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Research Report 6

Maize and livestock: Their inter-linked roles in meeting human needs in Ethiopia

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ISBN 92–9146–214–4

Correct citation: Berhanu Gebremedhin, Fernandez-Rivera S, Mohammed Hassena, Mwangi W and Seid Ahmed. 2007. *Maize and livestock: Their inter-linked roles in meeting human needs in Ethiopia.* Research Report 6. ILRI (International Livestock Research Institute), Nairobi, Kenya. 103 pp.

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Acknowledgments

The authors gratefully acknowledge the contribution of the local communities in the study area for their time in responding to our numerous questions, as well as Mr Kahsay Berhe and Mr Solomon Gebreselassie who supervised data collection and entry. We appreciate the contribution of Mr Abebe Misgina in cleaning and organizing the data. Especial thanks are expressed to the Sasakawa Africa Association (SG-2000), in particular to Dr Marco Quiñones and the late Mr Takele Gebre for the support provided to conduct this study as part of a broader effort to assess options for improving the value of maize residues and forage as livestock feed. We are thankful to Dr Aberra Debelo (SG-2000) and Dr Adugna Tolera (Hawasa University) for reviewing this publication and for their comments and suggestions. Appreciation is expressed to the sponsors of the Consultative Group on International Agricultural Research (CGIAR) for the funding provided through ILRI, CIMMYT and the CGIAR Systemwide Livestock Programme (SLP).

Executive summary

1. Objective

The major objective of this study is to understand the roles and interactions of maize and livestock in meeting the livelihoods requirements of Ethiopian households in the maize belt. Emphasis is given to the factors that determine the use patterns of maize in order to identify options for improving the use of maize as livestock feed.

2. Methodology

Based on their importance as maize growing areas, 56 peasant associations (PAs) were purposively selected from the maize belt areas of northwestern Ethiopia in the Amhara region (East Gojam and West Gojam); western, southwestern and southern Ethiopia in the Oromia region (East Shewa, West Shewa, East Wellega and Jimma); and southern Ethiopia in the Southern Nations, Nationalities and Peoples region (SNNPR) (Hadiya and Sidama). The communities in each *woreda* (district) were then stratified by agricultural potential and population density and grouped into four classes: high agricultural potential and high population density (H_aH_p); high agricultural potential and low population density (H_aL_p); low agricultural potential and high population density (L_aH_p); and low agricultural potential and low population density (L_aL_p). In each community, 4 households were randomly selected, thus generating a sample of 224 households. Data were collected at both the community (PA) and individual farm household levels. Household interviews were preceded by community interviews. Data were collected on household characteristics, maize production and use, livestock holdings and husbandry, feeds and feed management, and constraints to livestock production. Data were also collected on other crop production. Most of the data were collected for three consecutive years by recall. Analysis of descriptive information and multivariate econometric methods were used for data analysis.

3. Description of the study area

The study districts are located between 1591 and 2343 metres above sea level (masl). Sample PAs in the high agricultural potential areas are relatively closer to their district towns compared to PAs in the low agricultural potential areas. The PAs in the low agricultural potential areas are farther from all weather roads compared with PAs in the high agricultural potential areas.

The average population of a PA increased from about 8264 in 1999 to 9014 in 2001 with annual average growth rate of 4.4%. The population density (persons/km^2) also increased from an average of 563 in 1999 to 628 in 2001. The average household size in the study districts is about 8, while the average age of the household heads is 47 years. The proportion of males and females in the population is 49.5 to 50.5, which is similar to the national statistics. On the contrary, the proportion of female-headed households in the sample is only 5.4%. About 44% of household heads are literate. Of the total sampled households about 40% are Muslims, 34% are Orthodox Christians and about 25% are Protestants.

The land under cultivation, which is mainly rain fed, accounts for 69% of the total land area. Grazing land accounts for only 10% of the total land, followed by forest/wood lots (9%) and home stead (7%). The proportion of cultivated land is very high in H_aL_p accounting for 80% of the available land. This is followed by H_aH_p where cultivated land accounts for 71% of the total land. The average land cultivated per household is 1.68 ha.

4. Crop production

Maize is the most widely grown crop in the study area and is produced by almost all households (97%), followed by teff, which is grown by about 48% of the households and in all districts but two. Sorghum is produced by less than one-quarter of the households. *Noug*, finger millet and hot pepper are produced by about one-fifth of the farmers each. Maize accounts for 47% of the area cultivated, followed by teff (16%). All other crops individually occupy less than 6% of the cropped land. The average area allocated to different crops ranges from 0.04 ha for tomato to 0.8 ha for maize.

The average maize yield is about 2.11 t/ha, which is higher than the national average of 1.80 t/ha. After maize, wheat has the highest yield in the study area, at about 1.84 t/ha, (also higher than the national average of 1.36 t/ha in 2001/02). Maize and wheat are among the few crops that have wider adoption of improved technologies compared with other crops. The average yield of teff is about 0.72 t/ha, which is similar to the national average yield of 0.87 t/ha in 2001/02. The average yield of other major crops is lower than the national averages, particularly for sorghum (0.62 t/ha) and *Noug* (0.45 t/ha). The variability of yield across agricultural potential and population density is significant for dry maize, where maize yield was significantly higher in H_aH_p and H_aL_p and lower in L_aH_p.

5. Maize production

The average area planted with maize per household is about 0.8 ha. Maize production also shows an expansion during the study period. Maize has relatively more suitable technologies released compared to other crops. The use of improved technologies particularly hybrids and open pollinated varieties (OPVs) is higher for maize than other crops.

There is a tendency of increased use of improved varieties over the study period. The proportion of farmers using improved varieties increased from about 63% in 1999 to 69% in 2001. In terms of individual varieties, the proportion of farmers using the local variety decreased from 37% in 1999 to 31% in 2001. In the high agricultural potential and high population density areas, the local varieties and BH-660 are the most dominant varieties covering about 35 and 31% of the maize area, respectively. The two varieties cover almost similar proportion of maize area in the L_aL_p areas. In the H_aL_p areas, the hybrid BH-660 alone covers about 41% of maize area followed by the local varieties, which covers about 18%. In the high agricultural potential areas, BH-660 is very important covering more than 34% of maize area. The local varieties dominate in L_aL_p areas covering about 35% of the maize area and are second in the L_aH_p and H_aH_p areas. In the H_aL_p and L_aH_p areas, the variety Katumani covers more than 21% of maize area. Oxen ownership, household labour supply and dependency ratio are statistically significantly and positively associated with the use of improved maize cultivars.

Sixty per cent of maize growers used di-ammonium phosphate (DAP) and about 56% used urea in 2001. The number of livestock sold, education level of the household head, oxen ownership and distance to input supply shops explain fertilizer use on maize fields statistically significantly, all with expected signs. Education level of the household head increases the probability of fertilizer use. Distance to input supply shops is found to affect adoption of fertilizer negatively. Farmers who own oxen have higher probability of using fertilizer than those who do not own oxen.

Maize harvesting starts in September and ends in January. The peak harvesting time, however, is in November when about 62% of the producers harvest their maize. Yield of maize in the low agricultural potential areas is 22% lower compared to the high agricultural potential areas. The majority of farmers (more than 85%) harvest maize both as green and dry; while about 7.7 and 6.7% of the farmers harvest maize only as dry and green, respectively. The major variables affecting maize yield that are statistically significant ($P<0.05$) include maize area owned, total crop area and amount of fertilizer used on maize fields. As maize area increases, yield decreases. Total crop area and use of fertilizer are positively associated with maize yield.

6. Livestock production

Cattle are the dominant livestock species in the study area accounting for about 75% of the tropical livestock units (TLU, 1 TLU = 250 kg live weight) and owned by about 88% of the households. The average number of cattle heads owned by a household was 4.5. Only 15 and 16% of the households own at least a sheep and a goat, respectively. Donkey ownership accounts for about 85% of the equine population. About 32% of the farm households own at least one donkey. On the other hand, with the exception of donkeys and to some extent oxen, which showed increasing trends, the number of livestock in the districts surveyed decreased during 1999–2001 period. The major decline in cattle population occurred in the Rift Valley and partly in western Oromia perhaps because of environmental factors. The differences in livestock holdings between agricultural potential and population density categories are not statistically significant.

Farmers keep livestock for multiple purposes. Every species of livestock is kept at least for five different purposes. Oxen are predominantly kept for draught power. The three most important purposes of keeping cows are for milk production, asset building and cash income. Sheep are mainly kept for cash income and asset building. A considerable proportion of farmers also keep sheep for meat. The ranking of the reasons for keeping goats are similar with that of sheep except that goats are also kept for milk production. Equines are kept as pack animals and for cash generation. Animal products commonly used by farmers include milk, milk products, and hides and skins.

About 84.4% of farmers used veterinary services during the study period, of which about 97.3% used the service provided by the district offices of agriculture and rural development and only about 4.7% used the services provided by private veterinary service providers. The low agricultural potential areas are farther from the service centres compared with the high potential areas. Fifteen per cent of the farmers used artificial insemination (AI), which is provided only by the offices of agriculture and rural development. Higher proportion of farmers in the H_aH_p areas used AI services compared to the others areas. Only about 1 and 2.2% of farmers reported using watering troughs for livestock during the wet and dry seasons, respectively. Livestock are mainly watered in rivers and streams. The use of credit for livestock production is very low. The major purpose for wanting credit among those who sought credit was to purchase livestock (52%), which is an investment.

