plan (2.9 TLU) (Table 3). Herd size varied between the D-O and D-D optimum farm plans, because of the suitability of crossbred cows for traction as well as for milk. As a result of the reduction in the herd number required to sustain the D-D farm, surplus marketable roughage that amounts to about ETB 934 is sold. On the contrary, the D-O farm plan required the purchase of roughage equivalent to ETB 475 to cover the deficit in supply of farm-produced feeds. The traditional model (T-O), which involved no crossbred cows, gave 8.6 TLU at the optimum.

4.3 FARM INCOME AND RESOURCE PRODUCTIVITY

The use of crossbred cows for milk and traction (D-D) shows only a small increase in gross margins over the farm plan where crossbred cows are used only for milk (D-O). As shown in Table 4, the farm income above variable cost or gross margins is ETB 13,843, 13,223 and 9,379 for the D-D, D-O an T-D farms respectively. The increment in the farm
income of the D-D farm over the D-O and T-D farms is 4.7% and 48% respectively.

Table 2. Cropping pattern under different base plans (ha)

<table>
<thead>
<tr>
<th>Crop type</th>
<th>T-D</th>
<th>D-O</th>
<th>D-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>0.94</td>
<td>0.94</td>
<td>0.91</td>
</tr>
<tr>
<td>Tef</td>
<td>0.91</td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>Barley</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
</tr>
<tr>
<td>Fieldpea</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>Horse bean</td>
<td>0.46</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>Oats-vetch</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shared Wheat</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Total</td>
<td>3.90</td>
<td>3.90</td>
<td>3.90</td>
</tr>
</tbody>
</table>

Table 3. Number of livestock included in the optimum plans

<table>
<thead>
<tr>
<th>Particulars</th>
<th>T-D</th>
<th>D-O</th>
<th>D-D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Head</td>
<td>TLU</td>
<td>Head</td>
</tr>
<tr>
<td>Crossbred Cows</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Cross heifers</td>
<td>-</td>
<td>-</td>
<td>0.25</td>
</tr>
<tr>
<td>Cross young Bulls</td>
<td>-</td>
<td>-</td>
<td>0.68</td>
</tr>
<tr>
<td>Local cows</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Local heifers</td>
<td>0.3</td>
<td>0.15</td>
<td>1</td>
</tr>
<tr>
<td>Culled ox</td>
<td>0.4</td>
<td>0.48</td>
<td>0.4</td>
</tr>
<tr>
<td>Local young Bulls</td>
<td>0.56</td>
<td>0.32</td>
<td>0.4</td>
</tr>
<tr>
<td>Sheep</td>
<td>4</td>
<td>0.35</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>8.62</td>
<td>4</td>
</tr>
</tbody>
</table>

After meeting subsistence requirements, the cash income obtained is ETB 10,543,9923, and 6077 for the D-D, D-O and T-D farms respectively. In the D-D farm plan, as a result of production above the subsistence level, cash income was raised by 6.2% and 73%
over the cash income achieved in the D-O and T-D farm plans respectively. The increase in household income and returns to fixed farm resources is mainly a result of more efficient use of the available feed resources.

The share of the contribution of crops and livestock to cash income varies among the farm plans. In the D-D, D-O, and T-D farm plans, the share of livestock in total cash income is 52%, 58.8% and 15.8% respectively and the rest is contributed by crops. The introduction of crossbred cows can thus yield a higher proportion of farm income than the T-D farm plan. This will help reduce the risks from crop production inherent in the farming systems of the highlands with only local cows.

The productivity of labor, gross margin per employed family hour, is ETB 4.9, ETB 4.2 and ETB 4.00 in the D-D, D-O and T-D farms respectively. In terms of the returns per available family hour, the gross margins were ETB 2.4, ETB 3.7 and ETB 3.9 for the T-D, D-O, and D-D farm plans respectively. As shown in Table 4, given the same level of available family hour in the D-D and D-O farms, the use of crossbred cows for traction in addition to milk does not significantly increase the household income and the returns to labor for the average farm household of the sample farmers.
4.4 ANALYSIS OF PRODUCTION CONSTRAINTS

Agricultural operations follow one after the other and require different combinations of resources at different times. One activity can compete with another for the use of a given resource. Table 5 indicates that both arable and pasture land were the most important constraints to higher income under all the specified farm plans.

In order to capture seasonality of labor use, four periods were identified: Period One refers to season of plowing and planting, Period Two weeding, Period Three harvesting, and Period Four threshing.

In all the three farm plans, Period Three (family labor) was the limiting resource with a shadow value (or marginal value product) of ETB 1.00/hr (Table 5).

<table>
<thead>
<tr>
<th>Table 4. Farm income and returns to resources (ETB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Particulars</strong></td>
</tr>
<tr>
<td>1. Gross margin</td>
</tr>
<tr>
<td>2. Subsistence</td>
</tr>
<tr>
<td>3. Cash income</td>
</tr>
<tr>
<td>Crops (% of total)</td>
</tr>
<tr>
<td>Livestock (% of total)</td>
</tr>
<tr>
<td>Cross animals (% of total)</td>
</tr>
<tr>
<td>4. Gross margin per</td>
</tr>
<tr>
<td>Man-equivalent</td>
</tr>
<tr>
<td>Employed family hour</td>
</tr>
<tr>
<td>Available family hour</td>
</tr>
<tr>
<td>Hectare</td>
</tr>
</tbody>
</table>
Animal power is used for plowing and planting (Period One), harvesting (Period Three - mainly for transporting to threshing sites) and threshing (Period Four). All the farm plans have a zero shadow price of animal power in all the periods, except Period One on the D-D farm, which had a shadow price of ETB 0.6/pair of oxen hour.

This is because after making use of all the available animal hours from a pair of oxen, the model starts to use additional working cow hours with a specified additional amount of feed demand per hour of work. In other words, if there was an option of oxen hiring with a cost below the indicated shadow price, then cows would not be used for work. As the market rental price of a pair of oxen is ETB 78.
14 per six-hour day or ETB 2.3 per hour, the use of crossbred cows for draft power is a cost-effective option.

4.5. SENSITIVITY ANALYSIS

Sensitivity analysis was done on the base plans of the two dairy farm models (D-D and D-O) to assess and compare their effects on farm income. Two scenarios, i.e., when there is a decrease in the size of crop land and an increase in the price of concentrates, were considered.

4.5.1. Reduced Size Of Crop Land

In the D-D farm plan, the decrease in the area of crop land by one hectare reduced gross margins by 15% compared to the value achieved in the base plan (Table 6). As depicted in Table 8, the optimum farm plan excluded the use of local oxen and local cattle keeping required to support the pair of oxen. The farm rather used a pair of crossbred cows to meet its total draft power requirements and milk production. The increased work intensity of the cows (compare Tables 7 and 8) was made possible by feeding them more concentrates. In addition to the shared crop land that is allocated for wheat, only 2.3 ha of the arable land (95.8%) is used, leaving the rest unused (Table 9).

In the D-O farm plan, a one hectare reduction resulted in a decrease in the net farm income 21%. This is high compared to the D-D farm plan, suggesting that the use of crossbred cows for
traction and milk is more viable under a relatively scarce holding of crop lands.

Table 6. Gross margins after a change in crop land and price of concentrates

<table>
<thead>
<tr>
<th>Price of concentrates (ETB)</th>
<th>D-O</th>
<th>D-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% increase in the price of concentrates</td>
<td>13,153</td>
<td>13,646</td>
</tr>
<tr>
<td>Decrease crop land area by 1 ha</td>
<td>11,138</td>
<td>120,37</td>
</tr>
</tbody>
</table>

Table 7. Level of some selected activities included under different base plans

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unit</th>
<th>T-D</th>
<th>D-O</th>
<th>D-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross cow keeping</td>
<td>No.</td>
<td>-</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Local cow keeping</td>
<td>No.</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Local ox keeping</td>
<td>pair</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Roughage purchase</td>
<td>kg</td>
<td>-</td>
<td>1900</td>
<td>-</td>
</tr>
<tr>
<td>Roughage sale</td>
<td>kg</td>
<td>3590</td>
<td>-</td>
<td>3734</td>
</tr>
<tr>
<td>Concentrate purchase</td>
<td>kg</td>
<td>-</td>
<td>530</td>
<td>1170</td>
</tr>
<tr>
<td>Hours worked by cows</td>
<td>No.</td>
<td>-</td>
<td>530</td>
<td>1170</td>
</tr>
<tr>
<td>Hours worked by oxen</td>
<td>No.</td>
<td>850</td>
<td>850</td>
<td>601</td>
</tr>
</tbody>
</table>

4.5.2 Increased Price Of Concentrates

When the price of concentrates increased by 50%, a small reduction on the net cash income of the farms occurred, which is 1.9% in the case of the D-D and 0.7% in the case of the D-O. However, the price increment forced both the D-D and D-O farms to quit the purchase of concentrate.
Since in both the D-D and the D-O farms, the feed requirement of crossbred cows cannot be met by feeding them traditional roughage only, oats-vetch production (0.48 ha for D-O and 0.22 ha for D-O) was included in the cropping pattern of these farms.

Table 8. Level of some selected activities included under plans different from the base Plans

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unit</th>
<th>Crop area decreased by 1 ha</th>
<th>Price of concentrate increased by 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>D-O</td>
<td>D-D</td>
</tr>
<tr>
<td>Cross cow keeping</td>
<td>No.</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Local cow keep</td>
<td>No.</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Local ox keeping Pair</td>
<td></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Roughage purchase</td>
<td>kg</td>
<td>3594</td>
<td>0</td>
</tr>
<tr>
<td>Roughage sale</td>
<td>kg</td>
<td>-</td>
<td>7885</td>
</tr>
<tr>
<td>Concentrate purchase</td>
<td>kg</td>
<td>530</td>
<td>2165</td>
</tr>
<tr>
<td>Hours worked by cows</td>
<td>No.</td>
<td>-</td>
<td>497</td>
</tr>
<tr>
<td>Hours worked by oxen</td>
<td>No.</td>
<td>620</td>
<td>0</td>
</tr>
</tbody>
</table>
Mengistu and Belay: Use of crossbred cows for milk and traction in the Ethiopian highlands: A whole-farm evaluation

Table 9. Cropping pattern under plans different from base plans (ha)

<table>
<thead>
<tr>
<th>Crop type</th>
<th>D-O</th>
<th>D-D</th>
<th>D-O</th>
<th>D-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>0.66</td>
<td>0.66</td>
<td>0.86</td>
<td>0.78</td>
</tr>
<tr>
<td>Tef</td>
<td>0.64</td>
<td>0.64</td>
<td>0.84</td>
<td>0.75</td>
</tr>
<tr>
<td>Barley</td>
<td>0.52</td>
<td>0.42</td>
<td>0.67</td>
<td>0.58</td>
</tr>
<tr>
<td>Fieldpea</td>
<td>0.25</td>
<td>0.25</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>Horse bean</td>
<td>0.33</td>
<td>0.33</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>Oats-vetch</td>
<td>0</td>
<td>0</td>
<td>0.22</td>
<td>0.48</td>
</tr>
<tr>
<td>Share wheat</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Total</td>
<td>2.90</td>
<td>2.80</td>
<td>3.90</td>
<td>3.90</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS AND POLICY IMPLICATION

Based on the assessment of the results, the following major points have been drawn for further attention.

- When crossbred cows were used both for milk and traction by farmers, the number of local herd were reduced by half. Thus, the use of crossbred cows for traction can enable more sustainable development through deceased stock pressure on land. However, the benefits of reduced herd size are mainly long term and related to the sustainability of the system. Project farmers are being observed to use the additional income from dairy to increase their animal herds leading to
further difficulty in adequately feeding all their stock. Extension efforts need to be intensified to make farmers more aware of the potential benefits of reducing their herds by keeping fewer, more productive animals.

- An assessment of the sensitivity analysis results show that the use of crossbred cows for milk and traction is likely to be a more attractive option for small and medium land holding farmers than land-rich farmers. This is because as land size is reduced feed resources become more limiting and the need arises to keep a smaller number of animals to support the farm system.

- When the price of concentrates is increased by 50%, oats-vetch replace concentrates. This results in a decline in gross margins of only 2%, showing that on-farm production of oats-vetch could replace concentrates. This would depend, however, on sufficient quantities of oats-vetch seed being multiplied and made available to farmers. At present, concentrates are available throughout the Ethiopian highlands, but not seeds of oat-vetch. As in Kenya, it is reasonable to expect that on-farm forage production could become an important part of the measure aimed at encouraging dairy development. Appropriate policies and incentives are thus required to encourage seed multiplication and distribution.
The following points could influence the adoption of cows for milk and traction.

A. Because cultivation must be done during a limited period each year, substitution of oxen by working cows may be hindered by the coincidence of work period with critical stages in the reproduction cycle. Planned seasonal breeding is needed to avoid the coincidence of calving with the cultivation season.

B. The effect of social factors on the acceptance of the technology will depend on the strength of extension support. Careful anthropological monitoring of the adoption process over time need to be carried out to identify and overcome social constraints.

C. Services such as credit, veterinary, breeding and marketing, and government policies are crucial factors that could affect the acceptance of the technology. These factors also require careful study and monitoring.

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Kearl, L. C. 1982. Nutrient requirements of ruminants in developing countries. International Feedstuffs Institute, Utah State University, Logan, Utah, USA.


AN EX-ANTE ANALYSIS OF INTER-CROPPING FOOD CROPS WITH FORAGE LEGUMES IN MIXED CROP-LIVESTOCK SYSTEMS IN THE ETHIOPIAN HIGHLANDS

Menale Kassie*, Mohammed Jabbar**, Belay Kassa*** and Mohammed Saleem**
* Ministry of Agriculture, Region 3
** Alemaya University of Agriculture
*** International Livestock Research Institute

ABSTRACT

Linear Programming has been used to determine the economic impacts of food crop-forage legumes integration given the resource constraints and possible changes in prices of output and inputs. To assess the potential economic benefits of forage legumes-cereal crops integration in the highlands, a representative farm for Debre Zeit area was analysed. Model results demonstrate that the introduction of forage legumes with cereals is profitable. The model results indicate an optimal cropping pattern of growing teff, maize, wheat, pulses, sorghum, and barley in descending order of importance in terms of area allocation. This is different from the existing cropping pattern of teff, wheat, pulses, sorghum, and barley in the descending order. Improved technologies have the potential to remain profitable even when there is a decrease in price of outputs. The overall implication of adopting the cropping pattern obtained from the improved models solution is that resources allocated to the production of current crops have to be reallocated to the production of the new crops. The major crops that the farmers in Debre Zeit area are used to growing are teff and wheat. Thus, adopting the new cropping pattern will entail the education of the farmers through extension services in the production of maize. Introduction of forage legumes makes better use of resources and increases farm income and returns from resources considerable.

1. INTRODUCTION

1.1. Background and Justification
Like in most highland areas of tropical Africa, mixed farming predominates in the Ethiopian highlands. Apart from provision of meat, milk and draught power, animals lend an element of stability to the production system by helping to buffer the fluctuation in crop yield or income from bad weather. However, inadequate nutrition in the dry season has been identified as the main constraint to production, particularly in the highland areas, which constitute 32, 75, 88, 95, 91 and 40% of the country’s grazing land, livestock population, human population, cultivated land, forest land and massland, respectively (FAO, 1986; Bekele, 1991). As a result of increasing rural population and overstocking, the grazing land, the main feed source, is declining by 0.11% per year (FAO, 1961-1992). Nutrient availabilities from communal grazing and crop residues are of poor quality and insufficient, particularly in the dry season, far less than what is required for animals maintenance (Whalen, 1984; Getachew and Hailu, 1992). Cattle may lose up to 15-20% of their body weight during the dry season due to feed shortage (Octhere, 1986). Consequently livestock productivity is low for final outputs such as milk and meat. Although 12.5% of Africa’s 577 million cattle, sheep, and goats are found in Ethiopia, the country produces only 8.2% and 5.1% of Africa’s total meat and milk, respectively (FAO, 1984).
Economics of Integrated Crop and Livestock Systems in Ethiopia

The crop sub-sector is characterized by poor soil fertility, encroachment into grazing land and continuous cropping which leads to soil erosion. Soil erosion is a primary problem for farmers throughout the tropical world and it has become an increasing constraint to farm production as population pressure has brought more marginal slopping land into cropping systems (Humphreys, 1994). However, even where soil erosion in not a great problem, there is a continual loss of nutrients from agricultural systems due to removal in crops, leaching, and in the case of nitrogen (N) particularly, gaseous losses. Soil loss in cropped and pasture land averages 42 and 5 tons per hectare per year respectively in Ethiopia (Hurni, 1986). This phenomenon is very high in highland areas of Ethiopia, where two hundred million tons of soil are washed away annually (FAO, 1986). The total loss of crop output as a result of soil erosion in the country was 8,760 metric tons in 1985 and this is expected to increase to 331,900 metric tons by the year 2010 (Sutcliffe, 1993).

The predominant nutrient deficiency is N, over which farmers have greatest control through the farming practice they adopt and which is most influential in determining and sustaining crop production (Humphreys, 1994). From an estimate of soil nutrient losses, a net removal of 41 kg N per hectare of agricultural land between 1982 and 1984 was observed which was projected to increase to 47 kg N per hectare per year by the year 2000 in Ethiopia (Stoorvogel et al,
However, the overall average application of fertilizer by the farmers in the country is below 20 kg N per hectare (The Ethiopian Herald, 1997) and that of N-fertilizer is below 1 kg N per Hectare (FAO, 1990, cited in Peoples et al, 1995). Soil nutrient removal exceeds soil nutrient formation. Thus, decreasing crop yields with time is inevitable unless interventions in the farming systems are designed.

These problems, of course, can be alleviated by increasing the use of fertilizer and commercial feeds. However, the use of nitrogen and other fertilizers and commercial feeds depend a great deal on economic consideration such as farm income, the availability of credit, current prices of grain and livestock products, and availability of foreign exchange at national level. Moreover, the use of purchased inputs in general requires an effective infrastructure for production and timely distribution, and this is currently a crucial problem of Ethiopia. As a result, commercial feeds, concentrates and inorganic fertilizers have not been widely used to supplement poor quality feed and replace depleted soil nutrients. The use of purchased feed and fertilizer is unlikely to increase rapidly because most highland farmers are resource-poor, lacking adequate cash to purchase these inputs (Saka and Haque, 1992). In addition, since fertilizers are not from organic sources, they fail to replenish soil organic matter and fertilizers impose certain costs on the environment and human health (Sarrantonio,
Besides, the efficiency of utilization of fertilizer N by plants is poor, seldom exceeding 50% (Peoples et al, 1995).

As an alternative approach, integration of forage legumes with cereals that can be easily adopted by the farmers has been tested. The introduction of forage legumes in cereal based cropping systems is a promising strategy for increasing crop and livestock productivity. Forage legumes enhance soil fertility, improve yields and nutritive values of crop residues, sustain feed production during the dry seasons, suppress weeds, combat erosion (Tothill, 1986; Nnadi and Haque, 1988; Aina et al, 1977 (cited in Lal, 1984); Humphreys, 1994; Thung and Cock, 1979). In terms of technical feasibility of this approach, results in Ethiopia show that forage legumes such as lablab, clover and vetch are capable of leaving 30 to 60 kg N per hectare in the soil to be used by the next crop (Nnadi and Haque, 1988). This figure is very significant compared to the nation’s average N-fertilizer application of below 1 kg per hectare. The residual N of several legumes in Ethiopia increased the yield of maize, sorghum and wheat between 112-190, 138-174 and 105-124 percent, respectively compared to growing them after oat (Nnadi and Haque, 1988). Oat grain yields of 1.7 t per ha was obtained after vetch, compared to oat grain yields of 2.2 and 3.0 t per ha at 30 and 60 kg N per ha application, respectively. Also, the same authors reported a significant increase in wheat where dry matter (3.8 t per ha) and grain yields (2.6 t per ha) after forage legumes (trifolium and vetch) in relation to wheat
Menale Kassie et al. An Ex-Ante Analysis of Inter-Cropping Food Crops With Forage Legumes in Mixed Crop-Livestock Systems in the Ethiopian Highlands

grown on fallow land (2.7 t per ha) and after oat (2.3 t per ha). Yields increases by crops following legumes are often equivalent to application of between 30 and 80 kg N per ha (Peoples and Craswell, 1992).

Average fodder yields of 11.8, 8.6 and 6.0 tons per hectare of maize-lablab, sorghum-lablab and wheat clover, respectively is reported compared to 2.0, 2.0 and 1.8 tons of sole maize, sorghum and wheat crop, respectively without fertilizer for maize and sorghum (Abate et al, 1992; Astatke et al, 1995; Bekele, 1991; Denis, 1996; Umunna et al, 1995; FAO, 1984). Straw and stovers alone had an average crude protein content of 3.2% of dry matter whereas forage legumes crude protein content on average varies between 14-24% of dry matter (Annido et al, 1994; D’Mello and Devendra, 1995; Mannetje et al, 1980).

In general, nitrogen fixing plants offer economically attractive and ecologically sound means of reducing external inputs and improving the quality and quantity of internal resources.

Although much work has been done in Ethiopia on the technical feasibility of integrating annual forage legumes with cereals, no investigation has been done on the economic feasibility. Assessment of profitability, resource requirements and constraints likely help to develop strategies for diffusion of the technology.
The objectives of the research reported in this paper were:

- to closely explore the economic benefits of forage legumes-food crops integration
- to assess the impacts of forage legumes-cereal crops integration on farm resources productivity.

2. THE STUDY AREA AND ITS FARMING SYSTEMS

The study was conducted under a typical farm situation in Ada district in the highland of Ethiopia. Average rainfall of the study area, located at an altitude of 1850-2000 meter above sea level, is 860 mm, of which 70% occurs in the main rainy season between June and September (Gryseels and Anderson, 1983; Gryseels and Boodt, 1986). Ada is located 50 km south of Addis Ababa.

Average farm size is 1.75 hectares and about 80% of all farm produce is for household consumption (Gryseels and Boodt, 1986). Rural population in Ada district increased from 115,000 to 144,000 or by 25% during 1979-1990 (De Leeuw et al, 1992). The area is intensively cultivated and virtually no arable land is left for fallow and no private grazing land is available. Average farm household size is 6.3 or 5.07 adult equivalents (AE) and the average available agricultural workers in person equivalents (ME) is 2.64.
The main crops grown in the area are teff, wheat, maize, barley, sorghum, hoarse beans, chick peas, and rough peas. These are grown as mon-crops. Teff is the principal cereal crop.

Livestock are important sources of intermediate products such as traction, transport, fuel and security. Pasture and straw produced from food crops are the main sources of feed for livestock production (Table 1).

**Table 1. Estimated Feed Availabilities in Debre Zeit Area in 1979 and 1990**

<table>
<thead>
<tr>
<th>Feed sources</th>
<th>1979</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area ('000 ha)</td>
<td>DM ('000 ton)</td>
</tr>
<tr>
<td>Crop residue</td>
<td>42.5</td>
<td>59.5</td>
</tr>
<tr>
<td>Crop stubble</td>
<td>42.5</td>
<td>12.7</td>
</tr>
<tr>
<td>Grazing land and</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Fallow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>64.5</td>
<td>92.2 (645.4)</td>
</tr>
</tbody>
</table>

Source: Adapted from Bekele (1991)

( ) = Indicate Metabolizable energy in terms of MJ

Natural pasture is the main source of feed for most of the year, because of population pressure grazing land is limited to about 0.45 hectare per household (Bekele, 1991). Aftermath grazing and crop residues are also the main source of feed.

Cereal and pulse residues are mostly stacked and fed to livestock during the dry season when the quantity and quality of available fodder from natural pasture declines drastically. As depicted in
table 1, feed supply from 1979 to 1990 increased by 13\% in terms of dry matter (KG) and metabolizable energy (MJ), while it decreased by 11\% in terms of digestible crude protein. During this period, livestock numbers declined from 78,640 to 67,728 TLUs (Bekele, 1991). Although feed supply increased, the total quantity of feed available in 1990 from all sources (104,500 tons dry matter) was insufficient to satisfy even the maintenance requirements (112,000 tons dry matter) of 67,728 TLU in terms of MJ of metabolizable energy (Bekele, 1991). This in part explains the low productivity for all classes of animals. Thus, shortage of grazing land and inadequate feed supply are the major problems facing the livestock producers in the area. Most of the crop residues are used in the traditional way without any treatment. The integration of food crops with fodder crops in the area is non-existent due to inadequate research and extension services.

3. METHODOLOGY AND DATA

A linear programming model was constructed to represent the resource endowments and production activities of smallholders from Debre Zeit area in Ethiopian highlands. Linear programming (LP) is the most widely used technique for ex-ante evaluation of technologies before costly testing on farmers field (Menz and Knispheer, 1981; Knispheer et al, 1983). Other programming methods such as integer, risk, and quadratic programming can also be used to evaluate small farm problems. But because of limited
availability of data, adequacy of a linear model to capture interactions between activities on farm, and ease of implementation, a linear programming model was chosen rather than the above mentioned programming methods. An increase in income can also be considered as a major incentive to adopt a new technology (Ruthenberg, 1985) and linear programming is an appropriate tool for maximization of income. Risks also pay a major role in the adoption of a technology. Although direct incorporation of risk is prevented by data limitations, maximizing cash income under the condition of satisfying the household subsistence requirements from crops grown, a major means of risk management, was accounted for. To take into account other risks that will come through different sources, such as market, weather, price change etc, sensitivity analyses were applied to test the stability of the model results.