Feed resources in the study areas include grazing, on-farm produced crop residues, on-farm produced hay, purchased crop residues, purchased hay, and industrial and local beverage by-products. Planting forages is not common. Use of communal grazing was reported by 64, 52 and 29% of the sample PAs in the wet, harvesting and dry seasons, respectively. The major crop residues fed to animals by the majority of the farmers are teff, maize, finger millet and *enset* (false banana). The most important crop residue is maize stover, which was available as dry stover for about 79% of the sample households and as green stover for more than 58% of the households. The second most important crop residue is teff straw, which was used by about 48% of the sample households. *Enset*, tree legumes and hay were available for only about 10% of the households. Only one or two of the sample households planted improved forage during the 1999–2001 period. The important reasons for not planting improved forage were lack of awareness as reported by about 76%, and shortage of land as indicated by about 13% of the respondents.

Because of the dependency on natural rainfall, the availability of feed for livestock follows seasonal pattern both in type and in quantity. Certain types of feeds are available at specific periods only while others are stored for dry period use. Maize residues are fed to animals at green stage, during harvest and after harvest in the dry season. Use of purchased feed is not common. About 4% of farmers in dry season and 2% of farmers in wet season purchased hay. In general less than 12% of the livestock owners bought livestock feed of any type in any one season. About 27% of the farmers supplement livestock feed with salt and only during the wet season. Although some farmers sold crop residue, sales usually were not made to other farmers.

In general, the maximum level of feed security (60–80% of farmers reporting) occurs during the grain harvest season. This is followed by the wet season. During the first quarter of the year (January–March), there is a severe feed shortage. In the second quarter (April–June), the level of feed scarcity eases, as a result of the short rains. Because of the main rains, feed is reportedly relatively abundant in the third quarter (July–September). However, feed is reported to be scarce during the early wet season when access to grazing lands is limited and most land is under cultivation. Different types of livestock have different access levels to feed. Crop residues are stored for the dry and wet periods, particularly for draught oxen and milking cows.

The most important consequence of feed shortage, as prioritized by farmers, is weight loss of animals, followed by weakness, increased mortality, low milk yield and extended calving period. Farmers employ several strategies to overcome the problem of feed shortages. One strategy, used by about 68% of livestock owners, is de-stocking. Other options include moving the animals to other places, renting pastureland, storing hay and straw. Transferring the stock to other households was practised by less than one-third of the livestock owners. The majority of farmers reported feed shortage as the most important problem of livestock production, followed by diseases.

7. The multiple roles of maize

Maize is the most important crop for households both for household consumption, (accounting for 62% of all household cereal consumption), and as source of cash income (accounting for about 54% of cash income). About 65% of maize produce is used for household consumption. Wheat is the most marketed produce (44% of produce sold), followed by teff (about 37% of the produce marketed). About one-third of barley produce is also sold.

Farmers consume maize by preparing different dishes. These include bread, *injera*, thick porridge, boiled maize, roasted maize and local beer. About 93 and 92% of the maize growers make bread and *injera* from maize, respectively. About 83% of the farmers consume boiled maize, 72% make thick porridge and about 64% use maize to make the local beer, *tella*. Hence, in order of importance, maize is used for making bread, followed by *injera*, boiled maize, thick porridge and local beer.

Maize forage is derived from green stover (obtained from thinning, leaf stripping, plant tops and the entire green plant after removal of the ear) and dry stover. The use of maize grain as feed is very low, although few farmers reported its use. On average, farmers produce about 1 t and 1.51 t of green and dry maize stover per year, respectively. Of the produced maize stover about 69% is used as livestock feed. About 25% of the residue is used as fuel. Sale and construction account for very small proportion of the crop residue.

Maize accounts for about 77% of the total residue fed to the animals and about 99% of the total crop residues used for fuel. The majority of farmers use maize residue to feed milking cows and oxen. Regression results showed that the proportion of maize stover used for livestock feed is statistically significantly determined by the amount of teff residue produced, amount of maize residue produced, distance to livestock market, distance to input supply shop, population density and oxen ownership.

Distance to livestock market and input supply shop are negatively associated with maize stover use, as expected. Teff straw, as a substitute feed for livestock, decreases the proportion of maize stover used as feed. Amount of maize stover produced is positively associated. In areas of high population density, the use of maize stover for livestock feed increases.

8. Feed marketing

The number of farmers participating in feed marketing (buying and selling) in the study area is very low. Farmer participation in the feed market is geared more towards selling to generate income than buying. Those farmers who buy feed prefer grasses (pasture and hay) to residues. The few farmers who wanted to buy reported that they could not get the required amount. Interestingly, although many farmers did not buy livestock feed, they reported having information on feed prices. The major marketing problem reported by farmers who could potentially become feed buyers (reported by about 44% of respondents) is high prices particularly for natural pasture, bran and hay.

Not all farmers store crop residues and thus high feed availability fluctuation is observed widely. About 57 and 43% of farmers reported that they did not store sorghum stover and barley straws for future use during the study period. More than 20% of the farmers also did not store finger millet, barley and maize residues. Teff straw is the most stored residue (stored by about 98% of the producers). Only a few farmers store crop residues under shade. The average loss for major crops residues due to storage, as reported by farmers, ranges from 12% for sorghum to 23% for maize.

9. Conclusion and implications

This study examines the interactions and roles of maize and livestock in the livelihoods of people in the maize belt areas of Ethiopia. Maize is grown by about 97% of households in the study area, followed by teff and sorghum. Maize accounts for 47% of the cultivated area. The average area allocated to maize is 0.8 ha/household. About 69% of maize residue produced is used for livestock feed. The importance of maize in the crop choice of households in the study areas is increasing because of both its food and feed value. These results imply that interventions to improve maize as food and feed crop could contribute significantly to the livelihood of rural households and the alleviation of feed shortage. Improving the availability and feed value of maize stover could enhance the contribution of cattle production to the welfare of farmers and their families.

In spite of the multiple roles of maize, research and development efforts have focused on the importance of maize grain for food security and have neglected the importance of maize stover as livestock feed. Although farmers use all maize cultivars as animal feed, in general, they showed preference for local maize varieties in terms of stover feed quality. Hence, maize breeders need to study the traits of local maize varieties in order to incorporate them in the maize improvement breeding programs. Agricultural research aimed at developing improved maize cultivars needs to make explicit consideration of the value of the stover as feed and other uses. Quantitative assessments of the economic loss due to under nutrition of livestock and the trade-offs among the competing uses of maize stover should inform this effort. In addition, attention needs to be given to improved storage of maize stover and its management as feed. Overall, the contributions of maize to the welfare of farmers in the maize–cattle belt could be enhanced if policy, research and extension interventions place maize in a broader agricultural development context.

1 Introduction

1.1. Background

Ethiopia has the largest livestock population in Africa. In 2001/02 the country was estimated to have about 36.4 million tropical livestock units (TLU, 1 TLU = 250 kg body weight). Cattle are the dominant species accounting for about 80% of the TLU mass, whereas equines and small ruminants account for 11 and 7.8%, respectively. The regional states of Oromia, Amhara and South Nations, Nationalities and Peoples Region (SNNPR) account for 43, 26 and 20% of the national livestock population, respectively (CSA 2003).

The two major livestock production systems in Ethiopia are the mixed crop–livestock and pastoral/agro-pastoral systems. Mixed crop–livestock production is practised in the highlands (above 1500 masl) and in the crop producing lowland areas. Pastoral and agro-pastoral production is practised in the dry lowlands where crop production is not common. In the highlands and lowland areas, where both crop and livestock productions have important roles in the household economy, the interaction between the two subsystems is complex. In this system, crops and livestock compete for resources but they also complement each other (Gryseels and Anderson 1983).

In the mixed crop–livestock farming systems, the most important feed sources are crop residues and natural herbage. Livestock have access to crop stubbles and weedy fallows. The conversion of grazing land into cropland is likely to boost the importance of crop residues as livestock feed, especially in the highlands. Because of high population growth and farming, fallows have all but disappeared and private and communal pastures have become a small fraction of the total land. Consequently, the livestock industry in Ethiopia is highly constrained by the shortage of feed both in quantity and quality.

Maize was originated in Central America and introduced to West Africa in the early 16th century (FAO 1992) and to Ethiopia between the 16th and the 17th century (McCann 2005). Africa produces 6% of the total world maize production, most of which is used for human consumption (Reynolds 1999). Maize is the staple food crop for over 24 million households in East and Southern Africa (ESA) and is planted annually on over 15.5 million hectares of land. The crop is grown in nearly all countries of ESA even under suboptimal conditions. In southern Africa, only a single crop is possible per year, but in Kenya, Uganda and parts of Tanzania two cropping seasons are possible due to the bimodal rainfall. Governments in ESA have given top priority to maize production, because maize in this subregion is as important as rice and wheat in Asia (Byerlee and Eicher 1997).

At the end of the last decade, ESA produced over twice as much maize (23.4 million tonnes) as western and central Africa (11 million tonnes). Excluding the Republic of South Africa, the largest maize producers in ESA are Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Zimbabwe and Zambia (Smale and Jayne 2002). The average yield in West and Central Africa (WCA) is about 1 t/ha, compared to 1.5–2 t/ha in East Africa, Asia and Latin America (FAO 1993; Reynolds 1999). Despite the importance of maize, African maize production is characterized by lower and more variable yield. In countries such as Mozambique, Angola, Zimbabwe, Malawi, Tanzania, Zambia, and Ethiopia the coefficient of variation (CV) in maize yield is over 15%, while for Uganda and Kenya the CV was 10–15% (Byerlee and Eicher 1997). Climatic factors are largely responsible for this variation, but price variability also plays a vital role.

In 1997–99, maize accounted for 41% of total cereal area in ESA and 21% in WCA (Smale and Jayne 2002). Maize is planted in 75% or more of the cereal growing area of Kenya, Malawi, Zambia and Zimbabwe (Smale and Jayne 2002). In Ethiopia, maize stands first in total annual grain production and second in terms of area coverage (CSA 2003). The grain is mainly used for human consumption (Diriba et al. 2001). The contribution of maize as food in total calorie intake in Africa is high. For instance, in Malawi its contribution is as high as 67%, whereas in Ethiopia it has a share of 19% of the total calorie intake (Reynolds 1999).

In Ethiopia, crop production is dominated by cereals. In 2001/02, cereals accounted for 73% of the cropping area. The major cereal crops grown in order of area coverage were teff, maize, sorghum, wheat, and barley covering between 13.4 and 26.4% of the cereal area. Maize is cultivated in a wide range of altitudes, moisture regimes, soil types and terrains, mainly by smallholder crop producers. Three of the nine administrative regions account for the bulk of maize production. According to FAO (2002) estimates, Oromia, Amhara and SNNPR regions account for 56.5, 21.1 and 16.4% of the total maize production of the country, respectively, together generating 94% of national maize production. Of all food crops covered under the extension program, maize has received the highest attention owing to its wider cultivation, significance in its share of food crops and availability of productivity enhancing technologies. This can be seen from the fact that with a mean annual growth rate of 1.62%, the total area of land under maize cultivation increased significantly from 75,500 ha in 1961 to about 1.5 million hectares in 1998 and 1.7 million hectares in 2001/02. It constituted 12.8% of the total area under cereal crop in 1961, 23% in 1998 and 26.4% in 2001/02 (Tesfaye et al. 2001; CSA 2003). This trend reflects not only how important maize has remained in the cereal production of the country's agriculture, but also the shift of many farmers towards cultivation of maize, such as in the Amhara region.

In terms of grain production, maize stood first mainly because of the higher productivity over teff. The average smallholders' yield of major cereals ranges from 0.87 t/ha for teff to 1.81 t/ha for maize (Table 1). Maize productivity in large farms can be much higher due to the use of hybrids and fertilizer. Recently, rice was introduced in some areas in the country and the yield is comparable to maize. Maize accounted for 23.7% of cereal area and 33.7% of cereal grain production in the country in 2001/02. Over the last four decades, the yield of maize has doubled, from 0.96 t/ha in 1961 to 1.81 t/ha in 2001/02 (Tesfaye et al. 2001; CSA 2003). However, compared to other African countries that on average produce more than 2.5 t/ha, productivity of maize in Ethiopia is still very low.

Table 1. *Cereal area and yield under private holding in Ethiopia, 2001/02*

Crop	Area (× 10^3 ha)	% of cereal	Output (× 10^3 t)	Yield (t/ha)
Teff	1896	26	1657	0.9
Barley*	966	13	987	1.0
Wheat**	1090	15	1484	1.4
Maize	1702	24	3086	1.8
Sorghum	1195	17	1583	1.3
Finger millet	286	4	309	1.1
Oat	44	0.6	39	0.9
Rice	8	0.1	16	1.8

* Food and malt barley.
** Bread and durum wheat.
Source: CSA (2003).

In Ethiopia, maize grain is mainly used for human consumption as a variety of food products and also for local beverages. The use of maize for industrial processing is low but increasing. Maize is mainly processed at the household level with 76% used for home consumption, 9% for seed, about 10% marketed and the remaining 4% being used for different purposes (CSA 2003). Green cobs are also sold in big cities and towns.

Smallholders in Africa produce maize mainly for human consumption. Silage making is not practised because of technical difficulties and the priority given for household food (Reynolds 1999). Ruminant feed from maize is derived almost entirely from the residues. Ruminant feed from green stover is obtained from thinning, leaf stripping, plant tops or the entire green plant after picking the ear. It is also obtained from dry stover after grain harvest and this is used most widely for livestock feed. During crop failure at tasseling, farmers feed the entire maize stand to their animals.

The contribution of maize stover to the diet of ruminant livestock varies widely depending upon human population density, type of livestock, management system, market access and climate (Thorne et al. 2001). Under severe human population pressure such as in the highlands of Ethiopia, cereal straws and stover may also be used for bedding, fuel and as construction materials (Zinash and Seyum 1989). There are indications that maize crop will become increasingly important as a source of fodder (Staal et al. 1998).

Maize research in Ethiopia has mainly focused on grain yield improvement without concern of the yield and feed quality of the stover (Tolera et al. 1999). This is explained mainly because of the poor research linkages between crop breeders and animal nutritionists. Exceptions are the efforts that have been made to quantify the quantity of maize residue and its components and develop alternative interventions for the efficient use of the residue. Positive results were obtained from the under sowing of forages with maize and intercropping of forages with maize in different maize growing areas (Diriba et al. 2001). Integrating the feed value of the stover into the development and release system of improved cultivars[1] is at an infancy stage. Research on the use of maize stover by smallholders is one step towards bringing its importance to the attention of researchers.

As compared to other cereals, the contribution of maize as feed in Ethiopia is estimated to be substantial. For example, of the 13.7 million tonnes of crop residues produced as dry matter (DM), wheat, barley and teff, the typical highland crops, accounted for 6, 10 and 17% of the total, respectively (de Leeuw 1997). The residues from maize and sorghum/pearl millet growing in the mid- to low-altitude zones account for 39 and 36% of the total, respectively (de Leeuw 1997) probably because of an assumed high residue:grain ratios (3 for maize and 5 for sorghum) (Kossila 1988; Nordblom and Shomo 1995). The high importance of maize as livestock feed will have influence on the adoption of conservation tillage in Ethiopia.

Data and information on the actual level of use of maize residue for livestock feed and how livestock rearing affects the adoption of maize-based technologies in Ethiopia is scarce. There is little information on use pattern of maize residues by smallholders in the maize–livestock production system in the country. The relevance of socio-economic factors on use of maize stover for livestock feed has not been established. This research was undertaken primarily to fill these existing gaps in knowledge.

1.2 Objectives

The general objective of this study was to understand the roles and interactions of maize and livestock in meeting livelihoods requirement of Ethiopian households in the maize belt. Emphasis was given to the factors that determine the use patterns of maize in order to identify options for improving the use of maize as livestock feed. The specific objectives were to:

1. In this report, the term 'cultivar' is used to refer jointly to both hybrids and open pollinated varieties (OPV) whereas the term 'variety' is used only to refer to OPV.

1. characterize the maize–livestock production system
2. assess the availability and use of livestock feed in the system
3. analyse the role of maize as food and feed and
4. analyse the factors that affect the use of maize as livestock feed.

The report is organized as follows. The following section presents methods of study. Section three describes the study area. Section four presents crop production in the maize belt area. Sections five and six deal with maize and livestock production in the maize belt, respectively. Section seven presents the multiple roles of maize, while section eight describes the feed marketing situation in the study area. Section nine concludes the paper and draws implications.

2 Methodology

2.1 Sampling method and data collection

Data were collected from the maize belt areas of northwestern Ethiopia in the Amhara region; western, southwestern and southern Ethiopia in the Oromia region; and southern Ethiopia in the Southern Nations, Nationalities and Peoples Region (SNNPR). Using secondary information, districts where maize is the major crop in the farming system were identified. The communities in each *woreda* (district) were then stratified by agricultural potential and population density. Communities/peasant associations (PAs) were classified into high and low agricultural potential based on opinions of *woreda* level experts and key informants. Factors like drought, access to market and all weather roads were considered in this classification. Similarly, communities were classified into high and low population density. Communities with population density of 160 persons per km^2 or above were classified as high population density, and those below that as low population density areas. Hence, communities were grouped into the following four classes: high agricultural potential and high population density (H_aH_p); high agricultural potential and low population density (H_aL_p); low agricultural potential and high population density (L_aH_p); and low agricultural potential and low population density (L_aL_p). One community was randomly selected from each of the four agricultural potential and population density classes. In *woredas* where there were empty cells[1] of the combinations of agricultural potential and population density, four communities were randomly selected from the available cells. A total of 56 communities were selected. In each community, four households were randomly selected, thus having a sample population of 224 households.

The distribution of PAs by district, administrative zone, agricultural potential and population density is presented in Table 2. The majority of the PAs (71%) were in high agricultural potential (H_a) areas and only 29% were in low agricultural potential (L_a) areas. Moreover, 68% of the high agricultural potential PAs were in the densely populated areas, showing that the study villages are more in H_aH_p (52%) areas. Only 12.5% of the PAs were in the L_aL_p areas.

Data were collected at both the community/PA level and individual farm/household level. For the community/PA level survey, interviews were conducted with groups of farmers representing age groups, gender, and administrative responsibility within the communities and villages. Community interviews were followed by household interviews. In the household interview, a wide range of information was collected. This included data on livestock holdings and husbandry, infrastructure, feeds and feed management and constraints

1. Some *woredas* had communities of high population density (Hp) only.

to livestock production. Data were also collected on crop production and crop residues. Scales were used to measure the equivalence of local measures used to weigh crop residues. Detailed information was collected on maize production and use, in particular on the role of maize as livestock feed and for human consumption. Most of the data were collected for three years using recall system. For primary data collection, enumerators were hired to administer the questionnaire.