Farm level data with respect to impacts of forage legumes and cereal inter-cropping system were not available. Therefore, an ex-ante approach was considered to assess impacts of integration. Two farm plans have been developed for analysis with LP:

Plan I. This plan approximated the existing situation so that it could be used as a basis for comparison with improved plans that represented changes in the system.

Plan II. This plan maximized farm cash income with existing resources and practices, except that forage legumes inter-
cropped with cereals were introduced to provide improved feed for existing livestock.

The linear programming model for each of the plan has the following general form in which aggregate cash income from various activities is maximized subject to various constraints. The objective function can be stated as:

\[
\text{Maximize } Z = \sum_{j=1}^{N} C_j X_j
\]

subject to:

\[
\text{Maximize } Z = \sum_{j=1}^{M} a_{ij} X_j R_j \quad (i=1,2,3,...,M)
\]

and \( R_j \geq 0, a_{ij} \geq 0, X_j \geq 0 \) (\( j = 1,2,3,...,N \))

Where:

- \( Z \) = aggregate cash income, that is gross return less variable costs and consumption Value,
- \( C_j \) = cash income for \( j \)-th activity over variable cost and consumption value, and \( N \) the number of possible activities,
- \( X_j \) = level of \( j \)-th activity,
- \( R_j \) = The quantity available of the \( I \)-th resources,
- \( a_{ij} \) = \( i \)-th input per unit of the \( j \)-th activity or technical coefficient, and \( M \) the number of resources
The variables used in the model are described below. The important categories of activities and constraints that have been identified and used in the model are briefly presented below.

### 3.1. Crop and Livestock Activities

The cropping systems include both sole and inter-crop activities. The activities incur variable costs in the objective function. These variable costs include the imputed cost for seed and fertilizer cost for the production of one unit. The following crop activities are included in the model: improved wheat inter-cropped with trifolium (clover), maize and sorghum inter-cropped with lablab wheat, maize, sorghum, barley, chick pea, rough pea and horse beans. Inter-cropped yields were adjusted downward by 10% in order to take into account extra care taken by researchers and small plot size and to take into account local conditions (Ndengu, 1993). Seed for current production is usually taken from previous harvests.

Farmers in the study area maintain livestock for draft power and milk. Livestock production activities require variable costs such as veterinary services, salt, and breeding in the case of sheep. It is assumed that a representative farm has one cow, one sheep, one donkey and a pair of oxen. Ten years economic life span of local Zebu cow and oxen (Gryseels, 1988), 5 year economic life span of sheep respectively (Nordblom et al, 1992; Panin and Broken, 1993); 20 and 10% mortality rate for calves and lambs both for
traditional and improved (with forage legumes feed) respectively (Nordblom et al, 1992; Panin and Broken, 1993) and livestock dry matter intake of 2.2% of their body weight (Nicholson et al, 1994) are considered.

The introduction of forage legumes with cereals results in higher fodder production that may create in the long run changes in factor allocation. However, it is assumed that in the short run farmers keep both livestock numbers and herd composition constant.

3.2. Sales and Purchases Activities
Marketable surpluses of grain, straw, butter, manure, culled and surplus animals after replacement (after subsistence requirements are met) are assumed to be sold. The prices used for crops are averages of 18 months from January 1995-June-1996 in Debre Zeit area.

Farmers buy food items and straw to overcome bottlenecks whenever there is shortage. Purchase prices for grains were assigned 5 Birr per 100 kg higher than selling prices to reflect transaction and market costs (Gordon et al, 1995; Webber, 1996).

3.3. Consumption Activity
Small farmers’ first objective of production is to meet their consumption requirements. When requirements for subsistence are
met, they often generate income by selling the available surplus. Thus, consumption is included as a separate activity.

3.4. Resource Supplies or Constraints
The amount of scarce farm resources and other constraints, such as subsistence food requirements, constrained the farm activities. The resources available currently on the farm are used to derive the restrictions for each plan. The major constraints specified in the model includes land, human labour, working capital, and animal traction.

3.4.1. Crop and Pasture Land (ha)
The land area of the farm may contain different plots with different fertility and elevation or may also be suitable for different crops. However, it is assumed that the available land is equally suitable for all the crop activities in the model so that each crop in the model has an equal chance of competing for available land on the farm. The short rains occurring in the Debre Zeit area is unreliable (Gryseels and Anderson, 1983; Gryseels and Boodt, 1986). Thus, land constraint for each activity is based on a period of one year. No arable land is left for fallow and there is no own pasture land. The total arable land is constrained to be less than or equal to 1.75 ha based on the mean farm size in the area.

Based on the assumption that each household has equal access to a proportion of the available communal pastureland, feed from
communal grazing land is used. Farmers in Debre Zeit area have access to about 0.45 ha per household (Bekele, 1991) giving 4500 kg dry matter production per ha (Panin and Broken, 1993). However, the available consumable forage produced annually from communal pasture is adjusted downward by 50% because of cattle selectivity, trampling, overstaking rate, wildlife, fire, etc (Houerou and Hoste, 1977). The total area of pastureland used for grazing should not exceed the total area of pastureland available to the farmer.

3.4.2. Human Labour (person-hour) and Ox power (Pair hours)

The critical labour periods on the basis of important operations are categorized into six periods. Six labour periods of two months each were identified. The major labour input required by livestock is for herding, which is undertaken by children whose opportunity cost is assumed to be zero in the cropping activity (Getachew et al, 1993; Bezabih, 1991; Webber, 1996). Farmers in the study area on average work six hours per day.

Threshing is done by oxen as well as by other livestock, plus using neighbour’s livestock. The task is performed during slack periods when oxen do nothing but graze. For this reason threshing was excluded from oxen hours demand derivation. Thus, oxen labour was delineated into three periods.
3.4.3. Working Capital

Working capital to meet operating expenses is one of the most important constraints on small farms (Sisay, 1983; Getachew et al, 1983). The estimated cash expenses required in the production period were taken as equivalent to available working capital. The sum of cash expenses required for each activity was less than or equal to the available cash.

3.4.4. Minimum Subsistence Consumption

This constraint was designed to more or less reproduce the current production and consumption patterns. The household had 5.07 adult equivalents. Based on Gryseels and Anderson (1983), 200 kg of cereals 50 kg of pulses, 30 kg milk, and 500 kg of dung for fuel were assumed as average annual subsistence requirements per adult equivalent. It was assumed that families consumed the produced crops to meet their subsistence requirements in the same ratio as the average cropping pattern and amount of production. It was also assumed that in the short run, the amount of food required for home consumption would not change as a result of introduction of forage legumes with cereals. The total amount of cereals and pulses required from each crop was less than or equal to the amount of produce of each crop or obtained from other sources.

3.4.5. Feed Demand and Supply

Livestock feed was provided by the production of straw as by-product from crop production, aftermath grazing, and from natural
pastures. In the case of inter-cropping of cereals and forage legumes, additional feed was available from forage legumes. It was assumed that the feed from stubble and weeds covered 40% of the total feed requirement of the livestock in terms of dry matter (Webber, 1996). The feed requirements of livestock were for crude protein (CP), metabolize energy (ME) and dry matter (DM) and they were required for maintenance, pregnancy, milk production and traction. The feed demands of total livestock per household were calculated as a function of total number of livestock, their classes, functions and weights (Mukassa, 1981; Kearl, 1982; Gryseels and Boodt, 1986; MAFF, 1984; Nicholson et al, 1994; Hailemariam, 1995).

Feed requirement for sheep followers was calculated at 32% of the ewe feed requirement as estimated by Nordblom et al, (1992). The total feed required by each type of livestock after deducting the feed from aftermath grazing and weeds is less than or equal to the amount produced on the farm or purchased.

3.4.6. Crop, Nitrogen, Milk, and Manure Output Balances
These constraints were included in order to ensure that grain and nitrogen yield from crop production, and milk and manure from livestock were transferred to the subsistence balance, sale and purchase equation. Also, straw and pasture yield from crop and
pasture production were transferred to the livestock activities, sale and purchase equations.

One of the functions of forage legumes was to improve soil fertility. An increase in the soil nutrient status in a given year may be considered as an output of the system, in addition to the crop, whereas a decrease in soil nutrient may be considered as a cost (Farrell and Capalbo, 1986, cited in Jabbar et al., 1994). The nutrient uptake from inter-cropped systems was not significantly different from sole crop, particularly nitrogen, although there was initially high uptake in the inter-cropped systems (Mason et al., 1986, cited in Humphreys, 1994). Forage legumes (Lablab, Trifolium and, and vetch) inter-cropped with cereals produce 30-60 kg N per hectare in their root systems (Nnadi and Haque, 1988). In this study production of 45 kg N per hectare was assumed as an output of the inter-crop and valued at the market prices of chemical fertilizer. The data are rough approximations, because yields differ from year to year in the study area, between research station and farm condition. The production of dung from livestock was based on Barnard and Kristoferson (1985), Gryseels (1988) and Omiti (1995).

3.4.7. Model Scenarios
The above plans were developed based on fixed input-output coefficients, but this might not be the case in the real world. So
sensitivity of the results were tested to account for the following changes.

1. Decrease price of output by 30%
2. Decrease output price of wheat-clover, maize and sorghum lablab in the improved plan by 50%.

4. RESULTS AND CONCLUSION

4.1. Land Use Patterns
There is significant change in land use pattern after the introduction of forage legumes compared to the base plan. Land devoted to maize has markedly increased due to the combined effects of its higher quality and quantity of straw production, higher grain yield per hectare and because it demands no cash working capital. The area allocated for other crops is restricted to satisfy subsistence requirements (Table 2).

4.2. Resource Productivities and MVPs of Resources
Integrating forage legumes with cereals increases the average returns to farm resources significantly compared to Base Plan (Table 3). The LP methodology provides useful information about the marginal value productivities (MVPs) of resources available to farm households. The MVPs in the model solution give an indication of the importance of different limiting resources, and hence of priorities for policy interventions. With the introduction of forage legumes, the marginal productivities of human labour
and ox traction are zero, because neither of these resources are fully used for production under the existing or improved technologies. On the other hand, the shadow price of land is positive as expected, because the overall productivity and profitability have increased.

Given the land scarcity and the increasing rural population, intercropping of forage legumes with cereals will increase the value of land (and therefore land rental rates where rental is allowed or practiced). The marginal value productivity of pastureland decreases in the improved plan in relation to the base plan. This is a result of an increase in feed dry matter availability from intercropping. Higher MVP in base plan indicates that communal grazing pasture is an important feed source, both in quality and quantity (Table 4). Increased feed dry matter available under intercropping may reduce to some extent the problem of overgrazing and the associated erosion and complication of arable land.
Table 2. Land Use Pattern for Farm Plans (ha)

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Base plan</th>
<th>Plan II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop land</td>
<td>1.75</td>
<td>1.75</td>
</tr>
<tr>
<td>Pasture land</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Teff</td>
<td>0.96</td>
<td>0.66</td>
</tr>
<tr>
<td>Sole wheat</td>
<td>0.43</td>
<td>0.00</td>
</tr>
<tr>
<td>Sole sorghum</td>
<td>0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Sole maize</td>
<td>0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Barley</td>
<td>0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Horse beans</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td>Chick peas</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Rough peas</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Wheat-clover</td>
<td>-</td>
<td>0.30</td>
</tr>
<tr>
<td>Maize-lablab</td>
<td>-</td>
<td>0.56</td>
</tr>
<tr>
<td>Sorghum-lablab</td>
<td>-</td>
<td>0.04</td>
</tr>
</tbody>
</table>

(-) = indicates the crop is not included in the model, (0) = indicates the crop is included in the model, but not chosen in the optimal plan.

Table 3. Returns to Farm Resources from Farm Plans (Birr/Unit)

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Base plan (plan I)</th>
<th>Plan II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivated land (ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross margin/ha</td>
<td>2493</td>
<td>3240</td>
</tr>
<tr>
<td>Cash income/ha</td>
<td>302</td>
<td>1046</td>
</tr>
<tr>
<td>Family labour (person-day)</td>
<td>7.97</td>
<td>10.35</td>
</tr>
<tr>
<td>Gross margin/Man-day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash income/Man-day</td>
<td>0.98</td>
<td>3.36</td>
</tr>
<tr>
<td>Working capital Gross margin/working capital</td>
<td>9.94</td>
<td>12.92</td>
</tr>
<tr>
<td>Cash income/working capital</td>
<td>1.20</td>
<td>4.17</td>
</tr>
</tbody>
</table>

Working capital becomes an increasingly important constraint for the improved plan. This indicates that, working capital constrains increases in farm incomes. The above findings support our
hypothesis that integrating forage legumes with cereals increase the productivity of farm resources.

Table 4. Marginal Value Productivities of Resources in Farm Plans

<table>
<thead>
<tr>
<th>Resources</th>
<th>Base plan (plan I)</th>
<th>Plan II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop Land (Birr/Ha)</td>
<td>1757</td>
<td>3059</td>
</tr>
<tr>
<td>Pasture Land (Birr/Ha)</td>
<td>419</td>
<td>300</td>
</tr>
<tr>
<td>Human Labour (Birr/Hour)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ox Labour (Birr/Ox Pair-Hour)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Working Capital (Per Unit Birr)</td>
<td>0.33</td>
<td>0.99</td>
</tr>
</tbody>
</table>

4.3. Feed Demand and Utilities in the Model

The quantity of feed is one of the determinants of the dry matter intake of livestock. As the quality of the feed increases the livestock can satisfy their requirements at intakes lower than poor quality feed resources. Livestock under the base model consumed 98% of the dry matter allowable (Table 5). Under the improved plan, 81% of allowable dry matter intake was consumed. This decrease in dry matter intake under the improved plan results from the increase ME and CP content of feed in the improved situation. Decreased consumption by livestock allows additional straw to be sold. This also explains why the MVPs of pasture declined in the improved plans.
Table 5. Actual Feed Demand and Utilization by Livestock in Terms of Dry Matter (kg)

<table>
<thead>
<tr>
<th>Items</th>
<th>Farm plans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Plan (plan I)</td>
</tr>
<tr>
<td>Allowable DM intake, kg</td>
<td>4396</td>
</tr>
<tr>
<td>Predicted DM intake, kg</td>
<td>4319</td>
</tr>
<tr>
<td>Difference, kg</td>
<td>77</td>
</tr>
<tr>
<td>Percent utilized (%)</td>
<td>(98)</td>
</tr>
</tbody>
</table>

DM = dry matter

4.4. Farm Income

The introduction of forage legumes has increased farm income considerably when compared to the base plan. The base plan predicted a cash income of 528 Birr under the existing situation. This income does not include the imputed costs of home consumption. Compared to the base plan, cash income increased by 247% in the improved plans. The model results highlight the potential of introducing forage legumes to improve welfare of poor farmers of highland areas.

4.5. Sensitivity Analysis

The foregoing model results assume that input-output coefficients are invariant, i.e., non-stochastic. However, many of the coefficients used in the model are in reality subject to variation. Price of inputs and outputs may vary in a largely unpredictable way. The impacts of variation on the profitability of grain-legume inter-crops can be examined with sensitivity analysis. Sensitivity analysis involves changes to model coefficients within reasonable
bounds of the original estimate and is often used to determine if
the original ranking of alternatives is affected (Dillion and
Hardaker, 1993). In this study, it is also applied to assess the
 massibility of the objective value of improved situation as compared
to the base plan.

4.5.1. Effects of Price Reduction by 30 and 50 Percent

It was assumed that all output prices were 30% lower in the case of
Base Plan I and Base Plan II. The 30% price reductions are based
on variation in average prices of modeled crops that occurred
during a period of eighteen months.

A decrease in grain and straw prices results in lowering of the cash
income for all plans (Table 6). The relative drop in cash income is
the greatest for the base plan (48.7%) and the decrease in cash
income is the least for improved plan (22.0%). The resulting farm
incomes remain higher for the improved plan than the base plan.
The sources of cash income in the improved plan remains the same
as they were under the plan before price reduction.

Effect of reducing the output price of wheat-clover, maize-lablab
and sorghum-lablab on plan II were assessed. With the 50% price
reduction, the cash income decreased only by 10.1% as it was
under Plan II before price reduction. This indicates that with
higher price reduction the improved technologies remain
profitable.
Table 6. Effect of Output Price Reduction by 30 and 50 Percent on Cash Income

<table>
<thead>
<tr>
<th>Plans</th>
<th>Before</th>
<th>30%</th>
<th>Change</th>
<th>Before</th>
<th>50%</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Plans (Plan I)</td>
<td>528</td>
<td>271</td>
<td>-257</td>
<td>48.7</td>
<td>1831</td>
<td>1647</td>
</tr>
<tr>
<td>Plan II</td>
<td>1831</td>
<td>1428</td>
<td>-403</td>
<td>22.0</td>
<td>1831</td>
<td>1647</td>
</tr>
</tbody>
</table>

In sum, the above discussion indicates that the financial benefits from all plans do decline when prices decrease by 30%. Yet, the improved plan remains profitable and the relative profitability of the plan does not change. The relative profitabilities of improved technologies remain very high even after reducing the grain price by half. This denotes improved technologies are less sensitive to higher price reduction.

5. CONCLUSIONS AND RECOMMENDATIONS

It may be concluded from the above findings that integrating forage legumes with cereals can play an important role in increasing farm cash income and resource productivity compared to the present practice of the farmers, without forage legumes. However, the study is based on-station experiment results on wheat-clover, maize-lablab and sorghum-lablab. The yields of these crops were adjusted downward by the same factor, 10%, to take into account the managerial and small plot size factors that will result in yield variation. However, it is difficult to assume whether the magnitude of the linear adjustment of on-station yields
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to local condition is realistic. Thus, this highlights the need for initiating on farm research and extension programme under farmer management and practice to assess further the suitability of the practices as improved methods of crop production.

The agronomic benefits of grain-legume inter-cropping include higher biomass fodder production. However, other important contributions are not yet identified and documented (for instance, erosion impact, N availability, weed impact, & etc.). Thus, these additional contributions and their impacts on adoption need to be investigated.

The results on impact of integration are based on a single year model because of lack of time. However, forage legumes have carryover impact on the farming system (nitrogen carry over effect, increasing the organic matter of the soil and thus soil fertility). Thus, multi-period study that will take into account the dynamic aspects of the technology should be undertaken.

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Menale Kassie et al. An Ex-Ante Analysis of Inter-Cropping Food Crops With Forage Legumes in Mixed Crop-Livestock Systems in the Ethiopian Highlands


AN ECONOMIC ASSESSMENT OF BREAKDOWNS IN CROP AND LIVESTOCK INTEGRATION IN THE ETHIOPIAN HIGHLANDS CAUSED BY THE BURNING OF BIOFUELS AND ACCELERATED SOIL EROSION.

J.P. Sutcliffe

1. INTRODUCTION

Integration is seen as the supply of inputs from one enterprise to the other: manure as a soil ameliorate, crop residues as livestock feed, cattle as a source of draft power and livestock as a source of capital accumulation for potential investment in crop production. The benefits of closer integration of crop and livestock production are well documented, and integrated. “Mixed farming” is often seen as a desirable agricultural development objective. However, with increasing population pressure and land scarcity, competition for scarce resources develops, leading to breakdowns in crop-livestock integration. The paper examines some of these breakdowns, their impacts on crop and livestock production, and makes some preliminary estimates of these costs at the national and on-farm levels.

1 The analysis was undertaken as part of the formulation of the Conservation Strategy of Ethiopia (Sutcliffe, 1993)
The basic stages of development of crop and livestock integration have been well developed in the works of Boserup (1965), Ruthenberg (1987), Pingali et. al. (1987), and McIntire et. al. (1992). The latter authors saw the development of integration as a seven-stage process driven mainly by increasing population densities, but also strongly influenced by the development of markets, and the introduction of exogenous technology. The development process is seen to take on an inverted “U” form with integration gradually increasing from no integration with little or no specialization, to some form of maximum integration, finally progressing to no integration where production is highly specialized. The seven stages are briefly described as follows:

(i) At very low population densities, crop or livestock production systems are very extensive with no integration, and little or no contact with markets.

(ii) Similar to (i) but some interaction between crop and livestock production systems through markets.

(iii) With increasing population densities the first stage of integration with some transfers of manure and crop residues, although crop and livestock producers often remain specialized and separate.

(iv) With further increases in population density, competition begins for scarce resources (arable land or grazing land) and some crop producers start to invest in livestock, and some pastoralists undertake crop production,
(v) With increasing population densities there is increasing interaction between crop and livestock production which occurs at the farm level, leading to the development of "mixed farming",

(vi) Further increases in population densities lead to increasing competition for land, in particular with increasing expansion of crop production into grazing lands, removal of woody biomass, and increasing shortages of livestock feed and fuelwood,

(vii) With further increases in population density, development of markets and the introduction of exogenous technology (e.g. chemical fertilizers, insecticides, herbicides and planted forage, etc) a return to specialized crop or livestock production occurs with a decrease in integration but with an increase in the intensification of production.

All the various stages in the integration of crop and livestock production can be found in Ethiopian farming and pastoral systems. Much of the Ethiopian Highland farming systems might be described as lying within stages (v) to (vii). Stage (v) might be said to characterize much of the Highlands in the southwest and east. The transition to the last stage is still relatively undeveloped, except in and around some of the major towns. Here, in the livestock sector, fattening and urban dairying can be found with vegetable and specialized teff production occurring in the crop sector. However, it is stage (vi) which is the focus of the present
paper. Here, the lack of markets and problems associated with the introduction of exogenous technology are preventing either the sustainable maintenance of stage (v) or a transition to stage (vii).

**Dynamics of Natural Resource Use under Increasing Population Densities**

Population density and the people’s demand for food, together with the productivity of the land under the present crop mix and technology level determine the area of land required for crops. This is termed as the “population support capacity” of the land, and has been estimated at various scales in Ethiopia, from the peasant association to the country as a whole (Radcliffe et al, 1987; and Henricksen et al. 1989). In turn, the area that is cultivated determines the area remaining for grazing and fuelwood supply. The available pasture land and the seasonal changes in dry matter production and digestibility, together with the seasonal supplies of crop residues (including stored residues) determine the livestock carrying capacity. McIntire et al (1991) have defined the “minimum” feasible stocking rate as the sustainable rate in the season with the lowest combined supply of livestock feed. As a greater proportion of livestock feed is supplied by crop residues, the season of greatest shortage shifts from the dry season to the wet season.
As cropland expands, fallow and grazing lands contract. Increasingly, land is brought into cultivation which is marginal for cropping because of steep slopes and shallow stony soils. As this land is of lower productivity, a greater area per family is required to produce the same quantity of food and the process of conversion thus accelerates. The remaining grazing land is subject to much higher densities of livestock and higher rates of woody biomass removal.

These changes have a number of consequences, some positive and some negative. An increasing proportion of crop residues are removed from the fields and used as livestock feed, leading to breaches in soil nutrient cycles. Increasingly, manure substitutes for fallowing in the restoration of soil fertility. But this entails increased labour inputs, and where labour is in short supply may not occur on part or even all of the farm. Cultivation of marginal land leads to accelerated soil erosion, which on already shallow soils, leads to declining crop yields and decreased production. The contracting area of grazing lands leads to higher livestock densities, overgrazing, accelerated soil erosion, and declining dry matter production and lower digestibility. In addition, the stock of woody biomass on the grazing lands is reduced leading to increasing consumption of wood in excess of sustainable yield. Eventually household fuelwood deficits occur, and increasing amounts of dung and/or crop residues are used as fuel. These in
Farmers may respond to these negative impacts of resource competition by intensifying production. In crop production, they may respond by using external inputs (fertilizer, herbicides, etc), or by investing in soil conservation measures, or higher yielding varieties. Livestock production may be intensified through the cultivation of forage and improved residue management. However, these responses depend on two factors. Firstly, markets must develop through improved infrastructure and communications which in turn lead to higher output prices, lower input costs, decreased risk and increased incentives for farmers to invest in new technology. Secondly, appropriate technologies need to be adopted and facilitated by improved research and extension. Where markets are not developed or improved, technology is not introduced, the downward spiral of crop and livestock production caused by resource competition and degradation will accelerate. This paper examines some of the costs of these breakdowns in crop-livestock integration caused by resource competition, in particular soil erosion and the burning of crop residues and dung as fuel at the national and on-farm levels.
2. METHODOLOGY

With respect to soil erosion this paper takes as its starting point the premise of the Highland Reclamation Study (FAO/UNDP/GOE, 1986) and Stocking (1984) that the major impact of soil erosion on crop production in Ethiopia derives from reduced soil and water availability caused by a reduction of soil depth. A “soil life” model (Stocking and Pain, 1983) was used to simulate soil depth, soil water and crop yield interactions, and to model reductions in soil depth and thus estimate available soil water holding capacity and yield reduction (FAO, 1986). Supporting evidence for this in Ethiopia is given in Hurni (1985). These simulations indicated that on red volcanic soils negative impacts on crop yield commence only when soil depths are reduced to 80 – 95cms, and that crop failures (defined as 20 percent of maximum yield) occur when soil depths are reduced to 30 – 45cms. Annual decline in crop yield with erosion rates remaining constant were approximately linear over most depths between the maximum and minimum critical depths.

It was thus possible to relate the rate of soil loss with the rate of decline in crop yield using the annual average soil loss rates of different slope classes on cropland estimated by the Universal Soil Loss Equation as adapted for Ethiopia by Hurni (1985). The projected annual losses in crop grain production and the area of land cultivated were calculated for a 35 years period (1985 – 2020).
using as a basis the crop mixes, yields and areas for the three main attitudinal ranges in each of the three major agro-ecological zones calculated by the EHRS. The commensurate losses of crop residue were converted to tropical livestock unit equivalents. The base year of 1985 was adopted to enable a comparison with estimates made by the EHRS.