Table 2. *Number of sampled PAs by agricultural potential and population density*

Region	Zone	District *(woreda)*	Agricultural potential–population density				Total
			H_aH_p	H_aL_p	L_aH_p	L_aL_p	
SNNPR	Hadiya	Badawacho	4				4
	Sidama	Alaba	1	1	1	1	4
		Awasa Zuria	2		2		4
		Boricha	2		2		4
Oromia	East Shewa	Siraro	1	1	1	1	4
		Shashemene	1	1	1	1	4
	West Shewa	Bako Tibe	1	1	1	1	4
	East Wellega	Gobu Seyo	1	1		2	4
	Jimma	Kersa	3	1			4
		Omo Nada	3	1			4
Amhara	West Gojam	Bure	3	1			4
		Mecha	3	1			4
	East Gojam	Baso Liben	3	1			4
		Debre Elias	1	1	1	1	4
	Total		29	11	9	7	56

2.2 Data analysis

Data were analysed using both descriptive and multivariate methods. Descriptive statistics were used to present the general overview of the farmers' practices. These included description of crop production in general and that of maize in particular, livestock management, the role of maize as livestock feed and for human consumption, and feed marketing. The General Linear Model (GLM) procedure of SAS was used to determine the effect of agricultural potential and population density on key response variables (SAS Institute Inc. 1999). The General Linear Model was specified as:

$$Y_{ijk} = \upsilon + A_i + P_j + (AP)_{ij} + \varepsilon_{ij} \quad (1)$$

where:

Y_{ijk} = a dependent variable (the key variable to be analysed);

α OR υ = the population mean;

A_i = the fixed effect of agricultural potential for i = low or high;

P_j = the fixed effect of population density for j = low or high;
$(AP)_{ij}$ = the effect of the interaction between agricultural potential and population density; and
ε_{ij} = random error with a normal distribution, mean = 0 and variance = σ^2.

Econometric methods were used to determine the relationships between outcome variables of interest and explanatory variables. Factors affecting the use of improved maize cultivars as well as chemical fertilizer were identified using the probit model. According to Greene (2003) the probit model could be presented in the latent model framework as:

$$Y_i^* = \beta_1 + \beta_2 X_{i2} + ... + \beta_k X_{ik} + u_i \quad (2)$$

where

Y* is an unobservable magnitude which can be considered as the net benefit to individual i of taking a particular course of action (in our case using improved cultivar of maize (both open pollinated and hybrid)). We cannot observe that net benefit, but can observe the outcome of the individual having followed the decision rule.

$$Y_i = 0 \text{ if } Y_i^* < 0$$
$$Y_i = 1 \text{ if } Y_i^* \geq 0 \quad (3)$$

Y* as a latent variable, linearly related to a set of factors X and a disturbance process u. In the latent model framework, the probability of an individual making each choice is modelled using equations (2) and (3). We have:

$$\begin{aligned} &\Pr[Y^* > 0 \mid X] = \\ &\Pr[u > -X\beta \mid X] = \\ &\Pr[u < X\beta \mid X] = \\ &\Pr[Y = 1 \mid X] = \psi(Y_i^*) \end{aligned} \quad (4)$$

The function $\psi(.)$ is a cumulative distribution function (CDF) which maps points on the real line $\{-\infty\ \infty\}$ into the probability measure {0, 1}. The explanatory variables in X are modelled in a linear relationship to the latent variable Y*. The CDF of the normal distribution function is given by:

$$\Pr[Y = 1 \mid] = \int_{-\infty}^{X\beta} \varphi(t)dt = \psi(X\beta) \quad (5)$$

where

$\varphi(.)$ is the probability density function of the normal distribution.

The parameters of probit models may be estimated by maximum likelihood techniques. For each observation, the density of y_i given X_i may be written as:

$$f(y/X) = [\psi(X_i\beta)]^{y_i}[1-\psi(X_i\beta)]^{1-y_i}, y_i = 0,1 \quad (6)$$

This implies that the log-likelihood for observation i may be written as:

$$\ell_i(\beta) = y_i \log[\psi(X_i\beta)] + (1-y_i)\log[1-\psi(X_i\beta)] \quad (7)$$

and the log-likelihood of the sample is:

$$L(\beta) = \sum_{i=1}^{N} \ell_i(\beta) \quad (8)$$

to be numerically maximized with respect to the *k* elements of β.

One of the major challenges in working with limited dependent variable models is the complexity of explanatory factors' marginal effects on the result of interest. That complexity arises from the nonlinearity of the relationship. In equation (4), the latent measure is translated by $\psi(Y_i^*.)$ to a probability that $Y_i = 1$. While equation (2) is a linear relationship in the β parameters, equation (4) is not. Therefore, although X_i has a linear effect on Y_i, it will not have a linear effect on the resulting probability that y = 1. The marginal effect is given by:

$$\frac{\partial pr[y=1|X]}{\partial X_j} = \frac{\partial pr[y=1|X]}{\partial X\beta}.\frac{\partial X\beta}{\partial X_j} = \psi'(X\beta).\beta_j = \psi(X\beta).\beta_j \quad (9)$$

The probability that $Y_i = 1$ is not constant over the data. Via the chain rule, we see that the effect of an increase in X_j on the probability is the product of two factors: the effect of X_j on the latent variable and the derivative of the CDF evaluated at Y_i^*. The latter term, ψ(.), is the probability density function (PDF) of the distribution.

Multiple linear regression using OLS procedure was used to identify factors that affect maize yield. The OLS equation used to estimate the parameters is given as:

$$Y = \alpha + \beta_i X_i + u_i \quad (10)$$

where

Y_i is yield of maize in natural logarithmic form

X_i are dependent variables, in their natural logarithmic form for continuous variables and 0/1 for dummy variables

β_i are parameters to be estimated

α is constant term

υ_i is error term.

A similar model was used to identify the factors that affect the use of maize stover for livestock feed. The dependent variable in this model was the proportion of maize stover used for livestock feed. Data on proportion of maize used as livestock feed was missing for households where stover was not harvested or where cattle were not owned. The regression analysis used data from all households where stover was harvested and cattle were owned. Therefore, there was no need for using a two-stage estimation procedure.

3 Description of the study area

3.1 Physical features

Location and accessibility

The study districts are located in the northwestern, western, southern and south-central parts of Ethiopia. Those in the south (six districts in Oromia and SNNPR) are mainly located in the Rift Valley. Those in the west stretched from northwest in the Amhara region to southwest in Oromia.

Access to services is important particularly in areas where infrastructure is poorly developed as it hinders performance of the agricultural sector through its impact on information and marketing. The road networks radiate from the centre of the country and asphalt roads cross most of the study districts in the south and west direction (Figure 1). In the northwest, two districts are crossed by gravel all-weather road while the other two districts are not crossed by all-weather road. Distances from the main towns (where services are usually available) and all-weather roads to access services were measured in terms of both kilometre and time (walking hours) that it takes to reach the town and all-weather road. Since accessing these services and infrastructures is usually on foot and pack animals, these values were compared across districts and levels of agricultural potential. On average, villages are located 10 km far from their respective district towns and this distance ranges from 2 km in Bure and Shashemene to 17 km in Awassa Zuria (Table 3). PAs in the high agricultural potential areas are relatively closer (9.7 km) to the district town compared to PAs in low agricultural potential areas (11.5 km), but the difference is not significant. With an average speed of 5.4 km/hour on foot and 11.3 km/hour for pack animal (calculated from survey data), on average it takes farmers about 2 hour on foot and 1 hour by pack animal to reach the district town. On average, a PA is about 5.25 km away from the nearest all-weather road.

Table 3. *Accessibility of the selected peasant associations to district towns and all-weather roads*

Districts	Walking distance to district town (km)	Walking time to district town (hours)	Walking distance to the nearest all weather road (km)	Walking time to the nearest all weather road (hours)
Awassa Zuria	17.0	2:38	0.6	0:06
Boricha	15.0	3:08	6.5	1:05
Alaba	6.5	1:28	5.3	1:14
Badawacho	12.3	2:49	8.3	1:41
Siraro	12.0	2:45	9.9	3:15
Shashemene	5.8	1:13	3.1	0:39
Gobu Sayo	12.0	2:05	9.3	1:38

Districts	Walking dis-tance to district town (km)	Walking time to district town (hours)	Walking distance to the nearest all weather road (km)	Walking time to the nearest all weather road (hours)
Omo Nada	8.5	1:34	5.5	0:49
Kersa	8.5	1:32	2.8	2:30
Bako Tibe	10.8	1:45	1.4	0:10
Debre Elias	7.0	1:16	7.5	1:21
Baso Liben	8.1	1:15	8.1	1:15
Bure	9.3	1:50	3.0	1:10
Mecha	6.0	1:13	1.3	0:35
Mean	9.9	1:56	5.2	1:10

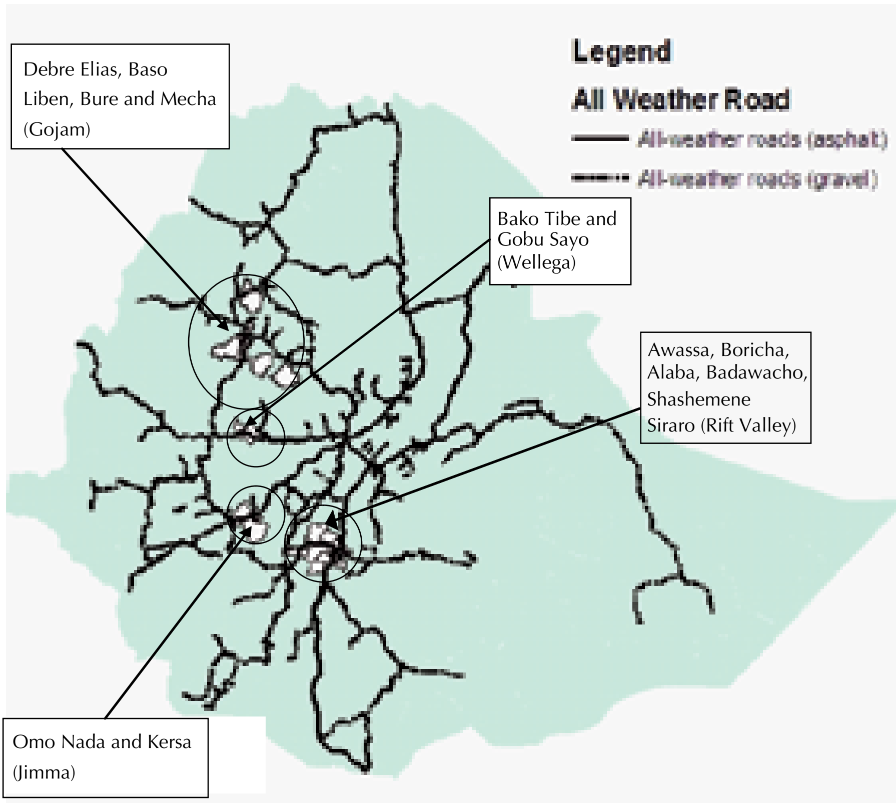

Figure 1. *Location of the study area and accessibility to road network.*

Relief

The study districts are stretched from West Gojam zone in the north to Sidama zone in the south following the major maize producing areas of the country. The altitude of the study villages ranges from 1591 masl in Siraro in the Rift Valley to 2343 masl in Baso Liben in the northwestern part of the country. The districts in West Gojam are on the highlands with an average altitude of more than 2100 masl. All other PAs are in the mid altitude zone below 2000 masl. The study districts could be clustered into four as indicated in Figure 2 with relatively different topography.