The methodology used to determine the impacts of burning of dung and residues on breaches of the nutrient cycle, and as a consequence, on crop and livestock production followed that established by Newcombe (1989), but used later more detailed estimates of the use of dung and residues as fuel (Cessen-Ansaldo/Finmeccanica, 1986). Firstly, impacts were calculated in terms of plant nutrients (nitrogen and phosphorous) lost and their potential contribution to increased crop production. Secondly, the burnt crop residues were also valued in terms of livestock feed and equated through live-weight gain in tropical livestock units. Finally, the burning of dung and crop residues were equated in terms of their equivalent as the chemical fertilizers, di-ammonium phosphate and urea.

Agricultural production foregone and chemical fertilizer equivalent due to soil removal and breaches in the nutrient cycle were given monetary values using rural market prices (in Ethiopian birr) and import/export parity prices (in US$). The former permitted an estimate to be made of the lost agricultural production in terms of the agricultural GDP, whilst the latter gave an estimate of the
foreign exchange costs of grain imports and the loss of livestock exports.

The value of land can be calculated using its economic rent, here defined as the discounted value of output of a piece of land put to its best use less the cost of all inputs (labour, fertilizer, seed, etc) except land (Found, 1971). Economic rent captures two components: the quality or productivity of the land and the location of the land with respect to the distance (and thus transport costs) to the market. It does not capture the more ephemeral residual nutrient "capital" such as nitrogen or organic matter derived from the application of manure or fertilizers.

However, whilst economic rent provides a productive value of 1 hectare of land and the soil upon it, valuing for example just 5mm of topsoil is more problematic. Losses from a soil within the critical depth range will have an immediate impact on productivity. Losses from a soil deeper than the maximum critical depth whilst not having an immediate impact on productivity do bring the day closer when the soil will be within the critical range. Thus, the value of 5 mm of soil material of a soil within the critical range was valued as the immediate decline of agricultural (ie. crop and livestock) production caused by the loss of the 5 mm of soil (by using the soil life model).

Soil material lost from a soil deeper than the critical maximum was valued using the loss of productivity caused by the loss of
5mm of soil, but discounting the value of this loss by the number of years an annual loss of 5mm of soil would take to reach the critical depth.\(^2\) This value could be described as the future cost of the loss of 5 mm of soil today or the "user cost" (Pearce et al. 1989), or more properly the "future use cost" of allowing soil to erode today.

In the on-farm analysis, farm-gate prices were used for agricultural output (grain and livestock products). As labour was assumed to be used during the agricultural "slack" season, a reservation wage of EB 1.85 per day was estimated to represent the opportunity cost of labour. To simulate situations where food for work is used, the local market values of 3 kg of wheat and 125 ml of oil were entered into the benefit stream in year 1.

3. RESULTS

(a) Soil Erosion and Impacts on National Agricultural Production:

The projected impacts of soil erosion on agricultural production (1985-2010) are consolidated in table 1 under physical quantities, costs (in birr) and as the value of import costs incurred and of export revenues lost (in US$).

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\(^2\)Example: Assume a critical maximum depth of 90 cm, minimum depth of 40 cm, a present depth of 100 cm and an annual loss of 5 mm of soil. It will take 20 years to reach the critical maximum depth at which point an annual loss of production of 1% will commence. If the annual value of production is EB 250/ha, then the value of the annual loss in production will be EB2.50/ha. However, this loss will only be incurred in 20 years time. The present value of EB2.50 in 20 years time using a discount rate of 9% is 0.178 (the discount factor) X EB2.50 = EB0.225/ha.
Table 1 Impacts of soil erosion on national agricultural production

1. Physical quantities of agricultural production

<table>
<thead>
<tr>
<th>Year</th>
<th>Cereals (mt)</th>
<th>Livestock (TLUs)</th>
<th>Cropland (ha)</th>
<th>Grazing land (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>7,647</td>
<td>6,690</td>
<td>30,949</td>
<td>412,657</td>
</tr>
<tr>
<td>1995</td>
<td>142,024</td>
<td>23,423</td>
<td>316,051</td>
<td>2,146,889</td>
</tr>
<tr>
<td>2010</td>
<td>341,852</td>
<td>153,350</td>
<td>482,874</td>
<td>5,747,357</td>
</tr>
</tbody>
</table>

2. Financial cost of agricultural production: EB million (1985 constant prices)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cereals</th>
<th>Livestock</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>6.8</td>
<td>1.0</td>
<td>7.8</td>
</tr>
<tr>
<td>1995</td>
<td>125.7</td>
<td>8.3</td>
<td>134.0</td>
</tr>
<tr>
<td>2010</td>
<td>302.5</td>
<td>19.1</td>
<td>321.6</td>
</tr>
</tbody>
</table>

3. Value of import costs incurred and potential export lost: USS million (1985 constant prices)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cereals</th>
<th>Livestock</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>2.0</td>
<td>0.6</td>
<td>2.6</td>
</tr>
<tr>
<td>1995</td>
<td>37.6</td>
<td>5.3</td>
<td>42.9</td>
</tr>
<tr>
<td>2010</td>
<td>90.6</td>
<td>12.1</td>
<td>102.7</td>
</tr>
</tbody>
</table>

Physical Quantities:
The projected annual grain losses obtained by the EHRS from 1985 to 2010 were 120,000 mt rising to 2.58 million mt. These are higher than this study's estimates by about 15 orders of magnitude. The EHRS did not calculate the number of livestock affected, thus, no comparison is possible. The projected annual loss of cropland is about 30,000 ha with a cumulated total loss of 0.49 million ha by
the year 2010. These estimates for the year 2010 are compared with the EHRS estimate of 7.6 million ha.

On-farm Financial Costs:

(i) Of Crops and Livestock Production Foregone:
One objective of using financial prices is that it permits a comparison with the aggregate values used in the national accounts. Thus, taking the 1995 agricultural GDP as £B 7204.6 million then the value of the 1995 crop and livestock production loss due to topsoil erosion was 1.9 percent. The 1985-1995 rate of decline of the agricultural GDP due to soil erosion was 0.2 percent compared with a recorded annual increase of about 6 percent.

(ii) Of the Permanent Destruction of Cropland and Pastures
At the point of abandonment of crop or grazing the land has no value for crop or livestock production (i.e. its land rent is zero). According to this study's calculations, the forgone value of agricultural production of the soil that has been destroyed continues to be counted. Thus, to include in the calculations the full (i.e. non-eroded) value of the land as it goes out of production would be double counting. For this reason, the present study ascribes no cost of land which is destroyed.
The Value of Import Costs Incurred and of Export Revenues Lost:

Using economic prices provides a measure of the impact of soil loss on the country's economy as a whole in terms of the costs of having to import grain to make up for grain lost or not being able to export livestock (because of the loss of livestock feed). In order to measure the value of production lost "import parity" (CF Asseb), prices are used for grain and "export parity" (FOB Asseb) for livestock. The actual 1985 crop grain imports of 2 million mt were valued at US$ 530 million and Ethiopia's livestock exports at US$43 million.

(b) Breaches in Organic Nutrient Cycling and the Loss of Agricultural Production

In measuring the opportunity costs of burning dung and crop residues, three approaches were used:

(i) Estimating the quantity of cereal grain lost by not applying dung and residues to the cropland and thus, losing soil nutrients

(ii) Estimating the quantity of chemical fertilizer (Di-ammonium phosphate and Urea) equivalent to the stored nutrient of the dung and residues which are burnt

(iii) Estimating the number of livestock (i) which would have been fed on the crop residues which are burnt and (ii) with the potential increase in the next season crop residues which are lost by not applying dying and residues to the cropland and thus losing their stored nutrients
With the increasing demand for fuel from a rising population and a decrease in the supply of fuel wood, the use of dung and residues as fuel will increase. The ENEC study projected the 1985-2010 increase for dung as 2.45% and residues as 2.50%. The results are consolidated in table 2.
Table 2 Impacts of burning dung and crop residues on agricultural production: Ethiopia 1985-2010

1. Physical quantities of agricultural production and chemical fertilizer forgone

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</thead>
<tbody>
<tr>
<td>1985</td>
<td>352.4</td>
<td>106.9</td>
<td>459.3</td>
<td>163.4</td>
<td>49.7</td>
<td>873.5</td>
<td>1,086.6</td>
<td>131.1</td>
<td>36.6</td>
</tr>
<tr>
<td>1995</td>
<td>448.9</td>
<td>136.9</td>
<td>585.7</td>
<td>208.2</td>
<td>63.3</td>
<td>1,112.6</td>
<td>1,384.1</td>
<td>167.0</td>
<td>46.9</td>
</tr>
<tr>
<td>2010</td>
<td>645.4</td>
<td>198.2</td>
<td>843.6</td>
<td>299.3</td>
<td>91.1</td>
<td>1,599.7</td>
<td>1,990.1</td>
<td>240.2</td>
<td>67.9</td>
</tr>
</tbody>
</table>

2. Financial cost of agricultural production and chemical fertilizer forgone (EB million)

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<tbody>
<tr>
<td>1985</td>
<td>315.8</td>
<td>96.1</td>
<td>411.9</td>
<td>25.2</td>
<td>2.0</td>
<td>134.8</td>
<td>162.0</td>
<td>573.9</td>
<td>126.3</td>
<td>35.3</td>
<td>161.6</td>
</tr>
<tr>
<td>1995</td>
<td>402.3</td>
<td>122.4</td>
<td>524.7</td>
<td>32.1</td>
<td>2.5</td>
<td>171.1</td>
<td>206.4</td>
<td>731.0</td>
<td>160.9</td>
<td>45.1</td>
<td>206.0</td>
</tr>
<tr>
<td>2010</td>
<td>578.4</td>
<td>76.0</td>
<td>654.3</td>
<td>46.2</td>
<td>3.6</td>
<td>246.9</td>
<td>296.7</td>
<td>951.0</td>
<td>231.3</td>
<td>65.3</td>
<td>296.6</td>
</tr>
</tbody>
</table>
### 3. Value of import costs incurred and export revenues lost in foreign exchange (US$ million)

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<tr>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>101.2</td>
<td>30.8</td>
<td>132.0</td>
<td>6.5</td>
<td>34.5</td>
<td>42.9</td>
<td>175.0</td>
<td>45.5</td>
<td>58.2</td>
</tr>
<tr>
<td>1995</td>
<td>129.0</td>
<td>39.2</td>
<td>168.2</td>
<td>8.2</td>
<td>44.0</td>
<td>54.7</td>
<td>222.9</td>
<td>58.0</td>
<td>74.3</td>
</tr>
<tr>
<td>2010</td>
<td>185.4</td>
<td>56.4</td>
<td>241.8</td>
<td>11.8</td>
<td>63.2</td>
<td>78.6</td>
<td>320.4</td>
<td>83.4</td>
<td>107.0</td>
</tr>
</tbody>
</table>
Physical Quantities:
There are significant differences between the crop production foregone due to soil erosion and due to nutrient breaches resulting from the burning dung and residues. It is estimated that, in 1995, the total grain foregone due to nutrient losses was some four orders of magnitudes **higher** than the grain production lost because of topsoil erosion. The amount of fertilizer equivalent which was foregone in 1985 (167,700 mt) was some **three** times higher than the total DAP sales (46,000) in 1986 to all farmers in Ethiopia.

Crop residues provide 40-60% livestock feed in the highland farming systems. Crop residue loss occurs directly from the burning residues as fuel, and indirectly because of the nutrients lost in the burning. It affects the yield of crop residues in the same way as it does affect grain yields. The estimated livestock production foregone in 1995 because of the total loss of livestock feed and thus live weight gain (1.4 million TLU'S) represents approximately 5% of the national herd (of about 27.5 million TLU's).

Financial Value of Agricultural Production Foregone
The costs of grain and livestock production foregone are 9% of the 1995 agricultural GDP.

Value of Import Costs Incurred and of Export Revenues Lost:
Use of economic prices provides a measure of the impact of burning dung and crop residues on the country as a whole in terms of importing grain to replace what is lost. Livestock foregone or that
is not exported. These costs amount to 23% of the 1985 value of grain imports and exactly the value of the 1985 livestock export earnings.

(c) Total Impacts of Physical and Biological Land Degradation on Agricultural Production In Ethiopia

The combined impacts of physical and biological land degradation (soil erosion and nutrient breaches) are set out in table 3.

<table>
<thead>
<tr>
<th>Table 3. Total impacts of erosion, burning dung and crop residues on agricultural production: Ethiopia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Physical quantities of agricultural production and chemical fertilizer foregone</td>
</tr>
<tr>
<td>Cereals ('000mt)</td>
</tr>
<tr>
<td>Year</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>1985</td>
</tr>
<tr>
<td>1995</td>
</tr>
<tr>
<td>2010</td>
</tr>
</tbody>
</table>

2. Financial costs of agricultural production and chemical fertilizer foregone (ER million)

<table>
<thead>
<tr>
<th>Cereals</th>
<th>Livestock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Soil erosion</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>1985</td>
<td>6.5</td>
</tr>
<tr>
<td>1995</td>
<td>63.4</td>
</tr>
<tr>
<td>2010</td>
<td>148.8</td>
</tr>
</tbody>
</table>
3. Value of import costs incurred and export revenues lost in foreign exchange (US$ Million)

<table>
<thead>
<tr>
<th>Year</th>
<th>Soil erosion breaches</th>
<th>Nutrient breaches</th>
<th>Soil erosion breaches</th>
<th>Nutrient breaches</th>
<th>Residues burnt</th>
<th>Total</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>1.9</td>
<td>132.0</td>
<td>0.5</td>
<td>8.5</td>
<td>34.5</td>
<td>43.5</td>
<td>177.4</td>
</tr>
<tr>
<td>1995</td>
<td>19.2</td>
<td>168.2</td>
<td>8.5</td>
<td>10.7</td>
<td>44.0</td>
<td>59.0</td>
<td>246.4</td>
</tr>
<tr>
<td>2010</td>
<td>45.0</td>
<td>241.8</td>
<td>15.4</td>
<td>63.2</td>
<td>88.6</td>
<td>375.4</td>
<td></td>
</tr>
</tbody>
</table>

The total cereal production forgone from both sources in 1995 is 7% of the very high 1995/96 cereal harvest of 9 million mt. Using an annual per capita cereal requirement of 2200 kg, the 1995 production forgone would have been enough to feed approximately about 2.7 million people (i.e. 5-6% of the 1995 population).

Using the 1985-1995 projections the increasing annual financial costs of grain and livestock production forgone due to topsoil erosion and nutrient breaches would amount to an overall annual decline of the 1985 agricultural GDP of about 3.5%. The recorded annual agricultural GDP increased during these years from EB 4370 million to EB 7204 million (at current factor prices) which amounts to an overall annual rate of increase of 7%. However, this is starting from the very low base of the 1984/85 drought year. Between 1975 and 1990, the overall annual rate of increase has only been 0.7%. This would indicate that a substantial part of the reason for the sluggish growth in agricultural production which has often been wholly attributed to policy defects and drought is large measure due to the increasing negative impacts of land degradation subtracting from any real increases in productivity.
Also of significance is that a substantial part of the impacts attributed to land degradation are due to biological degradation.

(d) On-Farm Analysis of Investing in Soil Conservation Measures

Probably the most important measure of comparison from the farmer's point of view is the payback period—i.e. the number of years they must wait until the initial investment costs are recouped. A more theoretical comparison value is the discounted benefit-cost ratio over a set number of years at a set discount rate. The period and the discount rate will vary from farmer to farmer. Farmers with higher and more secure incomes will have longer time horizons and lower discount rates. Setting time horizon and discount rates common to all farmers is thus impossible. Two sets of time periods and discount rates are used to try to represent low and high income farmer groups:

- 10 Years at 30% for low income farmers
- 25 years at 9% for income farmer

A benefit-cost ratio of 1 or more indicates positive discounted benefits. The payback periods and the benefit-cost ratios of the structures assuming EB 1.85 for labour and without and with food for work with benefits accruing from increased water conservation are shown below:

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### Economies of Integrated Crop and Livestock Systems in Ethiopia

#### (i) No Food for work

<table>
<thead>
<tr>
<th>Method</th>
<th>Strip</th>
<th>Bund</th>
<th>Fanya juu</th>
<th>Terrace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payback (years)</td>
<td>5</td>
<td>17</td>
<td>23</td>
<td>&gt;25</td>
</tr>
<tr>
<td>B/C(30% Over 10 yrs)</td>
<td>0.89</td>
<td>0.44</td>
<td>0.30</td>
<td>0.34</td>
</tr>
<tr>
<td>B/C(9% over 25 yrs)</td>
<td>1.85</td>
<td>1.15</td>
<td>0.91</td>
<td>0.45</td>
</tr>
</tbody>
</table>

#### (ii) Food for work

<table>
<thead>
<tr>
<th>Method</th>
<th>Strip</th>
<th>Bund</th>
<th>Fanya juu</th>
<th>Terrace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payback (years)</td>
<td>4</td>
<td>8</td>
<td>16</td>
<td>&gt;25</td>
</tr>
<tr>
<td>B/S(30% over 10 yrs)</td>
<td>1.03</td>
<td>0.99</td>
<td>0.67</td>
<td>0.35</td>
</tr>
<tr>
<td>B/C (9% over 25 yrs)</td>
<td>1.85</td>
<td>1.15</td>
<td>0.91</td>
<td>0.45</td>
</tr>
</tbody>
</table>

The rank order from this point of view is plain with grass strips having shorter payback periods and higher benefit-cost ratio. Even with food for work, there are still very high payback periods for fanya juu, bunds and terraces and resource poor farmers have benefit-cost ratio of more than 1 for soil bunds when food for work is provided indicating that this group of farmers may consider them worth the investment. When the benefits accruing to increased water conservation are included, the financial position improves although the rank order remains the same.

### CONCLUSIONS

Many areas of the Ethiopian Highlands are in or are rapidly approaching McIntire's stage (vi) where under high human and livestock population densities, poor development of markets and low adoption of endogenous technology competition for resources...
is accelerating among the needs of crop, livestock and tree production and bio-energy supplies. The primary needs for food are leading to an expansion of cropland and a contraction of the area of fallow, grazing and wood lands. Two major negative impacts of these trends have accelerated soil erosion and the loss of soil nutrients from agro-ecosystems due to the burning of dung and crop residues. These have been examined at the macro and the micro economic levels.

**Macro Economic Level:**

Whilst the present system of national accounting depreciates manmade capital, no account is made for the depletion or degradation of natural resources: they are viewed as "free gifts of nature" (Ahmed et al. 1989). Similarly, no account is made for increases in natural capital: e.g., through new discoveries of minerals, improved forest surveys, tree planting, major land improvements and thus of values on natural resource stocks. According to current national accounting practice changes in manmade capital (i.e., investment) are recorded and form part of the GDP/GNP. It has been suggested that increases in natural "capital" be similarly treated.

The discussion here focuses on soil resources which are different in some respects from renewable biological consumable resources (e.g. fisheries or forests) and from non-renewable mineral resources (e.g. oil or gold). Soil resources unlike mineral resources allow sustainable production of consumable resources (grass, trees) and
products (grain). However, they are similar to mineral resources in comprising a clay mineral component which can only be renewed relatively slowly over centuries and is thus "non-renewable" in the medium term; but nevertheless differ in having an important organic component which can be renewed relatively quickly (over months or years).

The issue is how to treat the immediate and the future impacts of land degradation in the National Accounts. The approach adopted in the present study with respect to current losses has been to assume that the National Accounts have correctly recorded the loss of agricultural production for the year in question arising from the immediate permanent (physical) and temporary (biological) degradation impacts, although the accounts will not have separately identified them. The objective in this case is to demonstrate what the potential agricultural GDP could have been in the absence of soil loss and nutrient breaches. In 1995, the agricultural GDP was estimated at EB 7204 million. Agricultural income forgone in 1995 from soil loss and nutrient breaches is estimated at EB 803 million. Thus, in 1995, approximately 11% of the potential agricultural GDP was lost because of immediate permanent and temporary land degradation.

It is important to note that nearly 90% of the reduction in the GDP due to degradation is accounted for by biological degradation caused by nutrient breaches and not due to physical soil erosion.
There are clear important policy implications here with regard to the relative priorities to be given to physical soil conservation and to improving the fuelwood supply and so reducing the need to burn dung and crop residues.

Thus far, no mention has been made of accounting for agricultural production losses occurring in the future resulting from soil erosion today. Soil resources are clearly part of the nation's "natural capital"; and if they are being permanently degraded, then the future loss of national income so caused should be reflected in some way in today's national accounts.

If the immediate annual production loss due to soil erosion in 1995 was valued at EB37 million, then this loss will be incurred every year in the future. In order to arrive at a present value of all these future losses they must be discounted. If a discount rate of 11% is used (ie the estimated opportunity cost of foreign borrowing and recommended for use in the National Economic Parameters for Ethiopia, 1989), the present value of all future losses is EB 336 million when discounted over an infinite time horizon. This amount represents the future costs of the soil erosion on soils within the critical depth range which occurred in 1995. The suggestion is that the net national income (NNI) should be debited by EB 336 million to reflect the depreciation of the nation's soil resources.
The annual production losses on soils greater than the critical maximum depth which will be coming on stream some time in the future (in the absence of defensive measures) can be accounted for in the same way. In the present study, the future (discounted) costs of the 1995 soil loss from soils outside the critical range have been calculated at EB 275 million which represents the future costs of soil erosion on soils deeper than the critical depth range which occurred in 1995. The total depreciation of the nation's soil wealth for the year 1995 is thus EB 611 million and the NNI should be adjusted accordingly. These are known as the "user costs" and the 1995 NNI adjusted in this way reflects the "true" or sustainable national income. 

Micro Economic Level:

The analysis at the micro economic level has been briefly outlined in this paper and more fully elsewhere (Sutcliffe, 1995). The main conclusions from this analysis are that where net soil loss is occurring on soils within the critical depth range and yield declines have started to occur, then changing the discount rate to simulate increasing tenure security does increase benefit-cost ratios, but that in rainfall sufficient areas ratios remain less than unity for farmers with high personal discount rates. Providing food for work to cover establishment costs brings the ratios to just at or above unity for grass strips and soil bunds for both classes of farmers. This indicates that food for work could have a positive role in inducing farmers to invest in these measures, but only where net soil losses
are occurring on soils within the critical soil depth range. In these areas contour trash lines may be a more appropriate measure to promote where large grain (maize and sorghum) stalks are available.

In drier areas, where there are increased benefits from soil water conservation, the benefit-cost ratios for soil bunds for farmers with high discount rates remain below unity, but well above unity for farmers with the lower discount rates. Again providing food for work shifts the ratio to above unity for tenure insecure farmers for both grass strips and soil bunds, again indicating a potential role for food for work, with the same proviso that investment is confined to slopes undergoing net soil loss on soils within the critical depths. The same conclusions can be applied to high value and moisture sensitive crops (e.g. coffee, chat) whose yields increase significantly with soil water conservation. There is clearly a need to determine farmers’ personal discount rates when assessing whether a particular technology or practice will be adopted. The very high discount rates of Ethiopian farmers and the very high costs of hitherto proposed soil conservation measures are clearly behind their non-adoptive in many areas. Similar conclusions have been reached in Malawi and Mali (Eaton, 1996, Bishop, 1995).

REFERENCES


HOUSEHOLD ENERGY SUPPLY AND LAND USE IN THE CENTRAL HIGHLANDS OF ETHIOPIA: THE CHOICE BETWEEN FIREWOOD AND CATTLE DUNG¹

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Agricultural Economist, Nazareth Research Center, IAR

ABSTRACT

Cattle dung burning is one of the major causes of land degradation in Ethiopia. In this study the choice between cattle dung and firewood as source of energy for cooking is assessed using land use planning by taking the case of Ada woreda. Although wood has higher energy value and is preferred to dung since it is less smoky, cattle dung is used as fuel rather than as a fertilizer because of shortage of firewood. Farmers have multiple objectives to fulfill among which production of grains to feed their family ranks first. In this study, the decision farmers make with regard to resource allocation and cattle dung burning are analyzed and the potentials for intervention are assessed. A dynamic non-linear programming model is used to analyze the problem. The data are analyzed under five different scenarios with regard to crop productivity, population growth and an alternative to change farmers’ decisions on dung burning. Another policy issue to reduce population pressure is family planning. Family planning and introduction of more efficient cooking stoves when considered separately can not bring a significant reduction on the contribution of dung to total fuel consumption. However, these measures combined with higher crop productivity can bring about a remarkable improvement in the sustainability of the farming system of Ada woreda.

¹ Derived from the author’s MSc thesis, Wageningen Agricultural University, The Netherlands
I. INTRODUCTION

The majority of the Ethiopian households get energy for cooking from firewood and cattle dung. Only an insignificant percentage (6%) of the population relies on electric power, gas and kerosene as a source of energy for cooking (Ethiopian National Energy Committee, 1980).

In the past, firewood was more commonly used than cattle dung as a source of energy. This has resulted in deforestation. In less than a century, the country’s forest and woodland cover has been reduced from 40% of the total area to 16% in the 1950s and an estimated 4% at present (FAO, 1993b). As a consequence, the time required to collect firewood has increased significantly. Firewood scarcity has resulted in diversion of animal dung from its traditional role as soil nutrient fixing to direct burning for fuel.

Increased burning of dung and crop residues deprives the soil of chemical, physical and microbiological inputs and thus, reduces soil fertility. Farmers know the value of dung as fertilizer, but they use it as fuel because of shortage of firewood.