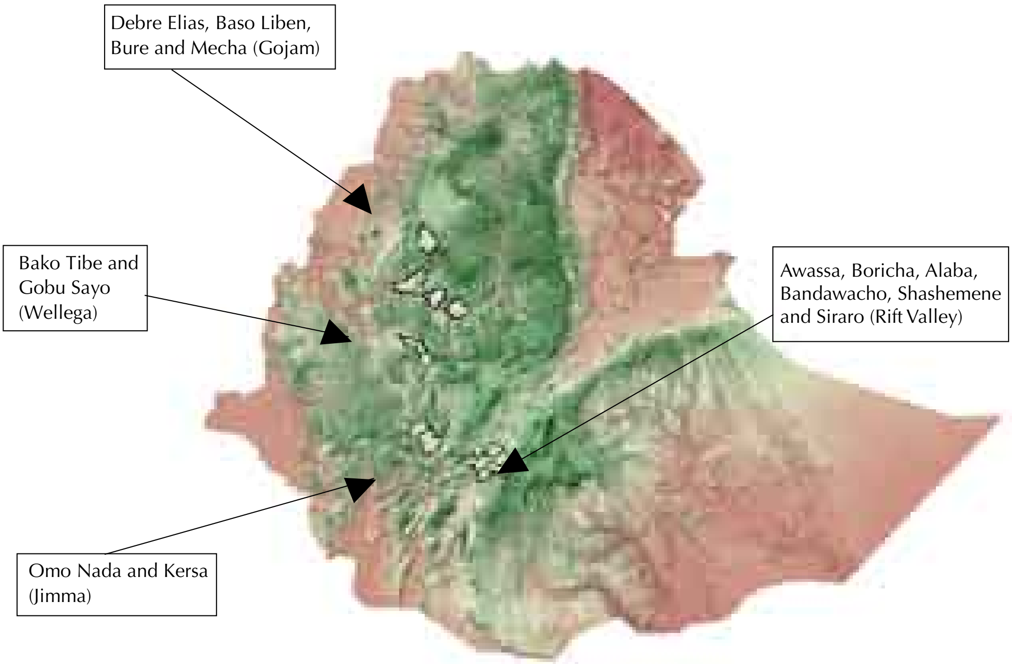

Figure 2. *Location of the study districts and the topography.*

Seasonality

One-year cycle was divided into three seasons: dry, wet and harvest. Group interviewees were asked in which of the three seasons a month falls. The results indicate that except July and August where in all PAs it is considered as wet season, in all other months there are differences in season among the PAs. For instance, 96% of the PAs reported that February is dry month and only in the remaining 4% of the PAs was February reported as wet. Similarly, January is reported to have different seasons in different PAs. Eighty-nine per cent of the PAs reported that January is a dry month, while the remaining nine and two per cent of the PAs reported that January is harvesting and wet month, respectively (Figure 3). The duration of the seasons varies due to geographical location and altitude. Following the rainy season, harvesting starts as early as September and extends to January. The peak harvesting months are November and December where about 89 and 70% of the PAs are on harvesting, respectively. Dry season covers longer period between January and March. Similarly, between April and September more than 70% of the PAs reported rain in their area. For more than 70% of the PAs, the dry season is between January and March; wet season is between April and September; and harvest season is between October and December.

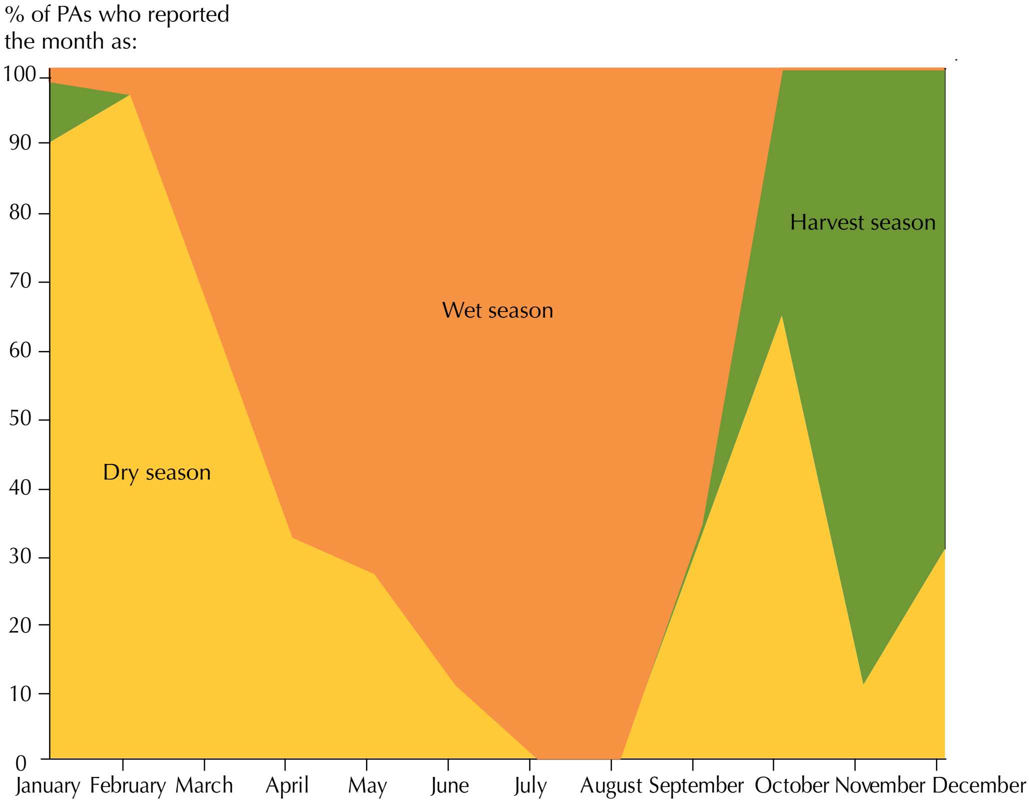

Figure 3. *Duration of seasons in the study area.*

Soil

Soils were classified into four types (clay, clay loamy, loam and sandy). Sandy soil is more common in the southern part of the study sites (Shashemene, Siraro, Alaba and Awasa). This soil type is with high sand content, low water holding capacity and low inherent fertility. Clay soil is more common in the districts found in the northwestern and western parts of the country. This soil is black in colour and mostly found in flat areas having water logging problems and poor aeration for crop production. Maize usually does not tolerate water logging and is not commonly grown in clay soils. Overall, the dominant soil types are clay loamy and loamy soils found in 63% of the PAs each. Clay loamy soils are red in colour and are usually well drained and suitable for crop production in gentle slope areas. Loam soils have a favourable proportion of sand, silt and clay with good fertility and are suitable for crop production.

In H_aH_p and H_aL_p, the three soil types, except the sandy soil type, are found in more than 26% of the PAs (Table 4). In both H_aH_p and H_aL_p, clay loam soil is found in only 13% of the PAs. Many of the PAs in L_aH_p have loam (43%) and sandy (36%) soil types. The high presence of loamy soil in L_aH_p indicates that this area is more constrained by moisture than the soil fertility. In L_aL_p, the PA with clay loamy and loam soil is 29% each; while 21% of the PAs have also clay and sandy soils.

Table 4. *Presence and abundance of different soil types in the study area*

Agricultural potential and population density category	% of PAs (abundance ranking: 1 = most abundant)			
	Clay	Clay loamy	Sandy	Loam
H_aH_p	28 (2.4)	32 (1.5)	13 (1.4)	27 (2.0)
H_aL_p	30 (2.1)	30 (1.3)	13 (2.3)	26 (2.2)
L_aH_p	7 (3.0)	14 (1.0)	36 (1.0)	43 (1.7)
L_aL_p	21 (2.0)	29 (1.0)	21 (1.7)	29 (1.8)
Total	54 (2.3)	63 (1.3)	36 (1.5)	63 (1.9)

Note: Numbers in parenthesis are abundance calculated as an average of ranks given to the soil type in the PAs.

The coverage of the different soil types was analysed using the average of their ranks (Table 4). The soil type with minimum average rank is the one with larger coverage. Accordingly, on average, the average rank ranges from 1.34 for the clay loamy soil to 2.3 for the clay soil. Therefore, the clay loamy soil is most abundant followed by sandy soil (1.5) and loam soil (1.9) and the clay soil is the least abundant. Although sandy soil is present in only 36% of the PAs, compared to clay and loam soils which are found in more than half of the PAs, it covers relatively wider area. This clearly indicates the dominance of maize in the relatively well-drained soils, as maize cannot tolerate water logging, which is common in black clay soils. In none of the PA did clay soil ranked first.

3.2 Demographic characteristics

The average population of a PA increased from about 8264 in 1999 to 9014 in 2001 with annual average growth rate of 4.4% (Table 5). The annual average growth rate was extremely high in Gobu Sayo district of Oromia (16.2%). The result shows that there was no increase in family size but the number of households increased with the same percentage, which could be due to the establishment of new households. Next to Gobu Sayo district, the highest growth rate was reported in Awasa Zuria (8.7%) and Badawacho (7.1%). In most other areas, the average growth rate was low (for instance in Shashemene, the growth rate was 1.2%). Similarly, population growth rate varied across agricultural potential. The average population growth rate during the three years (for which the data were collected) was high in L_aH_p (6.3%) and L_aL_p (5%), while relatively lower in case of H_aH_p (4.1%) and H_aL_p (4.4%). This may indicate the saturation of high agricultural potential areas and farmers moving more towards low agricultural potential areas, which may lead to environmental degradation as most of these low potential areas are fragile environments.

Table 5. *Demographic condition of the study districts*

District	Average annual population growth rate (1999–01)	Average family size (1999–01)	Population density (persons/km^2)		
			1999	2000	2001
Awassa Zuria	8.7	6.9	1166	1111	1381
Boricha	5.0	7.1	1016	1002	1113
Alaba	2.3	7.3	463	455	489
Badawacho	7.1	10.0	978	1009	1206
Siraro	3.6	11.0	544	538	583
Shashemene	1.2	6.5	1160	1090	1197
Gobu Sayo	16.2	9.8	236	263	338
Omo Nada	3.2	10.5	322	309	343
Kersa	4.2	7.8	320	303	352
Bako Tibe	4.3	8.0	279	264	301
Debre Elias	4.0	6.8	342	322	372
Baso Liben	2.1	6.8	403	382	417
Bure	5.2	7.5	304	305	330
Mecha	2.4	6.8	352	331	374
Average	4.4	8.0	563	549	628

The population density increased from an average of 563 in 1999 to 628 persons/km^2 in 2001. In 2001, the four districts of Awassa Zuria, Badawacho, Shashemene and Boricha had the highest population density of 1380, 1206, 1200 and 1110 persons/km^2, respectively. All other districts are by far less populated ranging from 301 persons/km^2 in Bako Tibe and 583 persons/km^2 in Siraro.

The average household size in the study districts is about eight. Family sizes in Badawacho (10), Siraro (11) and Omo Nada (10) were relatively higher than in other districts. In terms of adult equivalent, the average was 6.6, ranging from five in Baso Liben to 9.1 in Siraro. The female and male proportion of the households was 3.8 for males and 3.9 for females. The average household size did not change over the three years' period. Thus, the change in population over the three years was due to an increase expressed through the increase in number of household units from 1119 in 1999 to 1270 households in 2001 per PA. The family size among the agricultural potential and population density categories ranged from 7.64 in the L_aH_p to 8.14 in L_aL_p.

The gender structure in the sample population was similar to that of the country. The proportion of males and females in the population was 49.5 and 50.5%, respectively, similar to the national statistics. On the contrary, the proportion of female-headed households in the sample is only 5.4%.

The average age of the household heads was 47 years, ranging from 38 in Alaba to 59 in Omo Nada (Table 6). In terms of agricultural potential and population density, household heads in L_aL_p areas were relatively younger (40 years) compared to other areas (47–48 years). This may reflect the difficulty of living in L_aL_p and hence low population density. The average population density in L_aL_p is only 358 persons per km^2, while it is about 667 in the other areas.

Table 6. *Age and literacy level of household heads and other family members (%) by district*

District	Average age of household head (years)	Literate (%)					Under school age* (%)
		Household head	Other family	Male	Female	Total	
Awasa Zuria	56	37	59	36	22	58	20
Boricha	45	31	40	23	14	38	29
Alaba	37	25	28	29	4	33	27
Badawacho	46	31	40	26	14	40	24
Siraro	45	50	46	32	14	46	30
Shashemene	53	50	63	33	28	61	20
Gobu Sayo	43	69	61	34	31	65	18
Omo Nada	59	31	52	29	20	49	14
Kersa	52	37	51	26	22	49	21
Bako Tibe	43	50	72	43	25	68	23
Debre Elias	40	62	51	31	26	57	23
Baso Liben	45	56	61	40	20	60	20
Bure	45	50	46	28	19	47	23
Mecha	45	56	33	21	18	39	21
Mean	47	44	51	31	20	51	22

* Under school age is children less than 6 years old.

Of the total population in the surveyed households, about 77% were more than 6 years old, which are assumed to be enrolled in school, and the remaining 23% is under school age (Table 6). The level of literacy was 51% across all districts and it ranged from 33% in Alaba to 68% in Bako Tibe. Literacy level was relatively low in the south including Alaba (33%), Boricha (38%), Badawacho (40%) with the exception of Awasa Zuria (58%) which is higher presumably because of its proximity to the regional town, Awassa.

About 44% of household heads are literate, showing somehow an improvement over time with the new generation (since 51% of other family members are literate). However, in some districts such as Siraro and Gobu Sayo in Oromia, and Debre Elias, Bure and Mecha in Amhara, the literacy level dropped probably showing higher population growth rate compared to schooling rate. Given the gender biased cultural system in Ethiopia, it is not surprising to see an average of 11% more literate male than female in the survey area. The difference ranged from 3% in Gobu Sayo to 25% in Alaba. Literacy did not vary with the agricultural potential and population density. The proportion of illiterate and literate population was almost equal in H_aH_p, L_aH_p and L_aL_p. In H_aL_p as well the difference is not high, hence literate population is only 54%.

A large variability was found among the literate household heads in terms of their level of education. The majority (67%) of the literate household heads in the Amhara region did not have formal schooling and this varied from 56% in Mecha to 80% in Debre Elias (Table 7). In Alaba, the proportion of household heads that did not have formal school among the literate is 50%. In districts like Badawacho (60%), Bako Tibe (50%), Gobu Sayo (36%) and Awassa Zuria (33%), the proportion of literate farmers who completed elementary school was higher than in the other districts.

Table 7. *Per cent of household head by education level*

Districts	Illiterate	Education		
		Read and write only	Grade 1–6	Grade 7–12
Awassa Zuria	63	0	25	12
Boricha	69	0	31	0
Alaba	75	12	13	0
Badawacho	69	0	12	19
Siraro	50	0	44	6
Shashemene	50	0	44	6
Gobu Sayo	31	6	37	25
Omo Nada	94	0	6	0
Kersa	63	6	31	0
Bako Tibe	50	6	19	25
Debre Elias	38	50	6	6
Baso Liben	44	38	12	6
Bure	50	31	19	0
Mecha	44	31	19	6
Average	56	13	23	8

Of the total sample households about 40% are Muslims, 34% are Orthodox Christians and about 25% are Protestants. The spatial distribution of the main religions across the district was very distinct with Orthodox Christians being prevalent in Amhara; Protestant in Sidama and East Wellega zones and Badawacho district, and Muslim in East Shewa and Jimma in the Oromia region and Alaba district in SNNPR. Almost all farmers in the four districts of Amhara are Orthodox Christians and almost all farmers in Alaba and Siraro are Muslims.

Religion has a direct relation with the number of working days in a month. In Amhara region where Orthodox Christian is the only religion in the surveyed PAs, the number of non-working days in a month, including weekends, is three times higher (11–13 days per month) compared to Muslim and Protestant dominated societies (4 days per month). This shows only one non-working day per week in the south but three non-working days per week on average in the north. The heavy dependency of agriculture on rainfall and lack of labour saving technologies forces farmers to put more labour in specific period to complete the agricultural operation on time. Having nearly 40% of the working days out of agricultural activity may have serious repercussion on productivity and production.

3.3 Land use pattern

The land under cultivation, mainly rain fed, accounted for 69% of the total land area (Table 8). Grazing land accounted only for 10% of the total land, followed by forest/woodlots (9%) and homestead (7%). In the high population density areas, the proportion of cultivated land was higher than in the low population density areas. Irrigation accounts for only 1% of the land and it is mainly found in the H_aH_p and L_aL_p areas. In Awassa Zuria irrigated land accounts for 19.4%, while in many of the districts irrigation is minimal.

Table 8. *Land use by agricultural potential and population density (%)*

Land use pattern	Agricultural potential and population density category				Total
	H_aH_p	H_aL_p	L_aH_p	L_aL_p	
Cultivated rain fed	71	66	80	61	69
Grazing land	10	10	5	14	10
Forest/woodlot	6	18	1	8	9
Homestead	8	4	8	9	7
Waste land*	2	1	6	5	3
Cultivated irrigated	2	<1	0	2	1
Settlements	2	<1	0	<1	1
Area enclosure	<1	<1	0	2	<1
Others	<1	<1	0	0	<1

* Waste lands are lands that could not be put into any use.

The proportion of cultivated land is very high in H_aL_p accounting for 80% of the available land. This is followed by H_aH_p where cultivated land account for 71%. In L_aL_p the proportion of cultivated land is about 61%. The proportion of grazing land is only 10% ranging from 5.4% in L_aH_p to 14% in L_aL_p. The proportion of grazing land is relatively high in some of the districts like Badawacho and Bako Tibe, accounting for more than 17% of the land (Table 9). For most of the districts the proportion of grazing land ranges from 8–13%. A very small proportion of grazing land was found in Shashemene (2.4%), Omo Nada (5.7%) and Boricha (6.6%).

The proportion of cultivated land varied across districts ranging from 52 to 89% with an average of 70% (Table 9). In three of the districts, the proportion of cultivated land was more than three-quarter. Moreover, in some of the districts particularly those in Sidama and Jimma, homesteads tend to cover higher proportion of land relative to other areas. Homesteads in Sidama and Jimma are mainly covered with garden crops including *enset*.