Land degradation caused by inappropriate forest clearance, soil surface exposure and overgrazing stand out as the most severe environmental problem in Ethiopia. It is estimated that nutrient loss and soil erosion result in forgone agricultural production of close to
600,000 tons of grain per year, equivalent to 90% of Ethiopia's food deficit in 1993 (World Bank, 1995).

As soil nutrient loss caused by dung burning is a major source of land degradation, it should be stopped to prevent the irreversible damage of agricultural land. This can not be achieved without taking the problem of household energy supply into consideration, because energy demand for cooking is the driving force of accelerated deforestation and dung burning. In this study, the choice between cattle dung and firewood as source of energy for cooking is assessed using land use planning by taking the case of Ada woreda.

The specific objectives of the study are:

1. to study the reallocation of land to major crops of the area, cattle rearing and tree planting for firewood;
2. to identify possible means of intervening in the problem of soil degradation caused by cattle dung burning; and
3. to build alternative scenarios that can change the existing unsustainable farming practices.

The organization of the paper is as follows. Section 2 presents description of the study area. The methodology is discussed in section 3. Section 4 describes the scenarios under which the data are analyzed. Results and the discussion are presented in sections 5 and 6 respectively, and section 7 concludes the study.
Farmers of Ada woreda hold an average farm size (cultivated land plus grazing area) of about 3.12 hectares per household. As they are subsistence farmers, they can not specialize in one or two types of crops or livestock. The main reason to diversify production is to avert risk. The major crops grown are teff and wheat accounting for 54% and 30% of the cultivated land respectively.

The study area has one main rainy season which starts in June and ends in mid September. The area also receives some irregular rain from January to March. Annual rainfall received ranges from 700 to 1000 mm. The topography consists mainly of undulating plains with scattered hills. Ada woreda has two soil types: Light soils on the hill sides and heavy (black) soils on the plains and at the foot of the hills.

2. METHODOLOGY

2.1 Methodology of Data Collection and Sources
Initial resource endowments of the study area, production technology available to farmers, food and cooking energy requirements and input and output prices are the crucial data set required for planning resource allocation. All the data used in this study are secondary data collected from the office of the Ministry of Agriculture (MOA) in Ada woreda, Alemaya University of Agriculture (Debre Zeit Research Center), Ethiopian Grain Trade
Enterprise (EGTE), Forestry Research Center and International Labor Organization (ILO), Addis Ababa.

**Land**

Ada woreda covers an area of 78,000 hectares out of which about 54,380 hectares (70%) is cultivated land, 1576 hectares (2%) is communal grazing area and about 4813 hectares (6%) is under forest and bushes. Debre Zeit town and roads cover an area of about 18,031 hectares (23%).

**Labor**

In this study a year is divided into five periods of agricultural activities. In calculating the number of family labor available in each period, an estimate of about 20-23 days per month is assumed to be appropriate. The remaining 10 days are devoted to weekends, market days and religious holidays that the farmer celebrates by abstaining from work. The amount of labor (in man-days\(^2\)) available in the five periods is shown in Table 1.

\(^2\) 1 Man day = 8 working hours
Table 1  Agricultural activities grouped in periods and the amount of labor available in man-days

<table>
<thead>
<tr>
<th>Period</th>
<th>No. Of days</th>
<th>Activities</th>
<th>Available labor (MD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period 1 (Early March-late June)</td>
<td>80</td>
<td>Land preparation, planting faba bean</td>
<td>1,792,400</td>
</tr>
<tr>
<td>Period 2 (Early July-mid August)</td>
<td>30</td>
<td>Teff and Wheat planting</td>
<td>672,150</td>
</tr>
<tr>
<td>Period 3</td>
<td>13</td>
<td>Chick Pea planting, Teff and Wheat weeding</td>
<td>298,659</td>
</tr>
<tr>
<td>Period 4</td>
<td>20</td>
<td>Teff, Wheat and Chick Pea harvesting, Teff, Wheat and Chick Pea transporting, faba bean harvesting, bean threshing and winnowing</td>
<td>448,100</td>
</tr>
<tr>
<td>Period 5</td>
<td>13</td>
<td>Teff, Wheat and Chick Pea threshing and winnowing</td>
<td>298,659</td>
</tr>
</tbody>
</table>

Prices

A five-year average (1991/92-1995/96) of grain prices is used in the analysis. There is variation in prices between varieties of a given crop. However, average price of all the varieties is used.

The price of milk is estimated to be 0.5 Birr per litre based on prices of milk products such as butter and cheese.

The two major variable external inputs that farmers buy in the market are commercial fertilizers and herbicides. DAP and urea are commonly used fertilizers and they are sold at an average price of
265 and 245 Birr per quintal respectively. Farmers buy herbicide (2-4D) at an average price of 47 Birr per liter.

It was not possible to obtain data on firewood at Debre Zeit (capital of Ada woreda). Price data collected from markets in Addis Ababa were assumed to be reasonable approximation for prices in Debre Zeit.

Firewood

A Gompertz growth function estimated by Adegbebin et al. (1991) was used to calculate annual growth of *Eucalyptus tereticornis*. This study was done for Nigeria and it is assumed that the function is a reasonable approximate for Ethiopia. The average growth rate is calculated to be 18% per year.

Commercial and traditional fertilizers

Nitrogen and phosphorus can be obtained from Diamonium Phosphate (DAP), urea, or cattle dung. The average daily production of dung per ox and per cow is 10 and 8 kilograms respectively. Although natural fertilizers are more readily absorbed by plants and improve the organic matter content of the soil, both natural and commercial fertilizers are considered to be similar. Residual effects of fertilizer application and long term effect of manuring are ignored because of lack of suitable information.
The daily grain requirement per person is 500 grams (FAO, 1993b). The growing demand for food due to population growth is included in the model and it is assumed that the minimum cereal requirement grows at the rate of the annual population growth.

The daily feed requirement of cattle is 2.5 kilograms of Dry Matter (DM) per 100 kilogram of live weight (Gryseels and Anderson, 1983). Since the main purpose of keeping cattle is to supplement crop production, the feed requirement of oxen (used in land preparation and threshing) and cows (required to produce the oxen needed to supplement crop production) is taken into consideration. Bulls, heifers and calves are ignored for simplicity.

When no additional energy source is used, the estimated annual firewood requirement per person is 1.2 cubic meter (Dechassa', B., personal communication, August, 1996). One cubic meter of wood at 25% moisture content, wet basis (as sold), 500 kilograms per cubic meter basic density, has a caloric value of 19.035 Gigajoule per ton. Thus, the energy requirement of a person is equal to 11.4 Gigajoule per person per year (energy from 1.2 cubic meter of wood). For the rural population of Ada woreda, which is equal to 125,289 in 1996, about 1,430,900 Gigajoule is required to satisfy cooking energy demand. But this amount grows with the growth

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1 Staff of Forestry Research Center in Addis Ababa
4 World Bank estimates and UNDP/World Bank field work for energy assessment
rate of the population which is estimated to be about 3% per year. Cow dung as a source of fuel at 15% moisture content, wet basis is equivalent to 13.8 Gigajoule per ton. Although, whenever available, firewood is preferred to cattle dung for cooking as it is less smoky than dung, in this study the two were considered to be the same.

2.2 Analytical technique
A dynamic non-linear programming is used to analyse the problem. Dynamic programming is a method for solving optimization problems which can be formulated as a sequence of decisions (France and Thornely, 1984). An optimal policy has the property that, whatever the initial state and initial decision rule are, the remaining decisions must constitute an optimal policy with respect to the state resulting from the first decision (Bellman and Dreyfus, 1962). Dynamic programming is chosen in this study since the problem involves decision making of which the impact cannot be observed in one year. In other words, one has to wait at least five years for a tree planted this year to be ready for harvesting. An area planted to firewood trees in the first year will not be available for cropping or grazing in the following four years. Hence, the decision of how much grain to produce and how many cattle to keep this year depends on decisions made in the preceding years. To make decisions on activities whose costs and benefits extend over years, a multi-period programming is more appropriate.
The choice between DAP, urea and manure as a source of nitrogen and phosphorus are important variables that should be determined within the model. For this purpose, quadratic fertilizer response curves are fitted to data obtained from fertilizer trials and are included in the optimization problem as constraints. This explains why non-linear programming is preferred to linear programming in this study. Moreover, since the maximization involves decision making over a long period, it is important to consider the growing demand for food and firewood. Maximizing the net present value requires discounting future benefits which adds to the presence of terms that appear non-linearly in the model. In multi-year programming, future values are discounted because of time preference for money. Present values are better than the same values in the future, and earlier returns are better than later (Gittinger, 1982).

2.3 Model specification
The objective function is given by the monetary value of teff, wheat and milk produced minus the cost of purchased inputs (seed, fertilizers and hired labour) and firewood summed over the time period t (Appendix II).

Two types of firewood are identified in this study. First, wood can be obtained from already existing trees. Second, trees can be additionally planted to produce firewood. Using wood from existing trees has harvesting cost. Newly planted firewood trees have both planting and harvesting costs. Since net income is
maximized over a time period $t$, future values are discounted using a discount rate ($r=8\%$).

**Constraints**

The first constraint (equation 2) ensures the availability of minimum food requirement for the area. Farmers should be able to produce a certain amount of cereals to ensure the availability of food for their families. The sum of energy obtained from cattle dung, firewood and the energy deficit should be equal to the energy requirement of the area (equation 16). The minimum cereal and energy requirement grows at a rate equal to the population growth rate ($gp$). The sum of the quantity of energy obtained from firewood and cattle dung which is calculated as energy (in joules) per unit of fuel plus energy deficit should be equal to the yearly energy requirement (equation 3). In equation 2 and 3, the term $(1+gp)^{t-1}$ is a compounding factor.

The yield of teff and wheat depends on nitrogen (N) and phosphorous (P) application rates. In equation 4, the sum of nitrogen and phosphorous ($W$) applied determines crop yield ($Y$) and yield multiplied by area ($X$) gives quantity produced ($Q$). This equation balances quantity produced with area through yield. Equation 5, defines $W$ as the sum of nitrogen and phosphorous.

Two types of fertilizer response curves are estimated for teff by Newcombe, 1989. These equations (equations 1 and 2) are shown
Scnail Regassa: Household Energy Supply and Land Use in the Central Highlands of Ethiopia: The Choice Between Firewood and Cattle Dung

in Appendix I. In this study, similar response curves are estimated for wheat using data obtained from fertilizer trials conducted by Alemaya University of Agriculture (Debre Zeit Research Center) to represent the production function where nitrogen and phosphorus are the available inputs. The response curves estimated for wheat show that the first type of functional form presented in appendix I is not suitable for explaining the variation (some coefficients have unexpected sign and low t-values). Hence, the functional form that takes the sum of nitrogen and phosphorus as the explanatory variable is included in the optimization. The major shortcoming of this functional form is that it does not matter which combination of nitrogen and phosphorus is applied. As a result, the optimization model chooses the element that can be obtained at the least cost.

Nitrogen and phosphorus can be obtained from manure, DAP or urea (equation 6, Appendix II). Manure and DAP are also sources of phosphorus (equation 7). Since prices and nitrogen and phosphorus contents of these fertilizers differ, fertilizer choice affects cost of fertilizer (FC) (equation 8). The cost of fertilizer in turn affects the objective value (Z). Equation 8 defines cost of fertilizer (FC) as the sum of the total quantity of fertilizer used multiplied by their prices.

The sum of crop area (X) has an upper limit which is equal to the amount of cultivable area (CA) in Ada woreda (equation 9). The sum of the cultivated land and the grazing area is considered as the
upper limit to the land available for crop production, livestock rearing and firewood tree planting. The area under forest and bushes is not included in the available land for two reasons: first, these lands are left uncultivated because they may be fragile. Second, areas under forests and bushes are not privately owned. Even if these areas have potential for tree planting, the existing ownership structure may discourage farmers. Milk production is a function of milk yield (Y) in litres of milk per cow per year multiplied by the number of cows (NCW) (equation 10, Appendix II).

The cattle stock in the study area should get a minimum quantity of feed to survive and to be productive. The sources of cattle feed in the study area are crop residues and grazing lands (equation 11).

In planning crop production, the number of oxen available in the area must be taken into consideration, because oxen power is needed for land preparation. Oxen power requirement can be approximated by the number of man-days required for plowing. Since plowing is done with a pair of oxen, it is assumed that oxen power requirement per quintal of output is equal to twice the amount of labour needed per quintal of output (equation 13). Land preparation is done during a period of 80 days. The division of $11p_iQ_i*2$ by 80 gives the amount of “ox-days” required for cultivation.
Equations 14 to 16 are labour constraints. Although there are 5 periods of agricultural activity, there is labour shortage only in three of the periods (periods 2, 3 and 4). That is why periods 1 and 5 are not in the constraints. Since farmers do not usually hire labour in period 2, the possibility of hiring labour in this period is not included (equation 14). Since wood can be harvested in a period in which farmers are not busy, it is not included in the constraint. The labour force in Ethiopia grows at a rate of 2.2% per annum (Griffin, 1992). Hence, the amount of family labour available during these periods is assumed to grow at this rate. It is also assumed that this labour has no opportunity cost.

Equations 17 to 21 represent the dynamics of tree planting. More specifically, the area of firewood harvested in year \( t \) (\( R_{f_t} \)) must be equal to the sum of area of wood that is ready for harvesting in year \( t-4 \) (\( A_{f_{t-4}} \)), because trees need at least five years to be ready for harvesting, minus area not harvested in year \( t \) (\( L_{A_t} \)) (equation 17). The area of wood not harvested in year \( t \) (\( L_{A_t} \)) can be harvested during the following years.

\( Q_{F_{new, t}} \) is the quantity of newly planted firewood consumed in year \( t \). The stock of wood from area not harvested in year \( t-1 \) (\( L_{A_{t-1}} \)) grows at an average rate of \( g_t \). This quantity plus wood from area planted in year \( t-4 \) (\( A_{f_{t-4}} \)) is equal to the total stock of wood available in year \( t \) from newly planted trees. Quantity of firewood (new) consumed in year \( t \) is lower than the
stock available in the year by an amount which is equal to 
LAG_t*yfwnw5 (equation 18).

The stock of wood in year t is given by the stock in year t-1 minus 
quantity of firewood-new consumed in year t-1 multiplied by the 
average growth rate of trees (equation 19). The amount of dung 
produced in a year is the maximum available for burning and 
manuring. The sum of the quantity of dung used as fuel (Qf_{dung,t}) 
and manure (MNR_t) must be less than or equal to the total dung 
production (dgo\_NOOX_t, dgcw\_NCW_t) equation 20). As 
mentioned earlier, the quantity of firewood and dung consumed 
and the energy deficit sum up to the total energy requirement of the 
area. A monetary value should be attached to the energy deficit. 
Otherwise, it would be cheaper to have the deficit than to burn 
firewood and cattle dung. The cost of energy deficit should reflect:

1. cost of imported fuel given as price of kerosene which is 
sold at about 0.7 Birr per litre;

2. the difficulty of supplying the rural population with 
imported fuel; and

3. the negative impact of a household energy deficit on soil 
productivity. The seriousness of energy deficit is not 
limited only to the problem of cooking, but it is also easily 
transmitted to the declining productivity of agricultural 
land since cow dung will be diverted from its traditional 
use as fertilizer to energy source.
Because of points 2 and 3 above, it is difficult to express the cost of energy deficit in terms of a monetary value. However, some monetary value must be attached to it for equation 1 to be meaningful. The arguments given above are justifications to make the cost of energy deficit more expensive than the cost of cattle dung and firewood. The computer program GAMS (General Algebraic Modelling Systems) is used to analyse the model (Brooke et al., 1988).

**Variables**

There are 24 decision variables in the model. These include quantity of teff, wheat, firewood, and milk production. Another way to look at these variables is to see the land use types, in other words, area allocated to the crops, livestock and firewood. When the model is run by taking the number of oxen and cows as decision variables, it was found out that the number of oxen and cows are twice the number available in the study area. This overestimates the amount of oxen available for plowing and the yearly manure production. When the number of cattle population is treated as a free variable, the dung produced is enough both for manuring and burning but this is impossible given the size of cattle population which really exists. Therefore, the existing cattle population is taken as the upper limit.
3. SCENARIO DESCRIPTIONS

The data are analysed under five different scenarios with regard to crop productivity, population growth and efficiency of energy utilization. The following are cases in which the data are analysed.

Case I (Present situation): In estimating the fertilizer response curve for wheat, yield data from wheat fertilizer trials are reduced by 30% to approximate the present situation (equation 3 - Appendix I). This curve is used in the model as a constraint (equation 4 - Appendix II). This case represents the farmer’s situation and helps to analyse why farmers are not planting trees, or alternatively, why they burn cattle dung.

Case II (High productivity): An alternative scenario is to assume that the farmers’ yield level is close to that of the researchers. The same yield data from fertilizer trials are reduced by only 10% and a fertilizer response curve is estimated for wheat (equation 5 - Appendix I). The estimated curve is included in the model as a constraint (equation 4 - Appendix II). This assumption is made to see the impact of a change in farmers’ productivity on their decision to plant or not to plant firewood. This tests the hypothesis that farmers are not planting firewood because they give priority to production of their food requirements as long as they can use dung as a source of energy. Other variables are the same as in case I.
Case III (Low population growth rate): To analyse the effect of change in the rate of population growth, the model is run assuming 2% growth. The minimum food and energy requirement in this case grows at a rate of 2% and the labour force is assumed to grow at a rate of 1.5%. In this case crop productivity and efficiency of energy utilization are assumed to be low.

Case IV (More efficient cooking stoves): In this case the impact of introducing more efficient stoves, while other conditions are unchanged is analysed. The introduction of more efficient cooking stoves reduces the amount of fuel required for cooking. To analyse the effect of the 20% more efficient cooking stoves, the minimum firewood requirement is reduced by 20%.

Case V (High productivity and low population growth rate): Model V is run assuming higher productivity as in case II and lower population growth rate as in case III to study the impact of the combination of the two. Here, energy requirement is equal to the demand for energy in the present situation as (case I).

4. RESULT

As discussed in section 3, the analysis is done under five different conditions with regard to wheat productivity, population growth rate and efficiency of energy utilization. In each case, the model is run for a time period of 10 and 20 years. Table 2 shows the summary of the results of the eight cases for both planning periods.
Case I (Present situation): First, the model is run for 10 years. The quantity of teff and wheat produced is sufficient to supply the minimum requirements in all years. The area allocated for teff increases to ensure the supply of food demand and reaches a maximum of 18% of the cultivable land. Milk production is constant (7,700,100 litres per year) throughout the planning period. This milk production is equivalent to 1.18 litres of milk per day per household. The result of the analysis in which yield of wheat is reduced by 30% to represent the farmers’ condition shows that it is more economical to apply commercial fertilizer than manure. The sum of nitrogen and phosphorus represented by W is 127 kilograms per hectare for teff and 91 kilograms per hectare for wheat. Since the functional form used does not differentiate between the proportion of nitrogen and phosphorus the optimization process chooses the least cost fertilizer, urea, which contains only nitrogen. This does not mean that no phosphorus should be applied, but indicates the sum of nitrogen and phosphorus (W) that should be applied. The important point here is that commercial fertilizer is more economical to apply than manure.
Table 2: Summary of major results

<table>
<thead>
<tr>
<th>CASES</th>
<th>t=10</th>
<th>t=20</th>
<th>t=10</th>
<th>t=20</th>
<th>t=10</th>
<th>t=20</th>
<th>t=10</th>
<th>t=20</th>
<th>t=10</th>
<th>t=20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case I (present situation)</td>
<td>101,749</td>
<td>IN/feasible</td>
<td>85.5</td>
<td>IN/feasible</td>
<td>1.6</td>
<td>IN/feasible</td>
<td>315</td>
<td>IN/feasible</td>
<td>539</td>
<td>IN/feasible</td>
</tr>
<tr>
<td>Case II (high productivity)</td>
<td>52,412</td>
<td>67,251</td>
<td>44</td>
<td>48</td>
<td>1,2,3,5,6</td>
<td>1,2,4,5,7-8,11,16</td>
<td>1,325</td>
<td>1,535</td>
<td>631</td>
<td>772</td>
</tr>
<tr>
<td>Case III (Low population growth rate)</td>
<td>96,416</td>
<td>108,848</td>
<td>84.9</td>
<td>86.4</td>
<td>1,6</td>
<td>1,6,11,16</td>
<td>315</td>
<td>315</td>
<td>546</td>
<td>671</td>
</tr>
<tr>
<td>Case IV (more efficient cooking stoves)</td>
<td>74,026</td>
<td>94,327</td>
<td>77.8</td>
<td>84.6</td>
<td>1,6</td>
<td>1,6,11,16</td>
<td>315</td>
<td>315</td>
<td>579</td>
<td>709</td>
</tr>
<tr>
<td>Case V (high productivity &amp; low population growth rate)</td>
<td>46,984</td>
<td>52,029</td>
<td>41</td>
<td>41</td>
<td>1,6</td>
<td>1,2,4,5,7,8,9,11,16</td>
<td>1332</td>
<td>1585</td>
<td>637</td>
<td>787</td>
</tr>
</tbody>
</table>
firewood is planted in only 1,576 hectares. This area is regarded as grazing land in the present land use system (MOA, Debre Zeit). Usually, fragile lands are left uncultivated and therefore, are not included in the area that can be planted to crops in this analysis.

Labour is hired in periods 3 and 4. In period 3 the highest number of man-days of hired labourers is equal to 1,364,300. This is equivalent to 76 man-days per household or 2.5 months of hired labour per household. In period 4, a maximum of 1,003,700 man-days is hired in year 1. This is equivalent to 56 man-days or 1.9 months per household. This is not an unrealistic figure, but in reality they hire a number of workers at a time and the task will be accomplished in fewer number of days.

The area allocated for grazing is zero in all years except one, because, enough feed can be obtained from crop residues given the amount of feed required annually per cow and per ox (22.99 and 27.37 quintals of dry matter respectively) and straw production from teff and wheat (2.26 and 1.57 quintals of dry matter per quintal of grain output). The number of cows is equal to the maximum possible, while the number of oxen is lower than the number required to produce teff and wheat. This shows that Ada woreda has enough number of oxen although this may vary between individual farmers. Grazing land is equal to 1,576 hectares in year 9. This is not a useful output because of the fact that the model assumes that no firewood is required after year 10.
Dung and wood from already existing trees are used as sources of fuel in all years. On average 101,749 tons of dung per year is used as fuel and is the source of about 85.5% of the energy required for cooking (Table 2). Trees are planted on 1,576 hectares in years 1 and 6. This area is not a cultivable land. In the model, it is specified as an area that can be allocated either for grazing or tree planting. Firewood planting is zero in years 2, 3, 4, and 5, because, the uncultivable land (1,576 hectares) is already planted with trees in year 1 and the cultivable lands are being used to grow crops. Wood from the trees planted in year 1 is harvested in year 5. Therefore, there will be tree planting in year 6. In year 5, the amount of dung burned is reduced by 61,133 tons from the amount burned in year 4, although the energy requirement increased by 3%. Similarly, since more firewood is available in year 10, the amount of dung burned in year 10 is 72,210 tons which is lower than that of year 9. There is no energy deficit in all years. The sum of the discounted yearly income is 539,000,000 Birr.

The model was also run for a time period of 20 years and found to be infeasible. It is infeasible, because in the long run, the minimum food, feed and fuel requirement can not be satisfied given the amount of resources available and the high rate of population growth in the study area.

Case II (High productivity): The model was run assuming that farmers can achieve a productivity level of 10% less than the
potential yield. Since in this case they can produce their minimum requirements with less area of land, there is a possibility to plant trees. Like the previous case, minimum teff and wheat requirement is fulfilled. The main difference between the results in case I and II, where the analysis is done for 10 years, is that there will be no dung burning after year 5 except for years 7 and 8 in case II. In this scenario, the average dung burning is equal to 52,412 tons/year. This is equal to 52% of the yearly average dung burning in case I and only 44% of the energy required for cooking comes from dung. This case was also analysed for a time period of 20 years. The yearly average dung burning and its contribution to total energy consumption is more than that of the 10-year period. This is because the demand for food and energy is higher in the long run than in the short run and more land is required to produce the minimum grain requirement. The sum of the discounted income is 631,000,000 and 772,000,000 Birr for the 10 and 20 years of planning respectively.

Case III (Low population growth rate): In this case, the population is assumed to grow at a lower rate (2%) and the result shows that its impact on dung burning is insignificant. As a result of the change in the population growth rate, the contribution of dung as fuel declined by only 0.6% (Table 2). The average yearly firewood planting is 315 hectares and is the same as in the present situation (case I). The main difference between the present situation (case I) and the low population growth rate (case III) is that the later is feasible for 20 years.
Case IV (More efficient cooking stoves): The use of more efficient cooking stoves certainly reduces the fuel requirement. In this case, the contribution of dung to total fuel consumption is 77.8% for t=10 (Table 2). This is lower than case I and case III by 7.7 and 7.1% in that order. For t=20, dung accounts for 84.6% of the total fuel requirement and the yearly average of firewood planting is equal to that of case I (315 hectares).

Case V (High productivity and more efficient cooking stoves): The effect of a simultaneous change in wheat productivity and population growth rate is analysed and the result is shown in Table 2. The percentage share of dung in total fuel consumption is 41% for both time periods. For t=10, this is a 44.5% reduction as compared to case I (present situation). On average, 1332 and 1585 hectares is planted with firewood for t=10 and t=20, respectively. The sum of the discounted income is higher than the previous cases for both time periods.

5. DISCUSSION

Case I (Present situation): The result of case I which approximates the present situation shows that farmers are rational in using dung as fuel and in applying commercial fertilizer rather than manure. The main reason for this is that they need a given minimum quantity of grain to feed their family. This requires allocation of land to crop production rather than to tree planting.
As long as firewood is not available in sufficient amount, farmers are rational in not using dung as fertilizer. This result is in agreement with the finding of Newcombe, 1989, who concluded that sound logic is applied by farmers who sell their dung to urban market as a source of cash. In the present market price, dung returns more when sold as fuel than it does when used as a fertilizer to produce additional grain.

Wheat covers about 85% of the land in the first year and it declines throughout the years. Actually farmers are producing more teff (54%) than wheat (30%). This discrepancy between what is actually happening and the result of the analysis is due to the fact that the model does not take suitability of an area to a given crop into account.

Although the data from MOA, (Debre Zeit) shows that there is about 1576 hectares of grazing land, the result of the analysis shows that it is not economical to allocate land for grazing. Cattle feed can be obtained from straw of teff and wheat. The area of grazing land per head of cattle is equal to 0.03 hectare which is equivalent to 44 kilograms of DM (Dry Matter) per year for an ox or a cow (yield of natural pasture is equal to 1.5 tons of DM per hectare per year). The annual dry matter requirement of an ox is 2300 kilograms. 44 kilograms is 1.9% of the requirement. Therefore, the 1576 hectares which is regarded as grazing land by MOA (Debre Zeit) contributes very little to cattle feed. Crop residue is the major source of livestock feed in Ada woreda. This
confirms that the output of this analysis which allocates no land for grazing is not a strange result. As the result of case I (t=20), the present farming system is not sustainable in the sense that it will be impossible to produce enough food, feed and fuel in the long-term. Some measures have to be taken to improve the situation in such a way that the area can support the growing population.

Case II (High productivity): If it is possible to change farmers' productivity, the decision farmers make should be different from the present land use system (case II). The increase in the average yearly planting of firewood by more than 4 times justifies that afforestation is economical to satisfy the demand for energy as long as farmers are able to produce their food. This also implies that the amount of dung not used as fuel will have no opportunity cost and can be used for manuring. This makes manure the cheapest source of nitrogen and phosphorus (as compared to commercial fertilizers). The finding of Newcombe confirms this result. In economic terms, it would appear that in rural areas afforestation is justified in order to replace dung with wood. Dung could then be used as fertilizer and the peasants would get greater value for the dung than when it is used as fuel (Newcombe, 1989). The cost of energy from dung burning is about 22 Birr per joules and about 8 Birr per Gigajoules for wood. Wood can be produced at a cost less than half the cost of dung.
Case III (Low population growth rate), IV (More efficient cooking stoves) and V (high productivity and low population growth rate): Although the results are not as attractive as the increase in wheat productivity, lower population growth rate and more efficient cooking stoves are alternatives that can help to solve the problem. Decreasing the population growth rate will not significantly reduce dung burning, but can help to maintain the present situation for a longer period. This is also true for case IV (more efficient cooking stoves). The combination of high wheat productivity and low population growth rate has resulted in a remarkable reduction in the use of dung as fuel. The reduction would be higher for a simultaneous change in productivity, population growth rate and efficiency in energy utilization.

6. CONCLUSIONS AND RECOMMENDATIONS

This paper studies why farmers burn dung rather than use it as fertilizer and tries to look for possible means of intervening in the problem of firewood shortage. Farmers' decisions with regard to resource allocation are analysed using a non-linear dynamic optimization model. Moreover, models of alternative scenarios concerning crop productivity, population growth rate and introduction of more efficient cooking stoves are built and the impacts of the different scenarios on resource allocation and dung burning are analysed.
In addition to being a source of nitrogen and phosphorus and other major plant nutrients, cattle dung has many advantages over commercial fertilizer. It improves the physio-chemical properties of the soil by increasing the organic matter content, thereby creating a good environment for microorganisms. Besides, it does not impose additional demand for foreign currency as in the case of imported fertilizers. In spite of this, farmers rationally decide not to use dung as manure, because the concern for maintenance of land quality can not be the primary objective for subsistence farmers. Dung returns more when sold or burned than when used as manure to increase yield. This indicates that market signals can not be relied upon to make decision on the management of natural resources such as land.

To change the current practice, some means of intervention through agricultural policy is needed. Increased productivity is one alternative to change farmers' decision on dung burning. It is possible to protect and even improve the economic and social welfare of people while maintaining the sustainability of the environment, but this can be achieved only if it is possible to supply the basic requirements. To improve crop productivity in the area, there must be a strong agricultural extension service so that farmers can achieve a productivity level close to that of researchers.

Another policy issue is family planning to reduce population pressure. Population pressure is one of the root causes of poverty
and degradation of natural resources. Family planning and other population related policies can be possible means of changing the situation. The promotion of more efficient cooking stoves is also recommended. Family planning and more efficient cooking stoves, when considered separately, cannot bring about a significant reduction of dung in the total fuel consumption. However, these measures combined with higher crop productivity can bring about a remarkable improvement in the sustainability of the farming system of Ada woreda.

One limitation of this study is that, due to shortage of suitable data, distinction is not made between the two major (light and heavy) soil types of Ada woreda. Since aggregate data used for the analysis, the results of the analysis may not precisely represent the situation in each case. Moreover, individual differences between farmers with regard to resource endowment and objectives are not taken into account. Another limitation of the study is that some of the data used in the analysis are outdated. Although the outcome of the study can be used to propose measures that will help to deal with the problem caused by dung burning, the present situation can better be explained by collecting and analysing more recent data.

In this study, provision of fuel that can replace cattle dung is the main issue. Hence, a fast growing tree, eucalyptus, is used in the analysis. The problem can also be analysed using multi-purpose trees that can supply fodder, firewood and improve soil fertility as well. Distinguishing the two soil types and different classes of
farmers are also suggestions for further research. In this study, the long term impact of dung burning is not taken into account. The yearly decline in land productivity should be included to see its effect on the population support capacity of the land in the far future.

REFERENCE


APPENDIX I: Fertilizer response functions\(^5\)

Fertilizer response curves for teff are given by equation 1 and 2.

*Equation 1:*

\[
Y = 7.1 + 0.038N + 0.086P - 0.0004N^2 - 0.00038P^2 - 0.00063NP
\]

Where: \(Y\) = yield in quintals per hectare  
\(N\) = nitrogen in kilograms per hectare  
\(P\) = phosphorus in kilograms

*Equation 2:*

\[
Y = 755(kg) + 7.64X - 0.0219X^2
\]

Where: \(Y\) = yield in kilograms per hectare  
\(X\) = combined \(N+P\) application in kilograms

Fertilizer response curves estimated using data obtained from fertilizer trials on wheat (Experiments conducted by Debre Zeit Research Center).

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\(^5\) Equation 1 and 2 are published in Newcombe, 1989
APPENDIX II

Maximise $Z$

$$Z = \sum (\sum (P_i \cdot Q_a) - \sum s_{r_i} \cdot s_{p_i} \cdot Q_a - \sum h_{r_i} \cdot h_{p_i} \cdot Q_a - F_c - w_{s_i} \cdot H_{s_i} - w_{s_i} \cdot H_{s_i} - W_{PC} - W_{HC} - ced \cdot \text{EMDEF} ) (1 + r)^{-1}$$

subject to

$$Q_a \geq (M_{rs_i}) \cdot (1 + g_{p_i})^{-1}$$

for all $i$ and $t$ (2)

$$\sum s_{r_i} \cdot Q_a + \text{ENDEF} = \text{ENREQ} \cdot (1 + g_{p_i})^{-1}$$

for all $t$ (3)

$$Q_a = Y_{s_i}, W_{s_i}, X_{s_i}$$

for all $i$ and $t$ (4)

$$W_{s_i} = N_{s_i} + P_{s_i}$$

for all $i$ and $t$ (5)

$$\sum P_{s_i} = \text{RMNR}_{s_i} \cdot \text{DAP}_{s_i}$$

for all $i$ and $t$ (6)

$$\sum P_{s_i} = \text{RMNR}_{s_i} \cdot \text{DAP}_{s_i}$$

for all $t$ (7)

$$F_{c_i} = \sum \text{dapp} \cdot \text{DAP}_{s_i} + \sum \text{urea} \cdot \text{UREA}_{s_i} + \sum m_{mnr} \cdot \text{MNR}_{s_i}$$

for all $t$ (8)

$$\sum X_{s_i} \leq C_{s_i}$$

for all $t$ (9)

$$Q_{w_{s_i}} = Y_{w_{s_i}} \cdot NCW$$

for all $t$ (10)

$$\sum Y_{w_{s_i}} \cdot G_{s_i} \cdot \text{GRLD}_{s_i} \geq \text{fd}_{s_i} \cdot NCW + \text{fd}_{s_i} \cdot \text{NOOX}_{s_i}$$

for all $t$ (11)

$$\sum X_{s_i} \cdot \text{GRLD}_{s_i} \leq CGA$$

for all $t$ (12)

$$\text{NOOX}_{s_i} = \left( (\sum 11 \cdot P_i \cdot Q_{a_i} ) \right) / 80$$

for all $t$ (13)

$$\text{ld} \cdot Q_{w_{s_i}} + \text{hiwp} \cdot Q_{w_{s_i}} \cdot \text{ifwp} \cdot \text{AF}_{s_i} \leq L_{s_i} \cdot (1 + g_{l_i})$$

for all $t$ (14)

$$\text{lnw} \cdot Q_{w_{s_i}} + \text{lnw} \cdot Q_{w_{s_i}} \leq L_{s_i} \cdot (1 + g_{l_i})^{-1} + H_L$$

for all $t$ (15)

$$\text{ith} \cdot Q_{w_{s_i}} + \text{ith} \cdot Q_{w_{s_i}} \leq L_{s_i} \cdot (1 + g_{l_i})^{-1} + H_L$$

for all $t$ (16)

$$\text{RF}_{s_i} = \text{LAG}_{s_i} + \text{AF}_{s_i} - \text{LAG}$$

for all $t$ (17)

$$\text{QF}_{w_{s_i}} = \left( \text{LAG}_{s_i} + \text{yfwm}_{s_i} \right) \cdot (1 + g_{l_i}) + \text{AF}_{s_i} + \text{yfwm}_{s_i} \cdot \text{LAG} + \text{yfwm}_{s_i}$$

for all $t$ (18)

$$\text{S}_{s_i} = \left( \text{S}_{s_i} - \text{QF}_{w_{s_i}} \right) + \text{gl} + \text{AF}_{s_i} + \text{yfwm}_{s_i}$$

for all $t$ (19)

$$\text{QF}_{w_{s_i}} + \text{MNR} \leq \text{dgcw} \cdot \text{NOOX}_{s_i} + \text{dgcw} \cdot \text{NCW}$$

for all $t$ (20)

$$\sum \text{RF}_{s_i} \leq \sum \text{AF}_{s_i}$$

for all $t$ (21)

$$\sum X_{s_i} + \text{GRLD}_{s_i} + \text{LAG}_{s_i} + \text{AF}_{s_i} + \text{AF}_{s_i} + \text{AF}_{s_i} + \text{AF}_{s_i} \leq \text{CGFA}$$

for all $t$ (22)

$$\text{WPC}_{s_i} = \text{pc} \cdot \text{RF}_{s_i} + \text{yfwm}_{s_i} + \text{pc} \cdot \text{QF}_{w_{s_i}}$$

for all $t$ (23)

$$\text{WHC}_{s_i} = \text{hc} \cdot \text{RF}_{s_i} + \text{yfwm}_{s_i} + \text{hc} \cdot \text{QF}_{w_{s_i}}$$

for all $t$ (24)
ABSTRACT

The evidence derived from this study indicates that male and female household heads often have very different rights and responsibilities with respect to resource ownership and decision making in the process of agricultural production. In terms of access to and control of resources, it was found that there was no significant difference between male-headed and female-headed households particularly with respect to access to farm land. There were, however, significant differences in terms of number of cattle owned and family size between male-headed and female-headed households. Male-headed households have more access to education than female-headed households. Lack of education, draft power and labor will limit access of female-headed households to agricultural technology which will have a negative effect on agricultural production. Women in both female-headed and male-headed households make central decisions in allocating resources to crop and livestock production as well as in consuming and selling of the products and in keeping of the proceeds. Many decisions in male-headed households were made jointly by husband and wife.
1. INTRODUCTION

There is a growing recognition that men and women often have very different rights and responsibilities with respect to resource use and decision making. In gender analysis, it is recognized that the roles of women and men are largely determined socially rather than biologically (Rosaldo and Lamphere, 1974). This recognition has resulted in a number of studies documenting the different roles of women and men in various farm, non-farm, food preparation, household maintenance and child care activities (McSweeney, 1979; Dey, 1980; Whitehead, 1985; Adepoju and Oppong, 1994; Bryceson 1995). Other studies have shown that women and men are faced by differential access to new technology, education, health care and other resources (Ahmed, 1985; Abu and Oppong, 1987; Stamp, 1989). Furthermore, it has been recognized that both gender and household based approaches are useful frameworks for targeting policy and interventions in rural areas (Warner, et al. 1997). This study attempts to add to the growing empirical evidence on the role of gender in agricultural production. It assesses the role of gender in terms of resource ownership and decision making process in crop-livestock production in the mixed farming systems of Ada, Lume and Gimbichu woredas in the central highlands of Ethiopia. The specific objectives of the study were to determine the differential access to and control of resources of male-headed and female-headed households and to compare differences in their decision making processes.
Ethiopia is the largest producer of wheat (durum and bread) in Sub-Saharan Africa (SSA), accounting for over half the total wheat growing area (Hailu Beyene et al. 1990; Workeneh et al. 1994). About 64% of the area and 69% of the production of wheat are concentrated in the central and northern regions of the country. Tetraploid wheat (durum-indigenous to Ethiopia) is produced predominantly in the highlands of Shewa, Gojam, Bale and Arsi, while bread wheat is grown mainly in the Bale and Arsi highlands covering about 60% and 40% of the total national wheat area respectively (Tefsaye Tessema and Getachew Belay, 1991).

Ada, Lume and Gimbichu woredas are found in the central highlands where wheat is predominantly grown. Ada Woreda, about 40 km to the south-east of Addis Ababa, covers 1750 sq km. The largest part of it (66%) lies above 1800 m above sea level (Gryseels and Anderson, 1983). Much of the land in Ada is eroded and poorly drained. July and August are the wettest months, while April and May are the hottest months. The major crops grown are teff, wheat, barley, faba bean, chickpea and lentils (Workneh Negatu, 1989). Lume woreda lies north-east of Debre Zeit at an altitude ranging from 1700 to 2100 m. July and August are the wettest months while April, May and June are the hottest months. The major crops grown are teff, wheat, haricot bean, maize, chickpea, barley and faba bean. Gimbichu Woreda, at an average altitude of 2450 m above sea level, borders Ada on the northern side of Debre Zeit. July and August are, on average, the wettest
months. The major crops grown are wheat, teff, chickpea and faba bean. The major soil type in all the three woredas is vertisol.

The gender-disaggregated data used for the analysis were collected in 1996 and 1997. Multi-stage random sampling was used to select peasant associations (PAs) in each woreda. In the study areas, on average, about 90% of the households were found to be male-headed, while only 10% were female-headed. Female-headed households were those which were managed by a widow, divorced or single woman without the mediation of a husband, father or male relative in the routine day to day activities of that household. Male-headed households were those where a husband was present and made the final decision on important issues pertaining to the household (Starkey, et al. 1994). The male and female (de jure) households heads were purposively sampled in order to include enough female-headed households. A sample of 180 household heads (60 from each woreda) were selected for this study. Ninety-nine (55%) of the sampled households were male-headed, while eighty-one (45%) were female-headed households. The households were more or less homogenous in types of crops grown and farming operations.
2. RESULTS AND DISCUSSION

2.1 Socio-economic Characteristics of Female-headed and Male-headed Households

A summary of the socio-economic characteristics of male-headed and female-headed households is shown in Table 1. The average household size of male-headed households is 7.9 persons and when compared to 5.8 persons in female-headed households, this difference is significant ($t = 5.9; \text{ sig.} = 0.00$). However, except for daughters ($t = 4.0, \text{ Sig.} = 0.00$), there is no significant difference between male-headed and female-headed households in terms of the number of other members of the family. In general, female-headed households have been found to be smaller in size in comparison with male headed households in developing countries (Buvinic and Gupta, 1997). This implies that the male-headed households have more labor available than female-headed ones. Furthermore, it has been observed elsewhere in Africa that female farmers tend to limit their labor time in farm activities due to a heavy commitment to domestic chores (Chipande, 1987). Male-headed households are able to undertake their farm operations in a more timely fashion leading to higher productivity than female-headed households. Since labor in turn is one of the critical resources needed to effectively carry out farm operations and to adopt improved technologies, male-headed households, according to this study, could have a better chance of benefiting from the opportunities that could be derived from readily available family
labor. Again, elsewhere in Africa, it has been shown that labor constraint in female-headed households limits adoption of innovations (Chipande, 1987).

The average age of male household heads was 47.5 years compared with 47.2 years for female household heads (Table 1). This difference was not significant. Nearly 86% of female household heads were illiterate, about 12% attended literacy classes, while around 1% had primary and secondary education. In contrast, about 63% of male household heads were illiterate, 25% had attended literacy classes, while 10% and about 2% had primary and secondary education, respectively. In general, there was a difference in terms of access to education between male and female household heads. Other studies have found similar results. For instance, in Uganda, more than half of the women-headed households had received no schooling compared to less than a quarter of their male counterparts (Appleton, 1996). Likewise, in Tanzania, 96% of male-headed households had some formal education while 82% of female-headed households had no formal education (Bisanda and Mwangi, 1996). Hence due to their higher education, male-headed households tend to have higher productivity as they are better to decode new production technology than female-headed households. All female-headed households had farming as their main occupation, since the poor educational level of female-headed households did not give opportunities for employment in the off-farm labor market. Hence,
policies that expand education will lead female-headed households improve their access to economic opportunities.

Table 1. Socio-economic characteristics of female and male-headed households in Ada, Lume and Gimbichu weredas, 1996/97

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Gender</th>
<th>T-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (N = 81)</td>
<td>Male (N = 99)</td>
</tr>
<tr>
<td>Household size (no.)</td>
<td>5.8</td>
<td>7.9</td>
</tr>
<tr>
<td>No. of sons</td>
<td>2.4</td>
<td>2.7</td>
</tr>
<tr>
<td>No. of daughters</td>
<td>1.9</td>
<td>2.8</td>
</tr>
<tr>
<td>No. of relatives</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td>No. of non-relatives</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Age of household head</td>
<td>47.2</td>
<td>47.5</td>
</tr>
<tr>
<td>Access to education (%)</td>
<td>14.4</td>
<td>37.2</td>
</tr>
<tr>
<td>Farming as main occupation (%)</td>
<td>100</td>
<td>97</td>
</tr>
<tr>
<td>Farm size (ha)</td>
<td>2.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Cultivated wheat area (ha)</td>
<td>0.64</td>
<td>0.84</td>
</tr>
</tbody>
</table>

* = significant at one percent

2.2 Crop Production: The Case of Wheat

The average farm size for male-headed households was 2.9 ha, while it was 2.4 ha for female-headed households. The average farm size of both groups were not significantly different. This could be attributed to the nature of land ownership in the study area. Traditionally, in Oromo culture, women could only have access to land through marriage and even a widow’s land is still belonged to the husband. However, there has been a policy change
which enables female-headed households own land in Ethiopia. There is no overt discrimination of women by law with regard to land inheritance, or ownership and management of land, but the rights of women have not been asserted forcefully in the major legislation (Daniel Haile, 1980).

The area of land allocated to wheat production by male-headed and female-headed households was 0.84 ha and 0.64 ha, respectively, and it was not significantly different between the two groups. In male-headed households, the decision to plant wheat was made by the husband (male-head) 56% of the time; a joint decision between the husband and wife was made 44% of the time. In the case of female-headed households, the female-head made decision on her own 89% of the time and jointly with her son about 9% of the time (Table 2).

In general, respectively about 59% and 43% of male-headed and female-headed households grew wheat during the survey year. Again respectively about 28% and 19% of male-headed and female-headed households grew improved wheat varieties. Although the adoption of improved wheat varieties by both groups was low, the adoption by male-headed households was still higher than that of female-headed households. This was due to the relatively higher education of male household heads, which enables them to decode new production technology. Despite this, much needs to be done in terms of enhancing the use of improved
wheat varieties by both male-headed and female-headed households.

Almost all male-headed and female-headed households reported that they had been using commercial fertilizer, particularly urea and DAP, in the production of wheat. In male-headed households, the decision to use fertilizer was made mostly (59.3%) by the husband; and about 36% of the decision was jointly made by husband and wife (Table 2). In female-headed households, about 88% of the decision to use fertilizer was made by the female head while about 3% of the decision was jointly made with her son.

On the other hand, using manure to maintain soil fertility is not common with the farmers in the study area. Only about 8% and 12% of female-headed and male-headed households respectively, used manure to maintain soil fertility. There was in fact, a negative correlation between the number of cattle owned and the use of animal manure. The decision to use manure in male-headed households was made by the head in most cases (60%) while in female-headed households, the head made the decision all the time (Table 2).

As elsewhere in Ethiopia, farmers in the study area are aware of the advantages of using animal manure as fertilizer. However, its use is minimal because, firstly, the number of livestock kept by the farmers is limited due to the scarcity of grazing land; secondly,
since wood is scarce, farmers use animal dung as fuel and thirdly, land holdings distributed to them are far apart and this makes it difficult to transport the dung to every field (Behailu et al. 1996). Other studies have shown that selling animal dung cakes (made from a mixture of manure and straw) has become a major source of cash income (Teklu and Teklu, 1995).

Women in the study area both female-headed and male-headed households make central decisions in allocating resources to crop and livestock production as well as in consumption and selling of the products and in keeping of the proceeds, in an attempt to optimize family welfare (Chipande, 1987; Dessalegn Rahmato, 1991). This contradicts Boserup’s (1970) contention that in plough agriculture women either do not do any farm work or are only slightly involved.

Table 2. Decision making by male-headed and female-headed households of wheat growing, use of fertilizer and manure in Ada, Lume and Gimbichu Woredas, 1996/97

<table>
<thead>
<tr>
<th>Decision making</th>
<th>Female (N = 81)</th>
<th>Male (N = 99)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Head</td>
<td>Son</td>
</tr>
<tr>
<td>Decision to plant wheat (%)</td>
<td>89.1</td>
<td>1.6</td>
</tr>
<tr>
<td>Decision to use fertilizer (%)</td>
<td>87.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Decision to use manure (%)</td>
<td>100</td>
<td>-</td>
</tr>
</tbody>
</table>
2.3 Livestock Production

The types of livestock owned by the different households are shown in Table 3. There was a significant difference in ownership of cattle between the two groups. This could be attributed to the prevailing culture where women were not allowed to plough land as a result of which the number of oxen they own could be fewer than what men own. Furthermore, other studies have shown that the extra labor involved in managing animals has discouraged female-headed households from owning oxen (Starkey et al. 1994). This has implications for draft power availability. The relatively large number of cattle owned by male-headed households enable them accomplish farm operations without delay since it ensures a relatively adequate supply of draft power. It has also been shown that the number of livestock owned affects the adoption of technologies positively (Chilot Yirga et al. 1996). The observed significant difference in cattle ownership might have been one of the reasons why male-headed households had higher adoption rates for improved wheat varieties. Keeping sheep and goats is not common for both female-headed and male-headed households and there was no significant difference in ownership of small ruminants between the two groups (Table 3). There was a significant difference in the ownership of equines (donkeys and mules) between female-headed and male-headed households (Table 3). This is because even though both male-headed and female-headed households use equines, predominantly donkeys, for transporting their produce to the market, male-heads often ride mule, which is
Livestock are not commonly sold in the study area. During the survey year, there was no significant difference in the sale of livestock between male-headed and female-headed households. Although, poultry is commonly sold (Tadelle and Oegle, 1996), there was not much selling during the survey year. Both male-headed and female-headed households have similar reasons for keeping different classes of livestock besides the proceeds from sale of live animals. These include consumption of by-products, draft power, consumption of main products and transport.

Table 5. Control over crop/livestock output by male-headed and female-headed households in Ada, Lume and Gimbichu Woredas, 1996/97

<table>
<thead>
<tr>
<th>Crop/livestock output</th>
<th>GENDER</th>
<th>Male (N =99)</th>
<th>Female (N=81)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Husband</td>
<td>Wife</td>
<td>Both</td>
</tr>
<tr>
<td>Decision to sell crops (%)</td>
<td>53.9</td>
<td>-</td>
<td>56.1</td>
</tr>
<tr>
<td>Decision to keep proceeds from sale(%)</td>
<td>55.1</td>
<td>8.2</td>
<td>36.7</td>
</tr>
<tr>
<td>Decision to look after the produce (%)</td>
<td>49</td>
<td>4.1</td>
<td>45.9</td>
</tr>
<tr>
<td>Decision how much to consume of the produce (%)</td>
<td>27.6</td>
<td>-</td>
<td>72.4</td>
</tr>
<tr>
<td>Decision to sell livestock (%)</td>
<td>89.8</td>
<td>-</td>
<td>10.2</td>
</tr>
</tbody>
</table>
2.3 Livestock Production

The types of livestock owned by the different households are shown in Table 3. There was a significant difference in ownership of cattle between the two groups. This could be attributed to the prevailing culture where women were not allowed to plough land as a result of which the number of oxen they own could be fewer than what men own. Furthermore, other studies have shown that the extra labor involved in managing animals has discouraged female-headed households from owning oxen (Starkey et al. 1994). This has implications for draft power availability. The relatively large number of cattle owned by male-headed households enable them accomplish farm operations without delay since it ensures a relatively adequate supply of draft power. It has also been shown that the number of livestock owned affects the adoption of technologies positively (Chilot Yirga et al. 1996). The observed significant difference in cattle ownership might have been one of the reasons why male-headed households had higher adoption rates for improved wheat varieties. Keeping sheep and goats is not common for both female-headed and male-headed households and there was no significant difference in ownership of small ruminants between the two groups (Table 3). There was a significant difference in the ownership of equines (donkeys and mules) between female-headed and male-headed households (Table 3). This is because even though both male-headed and female-headed households use equines, predominantly donkeys, for transporting their produce to the market, male-heads often ride mule, which is
quite uncommon among female-heads. There was no significant difference between female-headed and male-headed households in the ownership of poultry (Table 3).