The average land under cultivation depends on the spatial distribution of the population. The average land cropped per household was about 1.68 ha ranging from 0.64 in Awassa Zuria to about 2.38 ha in Omo Nada (Table 10). In the Oromia region, the average was 1.96 ha and it ranged from 1.09 ha in Shashemene to 2.38 ha in Omo Nada; while in Amhara, the average was 1.82 ha and it ranges from 1.60 ha in Bure to 2.27 ha in Debre Elias. In the SNNPR where population pressure is high, average land holding was 0.79, 1.5 and 1.43 ha in Sidama, Alaba and Badawacho, respectively.

Table 9. *Percentage of land by land use type and district*

District	Land use								
	Cultivated rain fed	Cultivated irrigated	Home stead	Grazing land	Forest/ woodlot	Area enclo-sure	Settle-ments	Waste land	Others
Awasa Zuria	45	19	13	8	8	0	0	6	0
Boricha	71	0	7	7	4	0	0	12	0
Alaba	69	0	5	9	6	7	0	4	1
Bada-wacho	52	0	8	17	15	0	0	7	1
Siraro	65	0	7	12	8	0	0	8	0
Shashe-mene	89	0	8	2	1	0	0	0	<1
Gobu Sayo	65	4	6	13	5	0	1	6	0
Omo Nada	72	1	8	6	13	0	0	1	0
Kersa	77	0	12	9	0	0	0	<1	2
Bako Tibe	63	<1	7	18	4	0	0	8	0
Debre Elias	73	1	8	11	7	0	0	1	0
Baso Liben	83	0	8	7	2	0	0	1	0
Bure	58	0	3	9	24	0	5	1	0
Mecha	72	1	8	12	5	1	0	<1	0
Average	69	1	7	10	9	0	1	3	<1

Table 10. *Average cropland (ha) owned by farm households*

Location		Average crop land (ha)		
Region	Districts	District	Zone	Region average
SNNPR	Awasa Zuria	0.64	0.79	1.24
	Boricha	0.94		
	Alaba	1.50	1.50	
	Badawacho	1.43	1.43	
Oromia	Siraro	1.89	1.49	1.96
	Shashemene	1.09		
	Gobu Sayo	2.28	2.04	
	Bako Tibe	1.80		
	Omo Nada	2.38	2.34	
	Kersa	2.29		
Amhara	Debre Elias	2.27	2.02	1.82
	Baso Liben	1.77		
	Bure	1.60	1.62	
	Mecha	1.64		
	Average	1.68		

4 Crop production in the maize belt of Ethiopia

4.1 Crops grown

The proportion of farmers growing different crops is shown in Tables 11 and 12. Maize is the most widely grown crop and it is produced by almost all households (97%) followed by teff which is grown by about 48% of the households. Sorghum is produced by less than a quarter of the households. *Noug*, finger millet and hot pepper are produced by about one-fifth of the farmers and most other food crops are grown by less than one-fifth of the households. This variability was analysed in terms of agricultural potential and population density as well as geographical location.

Table 11. *Proportion of households (%) growing different crops by agricultural potential and population density*

Crop	H_aH_p	H_aL_p	L_aH_p	L_aL_p	Total
Maize	96	100	97	100	97
Teff	49	54	28	61	48
Sorghum	23	25	14	32	23
Noug	17	25	11	39	20
Finger millet	22	27	6	21	20
Hot pepper	15	20	19	36	19
Enset	16	4	42	0	16
Wheat	16	23	3	11	15
Horse/faba bean	12	14	3	11	11
Barley	10	14	3	14	10
Coffee	12	7	8	0	9
Chat	11	2	11	4	8
Haricot bean	9	2	11	7	8
Potato	5	4	17	0	6
Linseed	7	11	3	7	7
Others	34	20	11	4	23

The proportion of farmers producing maize ranged from 96 to 100% across agricultural potential and population density (Table 11.). On the other hand, teff, hot pepper, and *noug* were more commonly produced by farmers in L_aL_p. The proportion of farmers that produce teff was about 61% in L_aL_p, 55% in H_aL_p, 49% in H_aH_p and 28% in L_aH_p. Similarly hot pepper is commonly grown by farmers in L_aL_p (35.7%) compared to 14.5, 20.5 and 19.5% in H_aH_p, H_aL_p and L_aH_p, respectively.

Noug is grown on average by 21% of the households. *Noug* production is more important in L_aL_p (39%) than in H_aH_p, H_aL_p and L_aH_p, where it is grown by 17, 25 and 11%, respectively. Many crops including barley, wheat, sorghum, finger millet, linseed and faba bean are less frequently grown by farmers in L_aH_p. These crops are either more commonly grown in H_aL_p (wheat, barley, finger millet, linseed and faba bean) or in L_aL_p (sorghum).

Table 12. *Proportion (%) of farmers growing different crops by district*

Crops	Districts													
	Badawacho	Omo Nada	Bako Tibe	Kersa	Debre Elias	Baso Liben	Alaba	Shashemene	Awassa Zuria	Boricha	Bure	Mecha	Gobu Sayo	Siraro
Maize	88	81	94	94	94	88	100	81	63	94	94	88	94	100
Teff	31	63	25	56	94	94	69	19	6	0	94	56	56	13
Sorghum	13	81	0	81	0	0	50	44	0	0	0	0	50	6
Haricot bean	31	0	0	6	0	0	6	13	0	44	0	0	0	6
Enset	13	13	0	13	0	0	6	0	0	63	0	0	0	0
Hot pepper	6	6	69	0	0	0	50	6	0	0	25	0	0	0
Coffee	19	13	6	31	0	0	0	0	38	0	0	6	0	0
Chat	0	19	6	0	0	0	19	0	50	19	0	0	0	0
Barley	0	0	0	0	38	19	0	25	0	0	25	38	0	0
Banana	6	13	6	6	0	0	0	0	0	0	0	0	0	0
Potato	6	0	0	0	6	0	0	13	0	25	0	0	0	0
Wheat	0	0	0	0	63	88	0	44	0	0	13	0	0	0
Noug	0	0	13	0	69	0	0	0	0	0	0	81	44	0
Finger millet	0	0	0	0	0	0	13	0	0	0	94	94	31	0
Faba bean	0	0	6	0	38	19	0	0	0	0	50	0	0	0
Sugar cane	6	6	0	0	0	0	0	0	13	6	0	0	0	0
Linseed	0	0	0	0	31	13	0	0	0	0	0	13	0	0
Papaya	6	6	6	0	0	0	0	0	0	0	0	0	0	0
Godare	6	6	0	50	0	0	0	0	0	0	0	0	0	0
Chick pea	6	0	0	0	0	13	0	0	0	0	13	0	0	0
Field pea	0	0	0	0	6	31	0	0	0	0	0	0	0	0
Sweet potato	19	0	0	0	0	0	0	0	0	6	0	0	0	0
Tomato	0	0	0	0	0	0	0	0	13	0	0	0	0	0
Fenugreek	0	0	0	0	0	0	6	0	0	0	0	0	0	0
Hopes	0	0	0	0	0	6	0	0	0	0	0	0	0	0
Mango	0	0	6	0	0	0	0	0	0	0	0	0	0	0
Taro	0	0	0	13	0	0	0	0	0	0	0	0	0	0

Except in Awassa Zuria, where the proportion of farmers growing maize is lower, possibly due to the higher importance of *enset* in the highlands than in other districts, more than 80% of the farmers grow maize (Table 12). The second most commonly grown crop is teff, which is grown in all districts except Boricha in Sidama. About 57% of the farmers grow teff, ranging from 6% in Awassa Zuria districts to 94% in Amhara except Mecha where only 56% of the sampled farmers grow teff. Teff production is usually low in the south including some districts in Oromia (Siraro, Shashemene and Bako Tibe). Sorghum is also important as it is grown by 30% of farmers. Important areas where sorghum is widely grown are Jimma (59%), Gobu Sayo (50%), Shashemene (44%) and Alaba (50%). Other important crops commonly grown are wheat (20%), hot pepper (15%), *enset* (13%), finger millet (17%), *noug* (15%), haricot bean (14%) and barley (12%). Some crops are location specific, such as taro in Kersa (50%), *enset* in Sidama (72%) and field pea in Baso Liben (31%). In areas where *enset* is grown, the proportion of farmers growing *enset* is very high (81 and 62% in Awassa Zuria and Boricha, respectively). On average there are about eight different crop types grown per district showing how complex the farming system is. This ranges from 4 in Siraro to 14 in Badawacho.

4.2 Area coverage

The area coverage of crops may not necessarily correspond to the proportion of producers that grow them. Crops produced by many farmers could have smaller area coverage and vice versa. For instance, sorghum was third in terms of the proportion of farmers producing it, but fifth in terms of area coverage (Tables 11 and 13). Similarly, wheat was eighth in terms of proportion of farmers growing the crop but fourth in terms of area coverage. Thus, how widely a crop is grown should take into account both the proportion of farmers growing it and the area it covers.

Table 13. *Proportion (%) of area under each crop by agricultural potential and population density*

Crops	H_aH_p	H_aL_p	L_aH_p	L_aL_p	Total
Maize	43	51	53	49	47
Teff	14	19	12	19	16
Noug	3	5	15	7	5
Wheat	6	5	< 1	5	5
Sorghum	5	5	2	8	5
Finger millet	5	4	< 1	4	4
Others	24	11	17	9	18

Maize accounted for 47% of the area cultivated followed by teff (16%). All other crops individually occupied less than 6% of the cropped land. However, how much widely the crops are grown varies from location to location. Sorghum is more widely grown in L_aL_p. In the case of teff, the second crop in the study area, there is a tendency for being grown more in low densely populated areas as it covers about 19% of the cropped land in this area and only about 12 and 14% in L_aH_p and H_aH_p areas, respectively which is statistically significant (F = 2.34). *Noug* is more widely grown in L_aH_p (15.5%) compared to 2.7–6.6% in other areas.