Table 3. Average number of different classes of livestock owned by male-headed and female-headed households in Ada, Lume and Gimbichu Woredas, 1996/97

<table>
<thead>
<tr>
<th>Class of livestock</th>
<th>GENDER</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (N = 81)</td>
<td>Male (N = 99)</td>
<td>T-value</td>
<td></td>
</tr>
<tr>
<td>Cattle</td>
<td>4.9</td>
<td>6.4</td>
<td>2.92*</td>
<td></td>
</tr>
<tr>
<td>Equine (donkeys and mules)</td>
<td>0.6</td>
<td>0.9</td>
<td>3.1*</td>
<td></td>
</tr>
<tr>
<td>Sheep</td>
<td>1.8</td>
<td>1.8</td>
<td>-0.17 (NS)</td>
<td></td>
</tr>
<tr>
<td>Goat</td>
<td>0.8</td>
<td>1.2</td>
<td>1.3 (NS)</td>
<td></td>
</tr>
<tr>
<td>Poultry</td>
<td>2.5</td>
<td>3.4</td>
<td>1.67 (NS)</td>
<td></td>
</tr>
</tbody>
</table>

* = significant at one of percent.

Members of a given household are responsible for different livestock keeping activities, viz., feeding, treating sick animals, slaughter and sale, transport to the market and product processing. In male-headed households, the husband is mainly responsible for animal feeding, treating, slaughtering and transporting, while the wife is mainly responsible for processing animal products. The other members of the family (sons, daughters, relatives and non-relatives) mainly assist in animal treatment, slaughter and transporting. In female-headed households, other members of the family have the main responsibilities for all livestock activities (Table 4).
But it is important to note that in Ethiopia, even the sexual division of labor, and gender roles in general, vary from one cultural setting to another depending on whether the plough or the hoe is the main means of cultivation (Dessalegn Rahmato, 1991). For instance, elsewhere in Ethiopia, women do not sell or buy bulls, oxen, heifers or cows (Dessalegn Rahmato, 1991).

Table 4. Responsibilities for various livestock activities by male-headed and female-headed households in Ada, Lume and Gimbichu Woredas, 1996/97

<table>
<thead>
<tr>
<th>Livestock activity</th>
<th>GENDER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (N = 81)</td>
</tr>
<tr>
<td></td>
<td>Head  Other</td>
</tr>
<tr>
<td>Animal feeding (%)</td>
<td>38.2   61.8</td>
</tr>
<tr>
<td>Animal treatment (%)</td>
<td>31.1   68.9</td>
</tr>
<tr>
<td>Animal slaughtering (%)</td>
<td>35.6   64.4</td>
</tr>
<tr>
<td>Animal transport (%)</td>
<td>41.1   58.9</td>
</tr>
<tr>
<td>Animal product processing</td>
<td>3.3    96.7</td>
</tr>
</tbody>
</table>

The decision to sell livestock is made about 90% of the time by the husband in the male-headed households, while it is made by the head about 95% of the time in female-headed households. In female-headed households, decisions to sell crops, keep proceeds from sale, look after the produce and consumption of the produce are mainly made by the head. But in male-headed households these decisions are jointly made (Table 5).
Livestock are not commonly sold in the study area. During the survey year, there was no significant difference in the sale of livestock between male-headed and female-headed households. Although, poultry is commonly sold (Tadelle and Oegle, 1996), there was not much selling during the survey year. Both male-headed and female-headed households have similar reasons for keeping different classes of livestock besides the proceeds from sale of live animals. These include consumption of by-products, draft power, consumption of main products and transport.

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<tr>
<th>Crop/livestock output</th>
<th>GENDER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male (N=99)</td>
</tr>
<tr>
<td></td>
<td>Husband</td>
</tr>
<tr>
<td>Decision to sell crops (%)</td>
<td>53.9</td>
</tr>
<tr>
<td>Decision to keep proceeds from sale(%)</td>
<td>55.1</td>
</tr>
<tr>
<td>Decision to look after the produce (%)</td>
<td>49</td>
</tr>
<tr>
<td>Decision how much to consume of the produce (%)</td>
<td>27.6</td>
</tr>
<tr>
<td>Decision to sell livestock (%)</td>
<td>89.8</td>
</tr>
</tbody>
</table>
4. CONCLUSIONS

The evidence derived from this study indicates that male and female-household heads often have very different rights and responsibilities with respect to resource ownership and decision-making in the process of agricultural production. In terms of access to and control of resources, it was observed that there is no significant difference between male-headed and female-headed households particularly with respect to access to farm land. There are, however, significant differences in terms of number of cattle owned and family size between male-headed and female-headed households. Male-headed households also had more access to education than female-headed households. Lack of education, draft power and labor will limit access of female headed households to agricultural technology which will have a negative effect on agricultural production.

In both female-headed and male-headed households, women make central decisions in allocating resources to crops and livestock production as well as for consumption, in selling of the products and in keeping of the proceeds. But in male-headed households many decisions are made jointly by husband and wife.

Gender is culture neutral and interest in gender relations derives from its explanatory power as a primary organizing principle of society including agricultural production. Hence, the significance
of gender should not only be seen as a means of categorizing household headship. It is also a basic key to understanding structures and actions including production relationships within and across households, setting goals and priorities, mobilizing resources, willingness to take risk, and decision making vis-a-vis the rights to be derived from increased farm production. In fact, even in Ethiopia, one may witness an increase in gender-based conflicts over resources, as rapidly changing ecological and social conditions present women and men with new and often distinct opportunities and threats to their resource dependent livelihood. As a result, both the content and the term of gender divisions of labor, rights, responsibilities, knowledge, decision making and authority need to be constantly revisited and should not be taken as given.

Given this, it is crucial for policy makers, technology designers as well as those who extend technology to recognize the importance of gender in the development of Ethiopian agriculture. It is particularly important to bear in mind that in their present status female-headed households will be disadvantaged if the technologies being developed and extended are knowledge and labor intensive.

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Economics of Integrated Crop and Livestock Systems in Ethiopia


PROSPECTS AND OPPORTUNITIES OF INTEGRATED FISH CULTURE IN ETHIOPIA

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ABSTRACT

Huge water resources, salubrious climatic conditions, topography and varied soil conditions are conducive to start fish farming in Ethiopia. Despite the potential to develop fish farming in Ethiopia, it is almost non-existent. The main fish farming systems in practice are: small fish ponds which are very few and owned by Governmental and Non-Governmental organisations, and culture based stock enhancement operation which is mainly carried out by Sebeta Fish Culture Station. The major constraints to fish culture development are identified as biological, infrastructure and economic. It is, therefore, suggested that the Government should put emphasis on integration of fish culture with other activities. Extensive polyculture (stocking two or more species) in small lakes and artificial water bodies is also recommended as a means to increase productivity per unit area. Simultaneous production of fish in ponds, combined with livestock, poultry and horticultural crops in urban and pre-urban, is also suggested as one of the most productive culture system.

1 INTRODUCTION

In both developed and developing countries, there is increased competition for water resources resulting in deficiencies in supply and various forms of pollution. In developing countries, the nutritional potential of aquatic resources is, however, very important. Food production systems which permit farmers to meet
growing demands for food with technologies that are ecologically sound, protect the environment and conserve natural resources for future generations are thus required.

Integrated farming has a long history, both in developed and developing nations. Integration of fish culture with other agricultural activities is originated from Asia and is still mainly practised over there. The crops are used as fodder for the animals and fish, while the animal manure is distributed on farmlands and fishponds. The cultures are heavily dependent of each other. You could say that they form one single economic unit. To our opinion, this is the key feature to distinguish integrated farming systems from multi-cropping farming systems.

The use of integrated farming has many benefits in improving the economic viability of the separate parts of the integrated operations. Kestemont (1995) indicates that some distinctions may be made in agro-aquaculture systems according to weather integration is direct (use of the same area for different agro-aquaculture activities) or indirect (valorisations of by-products from other agricultural activities performed in other areas) or sequential (rotation of the different activities in the same area). Integrating aquaculture with other activities, plant or animal and fish farming is particularly interesting with polyculture. Evidence indicates that integrated farms are more productive than non-integrated units operating on the same resource base. Increased food production on small scale units increases the total amount of
food available in particular area and gives producers the opportunity to improve their diet both quantitatively and qualitatively (Smith, 1996).

The establishment of sustainable integrated systems requires a sound understanding of the structure and function of the aquatic ecosystems. Only then can a program which stress the interrelationship of the physical, chemical and biological components of integrated aquatic system and their catchments be designed.

Monocultural practices have led to the loss of biodiversity and the destruction of the environment. In Ethiopia with increasing population environmental degradation and decreasing land availability and fertility, the circumstances of the rural poor have been steadily worsening and appear to decline further. This situation must be reversed to ensure sustainable production of food in Ethiopia for Ethiopians. New approaches to food production and income generation must therefore be found if this sector of our community is to be assisted. Integrated aquaculture in particular may offer some solutions where the classic methods of improving farm output have failed and/or have been unsustainable (Brummett, 1995). A holistic approach must be adopted where the relationship between the farmer and the system is an intimate interaction in the continue symbiosis (Gomes, 1992).
World catch and culture of fish and shell fish in 1992 stabilised at the level of 1991, i.e., 96.9 million tones, following declines both in 1990 and 1991 (FAO, 1993). At present, fish supply through capture fisheries by far outweighs fish production from culture. However, the percentile increase in total world catch over the last 10 years is only 1-2 % per year, whereas aquaculture increased with some 8 - 10% per annum. With the declining seafood harvests from wild sources and rising populations, aquaculture producers see a growing demand for their products (Harvey, 1995).

Nevertheless, while integrated fish culture has been developing rapidly around the world, it is virtually non-existent in Ethiopia. However, some classical fish culture activities, apart from a few small fishponds, like culture based stock enhancement operations have been carried out by the Sebeta Fish Culture Station. Despite this fact, water resources, climatic conditions, topography and soils of the country are conducive to start fish farming in Ethiopia.

The objective of this paper is, therefore, to give an overview on the potential of integrated fish farming in Ethiopia and to give suggestions for further development of the sub-sector.

2 FISH AS A FOOD COMMODITY

In the early days of man-kind, fish, as proved by ancient remnants, certainly played an important role as a food commodity in the first, and much the longest food gathering stage of mankind. Later on,
the historical importance of fish and meat as a main diet component decreased, most probably because increased population pressure forced cereals on the scene as bulk food. Most fish species become food for the poor, although less common, highly priced fish species always remained a luxury commodity, even now (Huisman and Machiels, 1986).

As long as more land could be brought into production, increasingly less consideration was given to the water bodies as a food source: agriculture far out-distanced fisheries. At present, the greatest part of the world’s arable soils has been brought under cultivation and greater attention has been given to the fishery resources: widely appreciated as a food commodity.

On top of that, nutritionally fish is considered as health giving food. As far as fish proteins are concerned, it must be stressed that these contain rather high amount of essential aminoacids. As for fatty acids, fish lipids contain lower amounts of saturated fatty acids than mammalian lipids. As a result, fish lipids are generally poor in cholesterol. Fish liver oils are the richest sources known for vitamin A and D. Moreover, the mineral composition of fish helps for normal functioning of the body physiology and hampers the development of certain types of cancer and lays a preventive role in the cardio-vascular malfunctions and other physiological disorders (Huisman and Machiels, 1986).
The concept that eating fish is beneficial to health has received a further boost from recent research linking a fish fatty acid to better brain performance. Experimentation has shown that fish oils have an inhibitory action on the initiation and advancement of cancers of the breast and the large intestine in animals (Suzuki, 1993) as quoted by Smith (1996). Valuable information such as this can support a marketing program for fish use.

In conclusion, fish must be regarded as a very healthy food item as it plays an essential role in enhancing the nutritive value of many vegetable diets in developing countries with a scarce supply of protein of animal source.

3 THE DEMAND FOR AND SUPPLY OF FISH IN ETHIOPIA

The human population of Sub-Saharan Africa is projected to grow with an annual rate of 3.1% to the year 2025, while growth has surpassed food production and, at the moment, it is estimated that about a quarter of Sub-Saharan Africa (more than 100 million) are already facing chronic food insecurity (Azage, et. al. 1993).

The World Bank (1989) estimated that production of meat and milk in Sub-Saharan Africa will have to increase by 4% per year to ensure adequate supply of animal protein for the regions growing population and to reduce imports.
Ethiopia, which is one of the Sub-Saharan African countries, is not, both technically and financially, in a position to meet the expected growth in animal production. ILCA (1993) analysed growth rate in output of animal proteins for African countries in general and Ethiopia in particular (Table 1). When we compare population growth rate (2.5 - 3.0 %) with annual growth rate of animal products (1.03 - 2.2 %), it is evident that there is gap to feed the increasing population.

Table 1. Annual growth rate (%) of animal products in Ethiopia

<table>
<thead>
<tr>
<th></th>
<th>Period</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>0.2</td>
<td>1.8</td>
</tr>
<tr>
<td>Milk</td>
<td>1.6</td>
<td>3.8</td>
</tr>
<tr>
<td>Egg</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Average</td>
<td>1.03</td>
<td>2.2</td>
</tr>
</tbody>
</table>

The complex nature of livestock production in Ethiopia coupled with a low technical base and long generation time of livestock has slowed down progress in livestock production in the country. It seems that the expected demand will not be met unless other alternatives are searched.

Fisheries sub-sector, in spite of its significant potential contribution to food self sufficiency in general and animal protein in particular,
is the least exploited of the animal resources of Ethiopia. Despite the tremendous fisheries potential that the country is endowed with, Maximum Sustainable Yield (MSY) of more than 24000 metric tones of different species of fish per year from lakes, and the riverain fishery forecast of 5000 metric tones per year, the national per capita consumption is reported to be less than a kilo per year which is the lowest in Sub-Saharan Africa (Yaicob, 1995). The major constraints to this low level of fish consumption in Ethiopia are the low and irregular supply, and the underdeveloped marketing infrastructure and distribution channels besides socio-economic and cultural factors.

3.1 The Demand for Fish
The demand for fish is the amount that consumers wish to purchase per period of time. Several factors influence the demand for fish of which the most common ones include: population, frequency of fish consumption, quantity of fish purchased at a time, religion, price and taste (Yaicob, 1995). These being factors affecting demand, determination of effective demand and market projection of future demand are critically important in terms of formulating policies and launching strategic plans that are geared towards increased fish consumption on the one hand and utilisation of the huge potential of large water bodies on the other.

Two methods could be used to estimate the demand for fish: discussion with traders, hotel owners and households and response by households to survey questionnaire. According to the research
report by the Lake Fisheries Development Project (Yaacob, 1995), the quantity of fish demand was projected at 2975 to 5680 tones in 1994, which implies a per capita consumption of 0.81 to 1.5 kg/year of the target population of the project area (3.7 million). The report also indicated that the demand forecast for eight towns using the first method of demand estimation amounted 2499 tones which, once again, implied a per capita consumption of 0.81 kg/year (Table 2).

The demand forecast for 33 target towns using the second method, according to the same report, amounted to 5680 tones per year. This shows that the demand for fish in 1994 was estimated at about two and half times the supply that prevailed. If we were to extrapolate this result to a national perspective, the forecast demand would be enormous, clearly portraying the prevalence of unsatisfied demand for fish in the country. On the basis of this finding, therefore, contrary to the common notion, a large number of people in Ethiopia are expected to consume fish. The question, therefore, is how to satisfy the large demand on the one hand while exploiting the potential resources on the other?
Table 2. Current and projected fish consumption (kg) of selected urban centres

<table>
<thead>
<tr>
<th>Urban Centre</th>
<th>Pop. ('000)</th>
<th>Total 1994</th>
<th>PCC* 1994</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Projected 1995</td>
<td>(Kg)</td>
<td>(Kg)</td>
</tr>
<tr>
<td>Addis Ababa</td>
<td>2641</td>
<td>10512</td>
<td>0.40</td>
</tr>
<tr>
<td>Assela</td>
<td>46</td>
<td>326</td>
<td>0.71</td>
</tr>
<tr>
<td>Zeway</td>
<td>28</td>
<td>2784</td>
<td>9.94</td>
</tr>
<tr>
<td>Awassa</td>
<td>51</td>
<td>2264</td>
<td>4.44</td>
</tr>
<tr>
<td>Arba Minch</td>
<td>29</td>
<td>2532</td>
<td>8.73</td>
</tr>
<tr>
<td>Bahir Dar</td>
<td>78</td>
<td>5070</td>
<td>6.50</td>
</tr>
<tr>
<td>Gondar</td>
<td>114</td>
<td>678</td>
<td>0.59</td>
</tr>
<tr>
<td>Dessie</td>
<td>101</td>
<td>827</td>
<td>0.82</td>
</tr>
<tr>
<td>Total</td>
<td>3088</td>
<td>24993</td>
<td>0.81</td>
</tr>
</tbody>
</table>

* PCC is per capita consumption
Source: Lake Fisheries Development Project (Ya'cob, 1995)

3.2 The Supply of Fish

The supply of fish is the amount that producers wish to offer for sale per period of time. Given the large fisheries resource of the target water bodies, market supply of fish in Ethiopia, like in similar subsistence economies elsewhere, is a function, in the main, of the number of fishermen, production technology, climate and fishermen family consumption (Table 3). According to the report by Ya'cob (1995), the number of fishermen has doubled over the last few years in most water bodies. In 1994 for example, there were about 3200 fishermen of which 2100 were organised into service co-operatives. Only a few were organised as legal entities by the Ministry of Agriculture (MOA). The fishing has been, by and large, artisanal thereby contributing to the low supply of fish. However, modern fishing gears are being adopted all across the
target water bodies faster than inputs can be made available. According to the regional reports, average production from 1989/90-1993/94 was 2214 tones per year (Yaicob, 1995). LFDP's latest estimation was 8862 tones per year (Carlos, unpublished). During these years, production increased by less than 5% per year. Forecast supply using current trend also shows no major increase.

There is also no strong evidence that fish supply is responsive to price. This is because most fishermen look upon fishing activity as a way of life and as an additional source of family livelihood to crop and livestock farming, not as a business for generating profit.

Table 3. Sample Fish production, fishermen consumption and market supply (qt): Koka, Zeway and Langano lakes, 1994

<table>
<thead>
<tr>
<th>Place and month</th>
<th>Production</th>
<th>Fishermen Consumption</th>
<th>Market supply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Percent supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Koka lake</td>
<td>Jul.-Sept.</td>
<td>763 30.10 732.90</td>
<td>96.06</td>
</tr>
<tr>
<td>Zeway lake</td>
<td>July</td>
<td>449 22.0 427.00</td>
<td>95.10</td>
</tr>
<tr>
<td>Langano lake</td>
<td>July</td>
<td>425 21.00 404.00</td>
<td>95.06</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1637 73.1 1563.9</td>
<td>95.53</td>
</tr>
</tbody>
</table>

Source: Fishery Unit, East Shewa Zone, 1994

3.3. The Relationship Between Fish and Meat Price (Cross Elasticity)

It is not clear, except in the lakes areas where meat is scarce and expensive, whether or not price of meat, an important fish
substitute, influences the demand for fish. There are, however, indications that the price of meat influences the demand for fish. According to the research report by Yaicob (1995), in the lakes areas households indicated that fish is 'meat' for the poor. It was also reported that the price of fish is generally less than one fifth of the price of meat and fish is more abundant than meat (Table 4). In other areas the ratio is 1:3.

Until recently, fish replaced meat during fasting seasons when the Orthodox Christians did not consume meat and there was no competition between the two. Thus cross elasticity between meat and fish during this period is zero.

In general the cross elasticity between meat and fish is expected to be positive except during the religious holidays, namely: New Year and Meskel in September, Epiphany in January and Easter in February to April. These months are generally also wedding months when the demand for meat is at its highest.
Table 4. Meat versus fish price\(^1\) (Birr/kg) in selected markets, 1994

<table>
<thead>
<tr>
<th>Market centre</th>
<th>(Bone In)</th>
<th>Fillet</th>
<th>Gutted</th>
<th>Whole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addis Ababa</td>
<td>12-20</td>
<td>6.25</td>
<td>4.55(^3)</td>
<td>3.00</td>
</tr>
<tr>
<td>Nazareth</td>
<td>12-15</td>
<td>-</td>
<td>-</td>
<td>3.00</td>
</tr>
<tr>
<td>Assela</td>
<td>10-12</td>
<td>-</td>
<td>-</td>
<td>2.00</td>
</tr>
<tr>
<td>Zeway</td>
<td>10-12</td>
<td>-</td>
<td>1.35(^3)</td>
<td>0.9-1.5</td>
</tr>
<tr>
<td>Awassa</td>
<td>11-12</td>
<td>-</td>
<td>1.35(^4)</td>
<td>0.9-1.5</td>
</tr>
<tr>
<td>Arba Minch</td>
<td>11-12</td>
<td>3.00</td>
<td>-</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td>Bahir Dar</td>
<td>10-12</td>
<td>-</td>
<td>-</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Gondar</td>
<td>9-12</td>
<td>-</td>
<td>-</td>
<td>3.00</td>
</tr>
<tr>
<td>Haik</td>
<td>7-10</td>
<td>0.55</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1 is Retail price other than FPME’s prices
2 is Tilapia species or equivalent is assumed
3 is using 150 gm whole weight, 70 % gutted weight and adding cost of gutting, Birr 0.25/kg;
4 is Imputed price: 225 gm whole weight, 70 % gutted weight and adding cost of gutting of Birr 0.22/kg.

Source: Fish Marketing in Ethiopia by Yaicob Like, 1995.

In conclusion, the average gross catch per fisherman which is about 2300 kg per year, the use of artisanal fishing technology, as well as fishing in a limited months (June-April), and consumption of 5 % of the catch by fishermen family have resulted in limited fish supply. All indications are that if only supply impediments were solved and prices stabilised, there is not only possibility for satisfying the projected demand but further demand can also be stimulated to support the country’s aim for food self sufficiency in general and for reducing animal protein deficiency in particular.
The establishment of fish culture in potential areas is, therefore, one of the possible areas of intervention that will in one way or another play its part in fulfilling this objective.

4 HISTORICAL BACKGROUND OF FISH CULTURE IN ETHIOPIA

The first introduction of an exotic fish species into Ethiopia dates from 1936 (Getent, 1993). The reasons for this introduction were varied, including game fishing, improvement of local stocks and control of weeds and disease vectors. It was not until 1976 that the government became actively involved and that small experimental station was constructed. With the establishment of the Sebeta Fish Culture and Research Station in 1976, effort was directed toward developing fish farming.

Getenet (1993) arrived at a composite picture of initiated fish culture activities in Ethiopia. There are about 24 fishponds with an area of 10.93 ha and were stocked with 119,160 fingerlings. Twenty six small reservoirs and dams totalling 218 ha. have been stocked with 488, 200 fingerlings. Twelve lakes and large reservoirs (including lakes- Haik, Ardibo, Ashenge, Beshan Waka...) accounting a total area of 37,400 ha. have been introduced with 200, 200 fingerlings.
In general, fish culture activity in Ethiopia is underdeveloped and mainly it is limited to fish transplantation. The major reasons that cause decreased interest in fish culture are:

Economic constraints: In Ethiopia where annual fish catch has increased over the years (Table 5), fish is readily available with the high catch rate and maintains market prices relatively low. Any fish farming activity will therefore have to compete with this market.

Table 5. Total landings in tons (Carlos, unpublished)

<table>
<thead>
<tr>
<th>Year</th>
<th>Landing (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>3264</td>
</tr>
<tr>
<td>1994</td>
<td>4059</td>
</tr>
<tr>
<td>1995</td>
<td>6059</td>
</tr>
<tr>
<td>1996</td>
<td>8862</td>
</tr>
</tbody>
</table>

Fish Culture is not a priority of Ethiopian Government, which lay emphasis on projects with immediate economic returns. Assessing the current extension policy can substantiate this fact. The extension package currently practised in Ethiopia involves only crop and livestock sectors. On the other hand, integrated fish farming which could have significant contribution for attaining food self sufficiency is neglected.
**Infrastructure constraints:** This refers to what are known as institutional infrastructures like availability of effective and efficient extension service and information dissemination programs. These are literally non-existence and thereby curtailing the development of the sub-sector. Besides, the unavailability of professionals in the field of aquaculture/fisheries and lack of enough concern by the responsible government organisations has also remained as a constraint.

**Biological constraints:** (i) lack of knowledge of production and management techniques, (ii) lack of seed stock from the breeding centre.

**Socio-cultural constraints:** Local culture, religion and tradition play an important role in fish consumption. First of all, fish does not pertain to Ethiopian food habits especially in areas, which are located distant from water bodies. Ethiopians prefer to eat meat rather than fish. Often fish such as Catfish is neglected by the society for several socio-cultural reasons, whereas Tilapia is the most preferred species.

5 **THE RATIONALE OF INTEGRATED FISH FARMING IN ETHIOPIA**

Food insecurity and the lack of food self-sufficiency are the country's chronic problems, mainly since agricultural production is
not commensurate with population growth. Harnessing all the available natural resource will alleviate this problem.

From all sources of animal products for human nutrition, the most expensive converters of food are bovines, which need between 7 and 10 units of food to produce one unit of beef (although milk is additional product). Fish is the best food converter requiring sometimes 1 to 2 unit of food to produce 1.0 units of edible meat (Launa, 1983). In addition, fish do not need agricultural land, nor do they compete with humans for food. Fish culture requires 1/3 to 1/30 of the energy spent by agriculture. Water in which fish live can be utilised in many ways, from drinking water to irrigation or hydraulic power.

The current cut down in meat, egg and dairy products supply coupled with increasing price of this products will induce a more and more deficit in animal proteins (Table 1. 2 & 4). This will certainly generate a growing demand for fish, which in the long-term could lead to an overexploitation of natural fish stocks. Integrated fish farming would then become an essential alternative to capture fishery.

Ideally, fish should provide up to 5% of Daily Protein Requirement (DPR) about 10 Kg person$^{-1}$ yr$^{-1}$. Estimated maximum production from capture fisheries is about 57,000 tons. To provide 10 Kg person$^{-1}$ yr$^{-1}$ for 55 million in 1996, would require additional
495,000 tones of fish. If fish has to play an important role in areas of protein deficiency, it is therefore likely that this gap should have to be bridged up with fish farming.

Reservoirs and dams are built throughout the country for various primary purposes like irrigation, electric power generation, or drinking water supply, either for people or livestock. Fish farming therefore, can be integrated with the above activities. In addition, small natural lakes can be assessed for their suitability for fish production.

Integration of fish culture with the other activities will have the following advantages:

- Mitigate drought and hence establish continual food supply,
- Enhance multipurpose use of water, in other words; increase productivity per unit area,
- Raise farmers' income through off-farm activity of fish farming,
- Create employment opportunity.

6 POTENTIAL AREAS FOR INTEGRATED FISH FARMING

Due to the inability of capture fishery to fill the widening gap between supply and demand (Yaicob, 1995), the government should place emphasis on integration of fish culture with other
activities. The following areas are proposed as potential areas for fish farming.

6.1 Extensive Polyculture in Small Lakes and Reservoirs

More than one million fingerlings were introduced either into newly created water bodies (reservoirs, dams and ponds) or into lakes, which previously lacked fish population. However, only one fish species was stocked (monoculture). In this case there will not be efficient utilisation of natural food.

Better utilisation of natural food is most frequently cited as an obvious advantage of stocking two or more fish species (polyculture). In general, when the food habits of fish species are selected for polyculture are distinct, the co-competition for food is reduced and the potential for increased total fish production is increased. For this reason, the most profitable results are obtained in carp culture together with herbivores and detrivors fish (Sinha and Olah, 1982). Moreover, polyculture techniques improve environmental conditions and control aquatic weeds.

To cultivate different fish species in the same pond is of great interest, not only in terms of available food utilisation, but also with respect to the utilisation of all the ecological niches available in the pond ecosystem as surface, column or bottom feeder.
Moreover, due to positive interactions, the growth and yield of each species may be higher in polyculture than monoculture. The synergetic interactions among fish species reared in polyculture are clearly explained by Milstein (1990), as quoted by Kestemont (1995).

Polyculture is more relevant when integrated into well established agricultural practices. In the integrated system, fish species can be manipulated to best utilise the particular waste available and thus are very efficient in the Chinese "AAA" system being aquaculture, animal husbandry and agriculture (Smith, 1996).

Polyculture development depends on climatic and hydrographic conditions, fish species available and socio-economic conditions. Regardless of the divergence that may occur between water and air temperature, above all for small dams, natural lakes, general recommendation can be given for polyculture activities in Ethiopia. And also based on the experience from other east African countries (Dadzie, 1992) stocking of Oreochromis niloticus (tilapia) as main species, combined with Carp, Common Carp or Crucian Carp is suggested to water bodies which are already stocked by one species.

Additional species will therefore raise income/yield from the unit area. It can be achieved through an increase of total yield without a decline in the existing species production. For example, twenty six small reservoirs and dams totalling 218 ha have been introduced
with one species and their production is only about 30 ton yr\(^{-1}\) (Getent, 1993). If we introduce another species, this production could unquestionably be doubled.

Reseeding and replenishment of lakes and reservoirs (which were stocked with one species) with two or more fish species is simple local technique for increasing fish production in that region and again can be integrated in other projects such as those on the creation of water supply reservoirs or hydropower generation and irrigation projects. This intermediate system between fishing and fish farming has the advantage of input costs that are very low on average and enable operators to secure high productivity rates per unit area. To effect this extensive polyculture, a lot is expected from Sebeta Fish Breeding Centre to provide seed and the Federal/Regional Agricultural Offices to allocate the necessary budget, manpower etc.

6.2 Fish Culture - Animal Husbandry - Horticulture Integration

The existence of many embassies and international organisations brings many foreigners, well accustomed to fish and whose demand is ready to pay for a good quality and relatively expensive commodity. This coupled with the existence of many dairy, beef; poultry and backyard horticultural farms in and around Addis Ababa gives good opportunity for integrated farming.
Simultaneous production of fish in ponds, combined with livestock, poultry and horticultural crops, is one of the most productive culture systems. This production technique provides continual organic fertilisation of the pond and the garden by animals. It increases the profitability of animal farming, fish culture and horticultural activities through utilisation of wastes (Fig 1). In this system fish are not usually given artificial feed.

![Diagram of fish pond integrated with vegetable garden and animal wastes](image)

**Fig. 1.** The ways in which fish pond can fit into the farm.

### 6.2.1 Fish-Cum-Chicken Culture

Chicken can be reared in pens beside or over ponds at a density of 10 to 30 chickens per 100 m of ponds (Dadize, 1992). One chicken produces about 14 - 15 Kg excreta per year and a laying hen produces enough manure to generate about 6 - 8 Kg yr⁻¹ of fish biomass. After 4 to 5 months, the production of fish can reach between 3500 and 5000 Kg ha⁻¹ yr⁻¹ (35 to 50 Kg yr⁻¹ 100 m⁻¹ of pond surface).
Table 5. Commercial Farms in the Vicinity of Addis and their Fish Production Potential

<table>
<thead>
<tr>
<th>Farm Location</th>
<th>Farm</th>
<th>Location</th>
<th>Annual capacity</th>
<th>Fish Potential Kg yr⁻¹ (1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farm</td>
<td>Annual capacity</td>
<td>Layers</td>
<td>Broilers</td>
</tr>
<tr>
<td>Tseday</td>
<td>Debre Zeit</td>
<td>20,000</td>
<td>120-160</td>
<td></td>
</tr>
<tr>
<td>Almaz</td>
<td>Debre Zeit</td>
<td>50,000</td>
<td>300-400</td>
<td></td>
</tr>
<tr>
<td>Ex-soldiers coop.</td>
<td>Debre Zeit</td>
<td>18,000</td>
<td>108-144</td>
<td></td>
</tr>
<tr>
<td>Kale Hiwot Church</td>
<td>Debre Zeit</td>
<td>12,000</td>
<td>126-168</td>
<td></td>
</tr>
<tr>
<td>Abeba</td>
<td>Debre Zeit</td>
<td>2,500</td>
<td>15-20</td>
<td></td>
</tr>
<tr>
<td>NACID</td>
<td>Nazrach</td>
<td>11,000</td>
<td>66-88</td>
<td></td>
</tr>
<tr>
<td>Mekonen</td>
<td>Sebeta</td>
<td>12,000</td>
<td>72-96</td>
<td></td>
</tr>
<tr>
<td>Fantu</td>
<td>Addis Ababa</td>
<td>12,000</td>
<td>72-96</td>
<td></td>
</tr>
<tr>
<td>Jegnoch Amba</td>
<td>Debre Zeit</td>
<td>3,000</td>
<td>18-24</td>
<td></td>
</tr>
<tr>
<td>Alemayahu</td>
<td>Debre Zeit</td>
<td>9,000</td>
<td>54-72</td>
<td></td>
</tr>
<tr>
<td>Selam</td>
<td>Addis Ababa</td>
<td>2,000</td>
<td>12-16</td>
<td></td>
</tr>
<tr>
<td>Hope enterprise</td>
<td>Addis Ababa</td>
<td>3,000</td>
<td>18-24</td>
<td></td>
</tr>
<tr>
<td>Wondem</td>
<td>Debre Zeit</td>
<td>50,000</td>
<td>300-400</td>
<td></td>
</tr>
<tr>
<td>Getachew and Assefa</td>
<td>Addis Ababa</td>
<td>12,000</td>
<td>72-96</td>
<td></td>
</tr>
<tr>
<td>Adamu Hailu</td>
<td>Debre Zeit</td>
<td>16,000</td>
<td>96-128</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>33,500</td>
<td>208,000</td>
<td>1449-1932</td>
<td></td>
</tr>
</tbody>
</table>

Source: Alemu & Tadelle (Paper Presented at the 5th Conference of the Ethiopian Society of Animal Production (ESAP) 15-17 May 1997)

If we take the case of commercial poultry farms in and around Addis, they have the potential of producing about 14,490 - 19,320 quintals of fish per annum (Table 5). Similar type of analysis can be made for livestock - horticulture - fish integration. Generally, the integration of fish culture with livestock/poultry rearing increases substantially the return on investment compared to poultry/livestock rearing alone.
7. CONCLUSION

Fish culture in Ethiopia is under developed but, overall, it has good prospect for development of integrated with other activities. In the mid term, integration of fish farming with animal and crop farming in urban and pre-urban can be initiated. To effect this, strengthening Sebeta Fish Breeding Centre and training professionals at different levels are important elements that should be initiated soon by the Ministry of Agriculture and Higher learning institutes respectively.

Aquaculture development may have a positive influence on the development of a country. It has a potential to generate more income and profit than many agricultural activities. In addition, integrated aquaculture system is more economical than mono-agriculture. It diversifies food supply, reduces farm risks and generates foreign exchange earnings for the country.

For a successful introduction of integrated farming systems, it is necessary that organisation, research and development should lead to clear directives and systems of fish distribution, fish processing, marketing etc. Furthermore, the success will depend highly upon the existence and quality of credit facilities, training and consultancy systems.
However, if all these conditions can be matched with, integrated animal-fish farming may be an ideal answer to the ever-increasing food demands under limited expansion possibilities of agricultural land.

REFERENCES


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1. INTRODUCTION

It is well-known that savings and credit institutions play a crucial role in rural development. But the existing financial intermediaries are limited to urban areas. Only less than 2 percent of rural households have bank deposits. The bulk of the rural people rely on the informal financial sector (i.e., iqqub, iddir, money lenders, and friends and relatives) for their credit requirements.

The existing studies, of the informal financial sector in Ethiopia [Girma, 1978; Mauri 1987; Dejene, 1993a; 1993b] have explored the huge potentials of the formal and semi-formal financial sectors in urban areas. It is a high time to further examine the economic importance of this sector in the context of rural areas, where the bulk of the population lives. Rural finance is an area that is little known to policy makers and rural development practitioners as well as to researchers. Some of the still unanswered questions about this sector include: (1) Why is the informal sector popular among the people; is it because it involves lower transaction costs as compared to the formal sector? (2) Are there possibilities for using the informal sector
as a launching pad for the development of the formal sector? (3) What roles does the informal sector play in linking the crop production and livestock sub-sectors? (4) What factors constrain the development of the informal financial sector in rural areas?

Moreover, rural financial institutions have constituted a puzzle that is little explained by conventional economic theory, which is based on the postulate of individual choice and on the maximization of the individual's utility function. For example, how can one explain the fact that some people join the iqqub although they know that they do not maximize their own utility functions.

This paper has the following major purposes. First, it attempts to develop a theory of village economy and institutions. Second, it attempts to provide illustrations for a theory of cooperation and competition with particular reference to indigenous financial institutions. By doing so, it attempts to address the questions raised above. Third, it demonstrates that iqqub and iddir have affinities with other indigenous institutions. Fourth, it draws implications for strengthening the crop-livestock systems.

The paper is organized as follows. The first section provides the theoretical conceptual perspectives of rural institutions. The second section briefly reviews the major indigenous institutional arrangements relevant to the crop production and livestock sub sectors. It also provides illustrations for the theory formulated in the preceding section. The third section discusses iqqub, iddir and
money lending activities in rural areas. The fourth section provides conclusions and discusses relevant policy implications of the study.

Drawing on insights from recent developments in institutional economics, (see Dejene 1996) this paper argues that indigenous institutions are national resources that should be legitimized, updated, and be mobilized through grassroots-level participatory programmes. They are appropriate to the conditions of smallholder, because they have low transaction costs and they meet those needs of rural people which are not met by formal financial institutions.

The major sources of data for the study are: (1) Village profile of the Integrated Rural Household Surveys of the Department of Economics, A.A. University, (2) Various reports made by individual researchers and rural development practitioners, and (3) the anthropological literature.

2. THE VILLAGE ECONOMY AND INSTITUTIONS: CO-OPERATIVE AND COMPETITIVE RELATIONS

The "village", which is rarely discussed in the standard economic literature, can be conceptualized as an authority system exercising influence and control over actions of members of the community as underlined by Bromley (1991:111):

I start by focusing attention on the village or local community as an authority system, ...One could argue.
that the very purpose of a village was to serve as a locus of control and co-operation such that the welfare of the group would be enhanced. The effectiveness of the village as an authority system was dependent upon the exercise of influence and control over actions of members of the community.

The term "village" can also be conceptualized as referring to a hamlet where people live by family in a cluster of houses with a high degree of social and economic interdependence. In the Ethiopian case, the term village often coincides with a peasant association and, in this study, the two terms are interchangeably used. Village communities in Ethiopia are, to a large extent, self-contained and subsistence oriented, though there could be some degree of linkage with urban areas and with other villages.

For the purpose of this study, we use the term "village" interchangeably with the community. The household is linked with the village or the community through economic and non-economic relations. In Ethiopia, these relations include contractual arrangements (e.g., community-level labour exchange arrangements), financial institutions (e.g., iqqub), petty trade, religious associations (e.g., mahber), neighbourhood contacts, kinships, community-level ceremonies, and peasant associations.

Households are tied together, not only by kinship relationships, but also by the need of economic security and household survival. Living in the same geographical location, they have to cooperate in order to: (1) avoid over-exploitation of resources, (2) define and
enforce property rights, settle disputes among village members. In other words, collective action is required in order to determine and sustain the relation between man and the environment as well as relations among people.

The existence of production externalities demands collective action. For instance, households living upstream may divert water and cause shortages downstream. At this time the community intervenes to resolve conflicting interests of its members. Production externalities can also arise in different ways as in the following cases: (1) a farmer living on the periphery of the village is more exposed to wild animals than others; he (she) creates external economies by keeping away pests (e.g. baboons, porcupines, hogs, etc) from attacking the fields of others, (2) a farmer who does not control rodents on his fields creates external diseconomies on other farmers, (3) overgrazing a mountain pasture may increase the incidence of flooding the nearby crops, (4) there should be an agreed or customary path or lane crossing the village; otherwise there could be conflict among village members as everybody refuses to allow others to walk across his fields, (5) a person who brings an infected animal to the village may endanger other animals in the village, and so on.

Collective action is also required to address problems of labour shortages at the household level. Community labour or work party is required to reduce seasonal labour bottlenecks at the household level. Seasonality signifies the fact that agricultural activities are time-sensitive. Moreover, certain tasks such as the application of manure,
house construction, hunting, etc. require functional division of labour or need more than the labour of one person to undertake an activity. That is, technical reasons may necessitate community-level labour exchange arrangements.

The community is also required to provide and manage "public goods" such as roads, irrigation systems, and communal grazing land.

Table 1 provides a brief summary of the common cooperative institutions in rural Ethiopia (for details see Dejene 1996). The iqqub and iddir (as will be discussed at the appropriate place) serve the purposes of savings mobilization and the provision of informal insurance policy to members. Household-level labour shortages can be mitigated by resorting to community-level labour exchange arrangements such as debo, wenfel, etc. Resource-deficit households can get access to a particular resource on the basis of the principles of "mutual coincidence of wants." A farmer with only one ox can pair off his ox with his neighbour's (or friend's) ox and be able to till his land. This arrangement is known as mekenajo. A land-deficit but labour-surplus household can enter into an indigenous share-cropping arrangement, known as megazo meret. A household lacking enough labour and grazing land can enter into a mutually-benefiting arrangement known as ribi. This arrangement enables a poor household to share animal products and offsprings with a livestock-owning household in exchange for its labour input into herding of animals. A farmer lacking oxen can get one by tilling the land of an
oxen-owning household for, say, two days and then till his own land, say, for one day using his partners oxen.

Table 1 FORMS OF INDIGENOUS CO-OPERATIVE ARRANGEMENTS IN RURAL ETHIOPIA

<table>
<thead>
<tr>
<th>Type of institution</th>
<th>Primary function</th>
<th>Origins</th>
<th>Contract period (duration)</th>
<th>Level of Co-operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iddir</td>
<td>Provides insurance policy &amp; consolation to breved hhs</td>
<td>early 20th century</td>
<td>Permanent</td>
<td>Community</td>
</tr>
<tr>
<td>iqqub</td>
<td>Saving mobilization</td>
<td>early 20th century</td>
<td>One cycle but can be reinstituted</td>
<td>Community, friends &amp; neighbours</td>
</tr>
<tr>
<td>mekenajo</td>
<td>improved access to draft power by pairing off oxen</td>
<td>Unknown</td>
<td>Usually one crop season</td>
<td>individuals</td>
</tr>
<tr>
<td>ribi</td>
<td>improved access to livestock by poorer households &amp; improved access to labour and grazing land by labour deficit hhs also lacking grazing land</td>
<td>Unknown</td>
<td>several years</td>
<td>individuals</td>
</tr>
<tr>
<td>debo, wenfel, etc.</td>
<td>improved access to community labour</td>
<td>Unknown</td>
<td>One crop season</td>
<td>Community, friends &amp; neighbours</td>
</tr>
<tr>
<td>meazo meret</td>
<td>improved access to a land by land-deficit household and improved access to labour by a labour-deficit household</td>
<td>Unknown</td>
<td>usually one crop season</td>
<td>individuals</td>
</tr>
<tr>
<td>Labour for draft power</td>
<td>improved access to labour and oxen by two hhs each lacking either of the inputs</td>
<td>Unknown</td>
<td>One crop season</td>
<td>individuals</td>
</tr>
</tbody>
</table>

Note: "Labour-for-draft power" refers to an indigenous institution in which labour is exchanged for draft power.

Source: Adapted from [Dejene 1996].

Community - level cooperation or collective action requires institutions to regulate the behaviour of people in such a way that the
well being of individual members and of the whole community at large is maintained. According to Hayami (1978:1), "a choice of a villager is constrained by the choices of other villagers, so that one's welfare function depends on another's within the village community." Customary rules and cultural norms are thus required, among other things, to regulate the allocation, exchange and consumption behaviour of the individual. In other words, individual's choice is constrained, among other things, by informal institutions. The individual has to maximize his utility subject to the needs of the community. "Even if one expects large material gains from violating the rules, he may not dare to do so because of the risk of social opprobrium and perhaps ostracism" [Hayami and Kikuchi 1982:17]. That is, the utility function of an individual includes other person's reaction to his action (see the analysis of "social interactions" by Becker(1974;)). Further, a moral code, known as tizib, is behind this concern. In Ethiopia, before behaving in a certain way, people have the habit of asking themselves: "what do people say about my action or inaction?"

The community not only provides institutions to regulate the use of scarce resources and to settle dispute among its members, but also provides social relations which are geared to secure minimum subsistence for all the community members [Wolf 1966; Scott 1972; 1976; Platteau 1991; Hayami and Kikuchi 1982]. The moral economy approach suggests, among other things, that the utility function of one person is associated with that of others. Within the community, a "subsistence ethic" prevails to guarantee subsistence as
a "moral claim" or as a "social right" to which every member is entitled. It finds its social expression "in the patterns of social control and reciprocity that structure daily conduct" (Scott, 1976: 32, 40).

The moral economy argument suggests that the individual is capable of deriving utility not only from the possession of goods and services for himself, but from his fellow villagers' material welfare as demonstrated by the case of the Israeli Kibbutz [Don 1996]. This type of utility function can be explained in terms of the concept of "altruism", a term which is defined as the willingness to reduce" own consumption in order to increase the consumption of others" [Becker 1976: 818]. Of course, where altruism fails, society resorts to moral codes and other forms of restrictions to restrain the selfish behaviour of individuals. Further, it can be argued that altruism can enhance economic efficiency [Don 1996] because it promotes mutual confidence, an instrument reducing transaction costs of business dealings. For example, Japan is able to reduce costs by minimizing the number of lawyers per business enterprise, while the USA, on the contrary, boasts of having the largest number of lawyers in the world and hence an extremely high number of lawyers per business enterprise. In the absence of mutual confidence, people resort to legal means to tackle problems of fraud and default. Lack of mutual

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1 Of course, there are those who are opposed to the moral economy approach to the analysis of rural institutions. For example Popkin (1979) contended that peasants in pre-capitalist societies are egoistic and hard calculating agents intending to derive maximum personal advantage from all actions in which they get involved. It is possible that certain individuals exhibit this type of behaviour in pre-capitalist societies. But it is difficult to make a sweeping generalization on the basis of the behaviour of certain individuals. Of course, this type of behaviour becomes increasingly predominant with the expansion of markets, population growth and the rise of a modern state.
confidence leads to increased transaction costs. However, we do recognize the fact that the village is related to the outside world partly through markets and that market relations (or competitive relations) exist within the village itself.

The essence of the above given discussion is that the village economy has dual character, i.e. the co-operative (or the reciprocal) aspect and the market (or competitive) aspect as indicated in Figure 1. Accordingly, institutions such as iqqub and iddir involve both market and non-market relations between people. It is because of this cooperative and competitive characteristics that participants in rural financial institutions often exhibit both maximizing and non-maximizing behaviour. That is also why individual choices are sometimes superseded by collective choices. In addition, the village economy consists of relations which are neither market nor non-market as shown by areas B & C in the diagram.
Figure 1  THE VILLAGE ECONOMY: THE
COOPERATIVE AND COMPETITIVE
ASPECTS OF INDIGENOUS FINANCIAL
INSTITUTIONS

Notes:
1. Area A stands for cases where iqqub, iddir, and money-lending activities are merged.
2. Areas B and C stand for parts of the village economy which are neither competitive nor cooperative. B & C indicate institutions which are external to the village, e.g. areas where the state, donors, and NGOs operate.
3. It is interesting to note the relative sizes of the overlapping and non-overlapping parts of a circle. For example, the iqqub circle has more of its area falling within the competitive sphere than the iddir, suggesting that the former is more business-oriented than the latter.
Co-operation may not be automatic. Society has to device different mechanisms to impose its collective choices on individuals. Moral code is one of these mechanisms, as witnessed by the hadera practice in the village of Do'ona, North Omo of South Ethiopia:

With the depletion of the livestock population owing to various cattle diseases, there has developed a tradition called hadera. Hadera, literally resembling gift, is a kind of redistribution mechanism by which the relatively better-off lend their cattle to the deprived to sustain their lives. Accordingly, a person who received an ox in the form of hadera is supposed to look after it and return either the very ox he was given or in the form of a calf or milk and butter. If the hadera cattle dies, the receiver would not be under any obligation to pay compensation. Hadera is based on friendship lines and the governing principle is conscience, not pragmatism or utilitarianism. At the root of the institution of hadera lies the notion of hashe, fear of a similar fate in the future. There is a strong belief among the Gamo people that success and failure are not merely individual attributes [Dereje et al 1995].

Here, it is interesting to note that the hadera practice, which is based on the non-maximizing behaviour of individuals, provides a crude form of insurance policy (i.e., an iddir at its formative stage) to make sure that the less privileged members of society are guaranteed the minimum subsistence provisions. It is well-known that in the Gamo society cattle constitute a basic means of livelihood.

Moreover, the Gamo people strictly observe moral codes provided by the gome belief. Misfortune or natural calamity is often ascribed to
The moral economy of the village may be undermined when subsistence ethics is broken down due to market expansion, state action, social factors, natural disaster, or economic problems. Market expansion undermines, among other things, the patron-client relationship of the villagers by replacing personal relations with money or commodity relations. Reciprocal relations may give way to money or commodity relations. As noted by Tomich et al (1995:55), "The most basic change in villages that results from integration into large-scale markets is the weakening of reciprocity." The market provides not only purchased inputs such as wage labour, but also prestige goods to be used as status symbol. Villagers would violate the village institutions if they see opportunities where the gain from violation exceed the opportunity of doing so (Becker 1976; Hayami and Kikuchi 1982).

In Ethiopia, the moral economy of the village and the practice of collective action have been undermined and subsistence crisis set in not only by market expansion and the entrenchment of the power of the central authority in the mid-twentieth century, but also by the following additional factors:

(1) The land reform proclamation of March 1975, which destroyed the economic base of the traditional ruling class and
undermined the patron-client relationship that had existed prior to this period;

(2) The declaration of "scientific socialism" and subsequent campaigns which partly undermined village institutions;

(3) Chronic drought and famine which, in some places, dislocated the village economy; and

(4) Other social factors, such as the villagization and resettlement schemes of the 1980s', civil war, the demobilization of the army in 1991, etc. which displaced tens of thousands of people and destabilized traditional relations.

Because of these factors it can be contended that the typical Ethiopian village, in general, is today less cohesive and less tightly structured as compared to what it used to be in the past. As a result, behaviour tends to be more individualistic, hedonistic and more selfish. The individual can get away with doing something not approved by the community. Under such conditions, it is difficult to enforce village institutions and to predict possible reactions of people.

3. IQQUB AND IDDIR

The iqqub is defined in the literature as an indigenous saving association where each member agrees to pay periodically a small sum into a common pool so that each, in rotation, can receive one large sum [Dejene 1993; Aspen 1993]. The iddir is defined as an

Similar developments have been observed in other countries (for details, see Plateau 1991).
indigenous insurance scheme run by a community or a group to meet emergency situations or serious difficulties like death of family member.

In addition to playing financial roles, both iqqub and iddir (the latter in particular) constitute important media for social interactions, dissemination of news, and imposition of collective choice as noted by Lexander 1968:

All associations mentioned [i.e. iqqub iddir mahiber etc.] give their members the possibility to meet each other and relax and at the same time they are centres for the dissemination of news. They also function as pressure groups where the individuals are checked to confirm with the general group behaviour and ideas. Here we already find groups where it will be possible at an individual level to get in touch with a larger groups of people to inform them about activities and programs [in the village][emphasis added].

The greatest potential of the iqqub lies in its flexibility in order to meet the needs of people with differing economic status. There is always iqqub for everybody, at any time, for any purpose. In the village of Imdibir, there is iqqub for the poor as well as for the rich. In the village of Turufe-kecheme, where there were about 10 different iqqubs, poor women saved one Birr each week from proceeds generated from the sales of tella while relatively well-off shopkeepers saved as much as Birr 30 per week. In this village, there are separate iqqubs for men and women. The latter are free to use their collections from iqqub for whatever purpose they choose.
In the village of Aze Debo'a (Kembata) the poor contributed 2 Birr per week while rich businessmen contributed 100 Birr or more per week. There is iqqub for special purposes such as ceremonies, purchase of durable goods, etc. When a member of an iqqub is in need of money, he can "buy" it from the winner or from the members as a whole. For example, in Chilalo a needy member could "buy" the pool by paying a winner 5 to 10 percent of the total collection. This rate is much lower than the prevailing commercial rate, which is about 10 percent per month. A needy person can also get priority in collecting the pool (kitty). In addition, a needy person can get the first pool by organizing an iqqub. Some people may join an iqqub primarily to help a needy person. The size of the iqqub is highly flexible. For example, in Aze Debo'a four to ten women can contribute about one kilogram of butter, each, per week and give it to members in rotation. The one who gets the butter can sell it and use the money for investment purposes (e.g. buy livestock) [Lexander (1968); Data and Alemu 1995; Bekalu and Degafe 1995; Getachew and Mesfin 1995].

The origins of iddir and iqqub are little known. The hypothesis that iddir originated during the Italian occupation (1936-1941) is questionable (See Dejene 1993). It could have originated much longer than this period. For example, villagers in Koro-Degaga (Arsi)

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The practice of giving priority to a needy member demonstrate the fact that the iqqub has cooperative (i.e., non-maximizing) relations among the participants.

Note here that 1. contributions to iqqub can be made in kind (commodity) and 2. proceeds from iqqub is invested often in the form of livestock.
speculated that it was introduced into their village at the time of Emperor Menilik, who reigned at the turn of the century. It is also likely that iddir, in its present form, originated in the southern part of the country and, perhaps, first in urban areas. However, it should be underlined that iddir might have existed in rural areas in different forms before it assumed its present features. It might have evolved over quite a long period before it assumed its present form, which is characterized by written bylaws, cash contributions, regular meetings, differentiated and fixed coverage schemes, and periodically elected executive committee members exercising specialized responsibilities.

Mutual assistance, other than the iddir, is common in rural Ethiopia. For example, if a neighbour's house caught fire everybody rush to his help and render assistance ranging from efforts in putting out the fire to the contribution of timber for the construction of a new house. If a villager's animal is stolen or lost, everybody helps with the search and make contributions to replace the lost animal.

In some places, the iddir is at its formative stage. In that case, it lacks formal and binding rules such as regular meetings, fixed and regular contributions, and written by-laws. For example, in Aze Debo'a, where there are three types of incipient iddir (i.e., village or community iddir, religious iddir, and clan iddir, members contribute money only at the time when a person is in difficulty and they do not make regular savings expecting rainy days [Data and Alemu 1995].
The present author has recently observed a similar practice in parts of Wello. There, villagers have what they call kirie rather than iddir.

Iddir is highly flexible like iqqub as can be illustrated by the following examples. In a village in the Debre-Birhan area of North Shewa, nine households are organized to help each other on the event of death or loss of a milking cow or a draft ox. Each member contributes 2 Birr and fifty cents when a milking cow dies and 5 Birr when a draft ox dies (note relative value, 2 cows = 1 ox) [Melese et al 1995]. Similarly in Turufe-kecheme, there is an iddir to ensure the death or loss of a draft Ox [Getachew and Mesfin 1995]. In Geblen (Tigrai), people have an ad hoc type of iddir, which is meant for a specific purpose. For example, villagers set up a sort of iddir, which they call kuskus, to raise money for the purchase of beef, which they slaughter on the occasion of a religious holiday. They share the meat in proportion to their contributions, [Kiros and Solomon 1995].

The size of membership and contributions vary, depending on the purpose for which an iddir is set up. For example, village-wide iddir, (the main purpose of which is to bury the dead and provide financial and material assistance to the surviving family members) is quite large in terms of membership but small in terms of per member contributions. Specialized iddir is often small in terms of membership, but large in terms of per member contribution.

There could be, therefore, more than one iddir, within a single village, catering to the various needs of households. This can be
illustrated with the following examples from Ethiopian Village Studies. In the village of Yetmen (Gojam), there were six different iddirs with membership ranging from 20 to 401 households and monthly contributions Birr 1 per member for all of them, except one, which has 2 Birr per member [Tassew et al. 1995]. In Faggy, a poor village adjacent to Debre-Birhan, there were three different iddirs making very small contributions commensurate with the economic status of the local people. In one of them, the monthly contribution was 25 cents per member. In addition, each member contributes about 20 kilograms of beans per year. The grain was used, according to pre-established rules, to assist members facing extreme forms of food shortages. However, women household heads contribute only half that amount (10 kgs) [Melese et al. 1995]. This exhibits that iddir is highly flexible.

In a relatively rich village of Imdibir (the Gurage area), where a household can join more than one iddir, per member contributions are 2 to 3 Birr and the size of membership ranges from 100 to 300 persons. Interestingly enough, in this village iddir provides credits to members at an interest rate of 10 percent per annum [Bekalu and Degafe 1995]. Doesn’t this suggest that the iddir has also the competitive or business orientation element in itself?

In the village of Koro-Degaga (Arsi) there were four different iddirs with membership size ranging from 35 to 70 persons. Monthly contributions ranged from 1 Birr to 2 Birr per member. One of the iddirs provides insurance coverage for a loss (or death) of a draft ox.
In this village, as it is likely the case in most villages in the area, iddir membership is not a requirement for getting assistance in the event of very serious difficulties (more serious than a loss of an ox) such as the loss of the entire household property due to fire. In this case, the entire village community provides assistance to a disaster-stricken villager, irrespective of lack of affiliation to a particular iddir. By tradition, the village community attempts to ensure the survival of its member, although this is difficult in times of crises, such as drought and famine. The village has moral obligation to ensure the survival of its members.

The iddir has interesting similarities and differences with iqqub. Both institutions have evolved over time, without any external assistance (including absence of government support), to meet the financial, material, and social needs of the small producers. Based upon the principles of collective action, both institutions provide extremely useful services that are beyond the reach of the individual person or household. Both institutions involve not only financial transactions, but also other activities, including social gatherings in which news are disseminated, disputes are settled, common problems are discussed, and leisure is enjoyed when circumstances permit. Above all, iddir and iqqub provide social and personal interactions that are not provided by modern financial intermediaries. Moreover, they are, culture-appropriate, highly flexible and location-specific as compared to formal financial intermediaries. Their transaction costs (e.g. costs of acquiring information about a new member, monitoring,
In recent decades, iddir has been rapidly spreading in rural and urban areas, perhaps, due to the ever-growing economic insecurity resulting from drought, famine, and decline in per capita real income. Traditional sources of assistance (e.g., village heads, neighbours and relatives) are today incapable of sustaining a needy household requiring financial and material assistance. Tradition dictates redistribution of income as in the case of the notion of the hunduga of the Gamo people: "to have is to give". Prior to the land proclamation of March 1975, the patron-client relationship between the landlord and the local people provided a mechanism for rendering assistance to the very needy peasant. Today it appears that society is largely levelled at a minimum subsistence level where very few people are in a position to sustain the life of another person or to survive on their own. Social network gains increased popularity as people become less and less self-sufficient. Co-operation is partly necessitated by increased economic insecurity and poverty, though economic progress and market expansion, too, have similar effects.

There are very important differences, however, between the iqqub and the iddir, beyond the well-known difference that the former is business-oriented while the latter provides insurance coverage.

The iddir is perhaps the most egalitarian and democratic institution in Ethiopia. In most cases, it is open to all irrespective of ethnic
backgrounds, religion, political affiliation, sex, age, and economic or social status. Election of leaders and important decisions are based on the principles of one man, one vote. The executive committee, which is periodically elected, is responsible to the general assembly. The relationship between the executive committee and the legislative body (i.e. the general assembly of all members) is based upon the principles of checks and balance of power. On the other hand, iqqub is not open to everybody; it is open only to those who are able to regularly contribute the agreed sum of money, albeit it is a "formalized and democratic institution" (Aspen 1993:72). The iqqub is largely business-oriented.

Membership in iddir is most often limited to household heads or spouse (except women's iddir) while membership in iqqub is open to any member of the household capable of making cash or commodity contributions on regular basis. Contributions to iddir is made on monthly basis and every member is strictly required to be present in person at regular meetings. Delegation of an agent is possible only under special circumstances. Husband and wife, however, have equal rights in representing the household at an iddir meeting or funeral ceremony. Contributions to iqqub may be on weekly or monthly basis depending on the sources and nature of cash income a person gets. Iddir in general, is established for an indefinite time or perpetuity while iqqub could terminate after its life-cycle is

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This point has important implications for the theory of intra-household issues.
completed. In many cases, an iqqub is renewed after the completion of one life-cycle.

**Iqqub** has considerable saving potential as compared to iddir. In a poor village in North Shewa, a total amount of Birr 22,164 was saved by 97 members during the life cycle of an iqqub. Out of the total, 35 women saved Birr 7,930 (36%) or an average of Birr 226.6 per member.

In another iqqub in the same village, 45 household heads planned to save an average of Birr 5.8 per month and raised a total monthly contribution amounting to Birr 263. These households represented 27 percent of the sampled households. The saving potential of iqqub in the village, however, was reduced because most of the savings are used for the purchase of clothing. But iddir provides smaller savings per head [Aspen 1993].

The similarities and differences between iqqub and iddir are summarized in Table 2.
Informal financial institutions, far from being stagnant, are likely innovative and dynamic in character. It can be hypothesised that *iqqub* and *iddir* have in recent decades developed certain innovative practices including the following:

The introduction of the practice of "selling" collections from an *iqqub* in addition to the drawing of lots;

Table 2  **Iqqub and Iddir: Similarities and Differences**

<table>
<thead>
<tr>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both are indigenous and informal but well-organized institutions</td>
<td>The primary objective of <em>iddir</em> is to provide informal insurance policies to members through mutual assistance, while that of <em>iqqub</em> is to mobilize household and individual savings. <em>Iddir</em> involves strong social relations, while <em>iqqub</em> is basically business-oriented, although based on the idea of mutual assistance.</td>
</tr>
<tr>
<td>Both are voluntary, autonomous, self-sufficient and self-regulating, and are independent from the legal, financial and fiscal authorities of the country</td>
<td><em>Iddir</em> is ideally egalitarian and almost a perfectly democratic institution (before the <em>iddir</em>, everybody is equal though there could be some exceptions) while <em>iqqub</em> provides unequal benefits to members depending on the size of contribution a member makes.</td>
</tr>
<tr>
<td>In rural areas, none of them has relations with formal financial intermediaries, while in urban areas some of them deposit money in banks</td>
<td><em>Iddir</em> in particular, community <em>iddir</em>, has a high degree of permanency, while an <em>iqqub</em> may terminate at the end of a cycle unless it is reconstituted by members (big <em>iqqub</em> are more permanent than smaller ones).</td>
</tr>
<tr>
<td>In both cases transaction cost of financial operations are extremely low as compared to formal financial intermediaries</td>
<td>Membership in <em>iqqub</em> often involves homogeneous groups, while <em>iddir</em> (community <em>iddir</em> in particular) has more heterogeneous membership, which cut across class, economic, ethnic (in urban areas) and even political differences.</td>
</tr>
<tr>
<td>Both are governed by written by-laws, in particular, in urban areas.</td>
<td><em>Iqqub</em> is oriented towards fulfilling immediate or planned goals of individuals, while <em>iddir</em> is set up to address emergency situations, disaster, or difficulties that any member of the group may face at any time.</td>
</tr>
<tr>
<td>Both are highly flexible and adaptable to circumstances and are based on the principles of mutual confidence</td>
<td></td>
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</tbody>
</table>
The "selling" of iqquub at progressively declining purchase price reflecting the opportunity cost of money;

The practice of joining more than one iqquub or iddir within a given period of time;

The practice of developing a hybrid financial institution by setting up an iqquub within an iddir (and also introducing money lending activities) in combination with iddir;

The practice of compensating iqquub officials with financial benefits or with the right to collect the first pool;

Increased uses of banks for depositing iddir funds (also iqquub money, to some extent);

The practice of an iqquub gaining permanency through reinstitution at the end of a cycle;

Increased practices of drawing all lots at the start of the cycle of an iqquub so that members know when they would collect their own pool and plan the use of proceeds from iqquub;

In some cases, the socializing aspect of the iqquub is gradually giving way to an economic (or business) one;

Increased problems of fraud and default in urban areas;

Increased problems of declining value of collections from iqquub (with long life cycle) due to inflation, and

Increased transaction costs as iqquub and iddir become large and increasingly sophisticated.

What roles do iqquub and iddir play in strengthening the village economy in general and the crop-livestock systems in particular? As indicated in Figure 2, both iqquub and iddir play a vital role in
strengthening the input relation between the two sub-sectors of the rural economy. The cash incomes and commodities generated by the two sub-sectors are channelled towards iqqub and iddir in the form of regular contributions by households and individuals. Proceeds from iqqub are partly reinvested in the form of livestock. Some portion of the proceeds could be used to purchase farm inputs like seeds and fertilizers. Iddir can provide insurance policies in cases where households face disaster such as the loss of a draft oxen and a milk cow or when they face a total crop loss. The elements shown in Figure 2 are dynamically related. For example, with the purchase of an ox (with iqqub money), a household can raise crop production and, consequently, generate more cash income to be saved through iqqub. With increased saving, a household can expand its asset base and be in a better position to adopt modern technologies.

Figure 2 THE CROP-LIVESTOCK SYSTEMS AND INFORMAL FINANCIAL INSTITUTIONS
4. MONEY LENDERS

The money lender or usurer (which is known in Ethiopia as arata abadari), though charges high interest rate, has advantages in extending credit to mainly rural people. Some of these advantages, according to Padmanabhan (1988), are:

(a) There is little that escapes his eye in the circumstances of his debtors or of those who may one day be his debtors. This local feel keeps him in good stead at the time of loan transaction.

(b) He has different kinds and degrees of hold on those to whom he chooses to lend. Least important of all for him is the possibility of having recourse to the law and almost as unimportant is the possibility of acquiring his debtor's property.

(c) It does not follow that he will invoke the forces of compulsion the moment payment has become due. This is a matter on which, being unfettered by institutional codes, he can be as rigid or as elastic as realism dictates.

(d) Having, in the light of all possibilities, decided on whether and how much he is going to lend and on
what terms, he is free to follow as flexible a procedure as he likes in regard to the actual operation of lending.

(e) He is able to hand over the money promptly in order that some expenditure which brooks no delay may be helped at once, without having to obtain anybody else's sanction or authorization.

The positive factors of money lender credit from the point of view of rural borrowers are: proximity of the creditor to the borrower, quick credit, all-time access (i.e., no bureaucratic procedure), freedom of deployment (i.e., the money can be used for any purpose), repayment flexibility, and comfortable atmosphere (i.e., the borrower and the creditor speak the same language, understand each other, and are from the same cultural background) [Padmanabhan 1988]. Most of these factors tend to reduce the transaction costs of lending and borrowing.

The co-operative and commercial aspects of the village economy is perhaps, nowhere clearly discernible than in the money market. Interest-free loans operate side by side with interest-bearing ones. A needy person can get interest-free loans from relatives and close friends. In the village of Yetmen, (Gojjam), for example, it has been reported that 'generous villagers lend interest-free money to persons they trust' [Tassew et al 1995:21]. Similar practices were observed in the Debre-Birhan area and Chilalo district [Melese et al 1995; Lexander 1968].
On the other hand, interest-bearing loans are widespread throughout rural areas. Although there has never been any national survey on the money market, it is possible to make some observations regarding the size of interest rates. According to one study [Lexander 1968], interest rates varied within a village depending on the type of relationship between the contracting partners. Those who are closely related to the money lender or loyal to him pay lower interest rates (or even pay no interest). There could also be interregional and temporal variations in the magnitude of the interest rate. Moreover, it appears that the interest rate is inversely associated with the maturity period as can be illustrated with an example from Chilalo district [Lexander 1968]:

A petty trader could borrow Birr 10 for one day and pay interest amounting to 25 cents [i.e., 75% per month]. If the maturity period is raised to four days, the interest would be 50 cents for the same amount of principal [i.e. 37.5% per month]. If the maturity period is further extended to 30 days, interest would be Birr 1 [i.e 10% per month]. It is thus to the advantage of the borrower to take loans for a longer time than for a shorter time. High interest rate is a sacrifice made to meet unplanned and pressing needs.

A 10 percent (per month) interest rate has been reported for widely contrasting villages in the country such as Yetmen in Gojam, Aze Debo'a in Kambata, Chilalo, Tigrai, etc., [Melese and Million 1995; Data and Alemu 1995; Lexander 1968; Bauer 1977]. It is very surprising to observe an interest rate of 10 percent per month (i.e about 120 percent per year) in a country characterized by inadequate
infrastructure network, imperfect information, high transaction costs, and fragmented markets.

Interest can take different forms, i.e., interest in kind, cash or labor, depending on the contractual arrangement reached between the partners. According to Lexander (1968), a person can borrow 100 kilograms of grain and pay interest amounting to 50 kilograms after seven or eight months (i.e., interest rate of 50% per eight-month). On the other hand, a person can borrow cash and pay interest amounting to 10 percent per month (i.e., 80% of the principal over a period of eight months). Sometimes the credit market can be interlinked with the labor market as in the case when interest is paid in the form of labor service [Lexander 1968].

Loans can be obtained with or without collateral, depending upon past behavior of the borrower, extent of personal relations between the contracting partners, etc. For example, Lexander (1968:74) noted that in Chilalo loans "can easily be obtained ... provided that the borrower has proved to be honest in similar transactions in the past". Thus, the borrower has an incentive to reduce transaction costs, since good behavior means reduced search costs. In cases where the creditor has incomplete information about the behavior of the borrower, or when the borrower is not trustworthy, a guarantor or crop security (or pawn) is required to ensure repayment.

Contracting partners often exhibit opportunistic behavior that tends to raise transaction cost, as noted by Lexander (1968). A farmer
borrows grain from a trader and agrees to return in kind after a few weeks time. Suppose, in the mean time, the farmer discovers that grain prices have shot up significantly and would be tempted to sell the grain at the prevailing market price, pocket the difference between the original and current market price, and pay creditor in cash equivalent with the original price. This could lead to dispute and litigation as a result of which both partners could incur additional transaction costs (e.g. time lost, going to courts, fees, bribes, etc.).

Most loans are obtained during particular periods of the year. There is a high demand for credit from June to July, during which farm inputs (e.g. seeds and fertilizers) have to be purchased in large quantities and also during which taxes have to be paid. The pre-harvest period, during which food is purchased, is another peak time. Loans are repaid often during the post-harvest period, from December to February. The major reasons for taking loans, according to a workshop report of the Department of Economics, Addis Ababa University, are: to buy food and consumer goods (25%) and farm inputs (19%). Regions using modern technologies tend to get most of the loans to purchase farm inputs. For example, in the village of Sirbana-Godeti (East Shewa), where almost 90 percent of the farm households use chemical fertilizers, 69 percent of the total credit was obtained to purchase farm inputs.

In the workshop, it was also reported that the major sources of loans were friends and relatives (66%), money-lenders (15%), and other sources (19%). Banks accounted for a mere 0.2 percent of the total
credit supplied. It was also reported that only 1.1 percent of the reporting household members had a bank account. On the other hand, 20 percent of sampled households participated in the iqqub [Dejene and Kibre 1995].

It is extremely difficult to identify and characterize money-lenders, although it is likely that most of them are traders or better-off farmers. Nobody knows how many of them are found in rural Ethiopia. At the village-level their number has varied quite widely. In the village of Aze Debo'a, (kembata), where the interest rate is 10 percent per month, there are about four known money-lenders [Data and Alemu 1995]. It is possible that, with such a low number, they exercise oligopolistic power in the financial market. On the other hand, it has been reported that there were as many as seventeen known money-lenders in the Village of Sirbana-Godeti in East Shewa [Behailu et al 1995].

The degree of participation in rural credit markets is likely very high. According to reports made at a workshop by researchers from the Department of Economics, Addis Ababa University, half of the sampled households reported taking loans amounting to an average of Birr 100 in the five years preceding the survey period.

The money market has been surrounded by extreme secrecy. It is only with legalization of money-lending activities that nation-wide survey be undertaken on this important subject.
5. CONCLUSIONS AND POLICY IMPLICATIONS OF THE STUDY

This study has attempted to make some contributions to the literature on informal financial markets in Ethiopia. First, it provided a theoretical framework for the analysis of indigenous financial institutions. By doing so, the study has identified the dual characteristics of the village economies, i.e., the co-operative and competitive spheres of household relations. This distinction helps to address a puzzle regarding rural financial institutions: the fact that institutions like iqquub involve human relations which often violate the convention assumption of individual choice and utility. Moreover, the study has suggested that the unit of economic analysis should not be limited to the household or the individual; the village can and should be taken as an additional unit of economic analysis. The study has attempted to set iqquub and iddir in the context of a theory of the village economy, and to show that these institutions are closely related to other forms of indigenous institutions like the debo, wenfel, etc. Perhaps, the origins of iqquub and iddir can be traced to these types of indigenous, non-financial institutions. The study has also attempted to identify the role that indigenous financial institutions could play in strengthening the mixed farming system of highland Ethiopia.

It is well known that iqquub and iddir are almost totally neglected by policy-makers and major donors. It was only recently that the World Bank and USAID showed interest in the area.
In formulating policies relevant to the iqqub and iddir, the following points should be taken into account.

- Uniform formulas, ready for duplication and guaranteeing success, do not exist. For example, the Grameen Bank model may be appropriate to the conditions of Bangladesh and should be adopted with utmost caution.

- NGOs have little experience in setting up and managing rural financial institutions; their major orientation has always been welfare and relief (see Abugre 1994).

- Before projecting their own conceptions onto the conditions of rural Ethiopia, donors and NGOs need to understand the cultural and social intricacies of the people.

- Before considering the iqqub and iddir as a launching pad for state-or NGO-sponsored financial institutions, it is important to appreciate the fact that indigenous institutions had emerged and sustained themselves because they are appropriate to local conditions and because they are flexible. An attempt at modernizing them without retaining their positive aspects may make them rigid in responding to changing circumstances.
The strength of these institutions lie in their flexibility, adaptability, and informality. They are popular, because they mesh together social interactions and financial relations and have low transaction costs.

Policy intervention points in supporting and strengthening the iqqub and iddir include: (i) recognition, legitimization, and provision of legal provisions for the development of indigenous institutions (including the granting of legal personalities to these institutions), (ii) establishing and strengthening the relationships between the formal and informal financial institutions, and (iii) updating and developing the accounting systems and by-laws of iddir and iqqub.

In Ethiopia, money-lending activities (usuary) are surrounded with secrecy because they are considered immoral and are nearly illegal. In the absence of legal protection, money lenders tend to device various mechanisms to avoid default and fraud. For example, they never mention the term "interest" in the contractual agreement entered with the borrower; instead, the latter is required to declare that he borrowed an inflated sum of money (i.e., the principal and interest). Ethiopia's civil law has provisions for debt but not for interest. This is obviously a subtle way of hiding from legal authorities the fact that interest is involved in the transaction. Moreover, it can be argued that a lack of legal and official recognition of informal activities make interest rates extremely
high/usually 10% per month as risk is involved in lending money to the needy ones. In addition, it should be underlined that both money lenders and borrowers face a highly imperfect market as inflows of information are constrained by secrecy. Therefore, it can be proposed that money lending business be legalized so that the link between the formal and informal sector are reduced and that the informal sector becomes competitive.

REFERENCES


The Agricultural Economics society of Ethiopia (AESE) is a non-profit-making professional society established in 1995.

The objectives of AESE are to contribute to the development of Ethiopian agriculture by promoting research and development in agricultural economics, to promote the study of agricultural economics in the country's educational institution, to promote agricultural research and assist in the dissemination of results, to provide fora for the discussion of problems of agricultural development, to promote the professionalism of agricultural economists and enhance contacts among agricultural economists and other related professionals in Ethiopia and abroad.

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