The area coverage of maize ranges from about 14% in Debre Elias and 15% in Baso Liben to 95% in Siraro (Table 14). The area planted with maize in Siraro is extremely high and the small area left is covered by teff, haricot bean and sorghum. The other districts where maize covers the highest cropped area are Bako Tibe (67%) and Kersa (64%). Generally, the area coverage of maize is high in the Oromia region followed by SNNPR and lower in Amhara. Teff is the second crop in terms of area coverage and it covers about 16% of the cropped land. In the Amhara region, except in Mecha where it is only 11%, the coverage of teff is high (29% in Bure and 35% in West Gojam). In Oromia, relatively high (13–16%) area coverage of teff is observed in the western part of the region (Jimma and Gobu Sayo); while in the south-central Oromia and Bako Tibe, area coverage of teff is not more than 6%. In SNNPR, the area coverage of teff is high in Alaba (22%); while in other districts its coverage is low (below 6%). Most other crops including wheat, haricot bean, *noug*, *enset*, finger millet, coffee and *chat* are limited to specific areas in terms of their area coverage.

The average area allocated to different crops ranges from 0.04 ha for tomato to 0.8 ha for maize. Larger areas are usually allocated to staple food crops (maize, wheat and teff) and cash crops (*noug* and coffee). General Linear Model (model 1 in methodology) was used to see if area allocated to crop is affected by agricultural potential, population densities and the interaction between these categories. We find that only area of wheat is affected by these parameters. In L_aL_p, because of low population density and relative abundance of land, farmers grow wheat extensively. In H_aH_p wheat is an important crop and it is grown on relatively wider area (Table 15).

Relatively high variability exists across geographical locations; as the area allocated to different crops depends on land availability as well as the importance of the crop in that particular farming system. Except in Badawacho, Debre Elias and Baso Liben, in all other districts farmers allocate more land to maize compared to other crops. The average area allocated to maize ranges from 0.29 ha in Baso Liben to 1.8 ha in Siraro. Except in Shashemene, where average land allocated to maize is 0.55 ha, in all other districts in Oromia, the average area allocated to maize is more than 0.98 ha. On the other hand, in SNNPR, the area allocated to maize is low ranging from 0.45 ha in Awassa to 0.81 ha in Alaba mainly because of land shortage. In the Amhara region, the area of maize is usually low particularly in West Gojam where the average maize area is 0.35 and 0.29 in Debre Elias and Baso Liben, respectively. In East Gojam, it is higher with an average of 0.51 ha in Bure and 0.56 ha in Mecha. Although teff is second to maize in terms of area coverage, it is third in terms of average area allocated by individual farmers (Tables 11 and 15). Area of teff is high in the Amhara region particularly in West Gojam with an average area of 0.84 ha in Debre Elias and 0.66 ha in Baso Liben. In the Oromia region, teff area is high in the west particularly in Omo Nada (0.61 ha) and Gobu Sayo (0.57 ha); while it is low in southern Oromia (0.37 ha in Siraro and 0.33 ha in Shashemene). The average area planted with sorghum is about 0.34 ha. A larger plot size is allocated to sorghum in Omo Nada (0.44 ha) and Gobu Sayo (0.56 ha). In most districts, the average area allocated to sorghum is less than the area allocated to the other major cereals.

Table 14. *Proportion (%) of crop area coverage by district*

Crops	Awasa Zuria	Boricha	Alaba	Badawacho	Siraro	Shashemene	Gobu Sayo	Omo Nada	Kersa	Bako Tibe	Debre Elias	Baso Liben	Bure	Mecha	Total
Maize	44	55	54	39	95	47	53	44	64	67	14	15	32	32	47
Teff	2	0	22	6	2	6	14	16	13	6	35	35	29	11	16
Wheat	0	0	0	0	0	19	0	0	0	0	12	34	3	0	5
Sorghum	0	0	8	2	< 1	7	12	15	13	0	0	0	0	0	5
Barley	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Chick pea	0	0	0	2	0	0	0	0	0	0	0	3	2	0	< 1
Haricot bean	0	19	1	6	2	6	0	0	1	0	0	0	0	0	2
Noug	0	0	0	0	0	0	9	0	0	5	28	0	0	21	6
Enset	27	17	4	2	0	0	0	1	< 1	0	0	0	0	0	2
Sweet potato	0	2	0	3	0	0	0	0	0	0	0	0	0	0	< 1
Potato	0	4	0	2	0	6	0	0	0	0	< 1	0	0	0	1
Finger millet	0	0	1	0	0	0	6	0	0	0	0	0	20	28	4
Linseed	0	0	0	0	0	0	0	0	0	0	3	2	0	3	1
Coffee	8	0	0	25	0	0	0	1	4	< 1	0	0	0	< 1	2
Chat	14	2	2	0	0	0	0	1	0	< 1	0	0	0	0	1
Faba bean	0	0	0	0	0	0	0	0		0	3	2	8	0	1
Sugar cane	4	1	0	1	0	0	0	1	0	0	0	0	0	0	< 1
Tomato	1	0	0	0	0	0	0	0	0	0	0	0	0	0	< 1
Hot pepper	0	0	7	2	0	1	5	< 1	0	12	0	0	3	0	2
Papaya	0	0	0	7	0	0	0	7	0	2	0	0	0	0	1
Fenugreek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	< 1
Banana	0	0	0	1	0	0	0	14	0	3	0	0	0	0	2
Taro	0	0	0	1	0	0	0	1	6	0	0	0	0	0	1
Hopes	0	0	0	0	0	0	0	0	0	0	0	2	0	0	< 1
Avocado	0	0	0	0	0	0	0	0	0	0	0	0	0	0	< 1
mango	0	0	0	0	0	0	0	0	0	3	0	0	0	0	< 1
Field pea	0	0	0	0	0	0	0	0	0	0	1	6	0	0	<1

Table 15. *Average area (ha) per household for each crop by agricultural potential and population density*

Crops	H_aH_p	H_aL_p	L_aH_p	L_aL_p	Average	Range
Maize	0.72	0.94	0.83	0.85	0.80	0.13–6.00
Teff	0.48	0.64	0.65	0.56	0.54	0.13–1.75
Sorghum	0.34	0.35	0.20	0.42	0.34	0.13–1.00
Barley	0.24	0.30	0.25	0.22	0.25	0.06–0.75
Wheat	0.62	0.38	0.25	0.83	0.55	0.25–1.25
Chick pea	0.35	0	0	0	0.35	0.25–0.50
Haricot bean	0.31	0.25	0.56	0.38	0.37	0.13–0.75
Noug	0.38	0.47	0.33	0.41	0.41	0.13–7.50
Enset	0.20	0.03	0.23	0	0.20	0.06–1.00
Sweet potato	0.21	0	0.25	0	0.22	0.13–0.25
Potato	0.11	0.50	0.05	0	0.14	0.06–0.50
Finger millet	0.38	0.30	0.06	0.31	0.34	0.13–1.00
Linseed	0.08	0.21	0.38	0.13	0.14	0.06–0.05
Coffee	0.54	0.21	0.10	0	0.43	0.06–5.00
Chat	0.13	0	0.16	0.25	0.13	0.06–0.25
Horse/faba bean	0.18	0.09	0.25	0.17	0.16	0.06–0.50
Sugar cane	0.19	0	0.25	0	0.17	0.13–0.25
Tomato	0.03	0	0.06	0	0.06	0.06
Hot pepper	0.20	0.29	0.07	0.18	0.19	0.06–0.75
Papaya	2.00	0	0.50	0	1.50	0.50–2.50
Fenugreek	0	0.25	0	0	0.25	0.25
Banana	1.25	0	0	0	1.25	0.25–5.00
Taro	0.23	0.25	0	0	0.24	0.13–0.38
Hopes	0.50	0	0	0	0.50	0.50
Mango	0.75	0	0	0	0.75	0.75
Field peas	0.27	0.00	0	0	0.21	0.13–0.50

4.3 Grain yield

To analyse the grain yield only major crops (crops with more than 4% area coverage and grown by at least 20% of the households) were considered. Accordingly, six crops were identified: maize, teff, sorghum, finger millet, *noug* and wheat (Table 17). The average maize yield is about 2.05 t/ha, which is higher than the national average, 1.80 t/ha, in 2001/02 (CSA 2003). This is probably because the average yield found in this study is only from major maize producing areas, which exclude marginal and low yield areas for maize (see the detail of maize yield in chapter 5). Next to maize, wheat is second in terms of yield per hectare, which is about 1.84 t/ha, also higher than the national average of 1.36 t/ha in 2001/02. These two crops are among the few that have better seed technologies compared to others.

Table 16. *Average area (ha/household) allocated to crops in different districts*

Crops	Awasa Zuria	Boricha	Alaba	Badawacho	Siraro	Shashemene	Gobu Sayo	Omo Nada	Kersa	Bako Tibe	Debre Elias	Baso Liben	Bure	Mecha	Total
Maize	0.35	0.52	0.81	0.56	1.80	0.55	1.22	0.98	1.3	1.21	0.35	0.29	0.51	0.56	0.80*
Teff	0.25	0	0.48	0.27	0.37	0.33	0.57	0.61	0.46	0.44	0.84	0.66	0.50	0.32	0.54*
Sorghum	0	0	0.23	0.25	0.12	0.16	0.56	0.44	0.30	0	0	0	0	0	0.34*
Barley	0	0	0	0	0	0.37	0	0	0	0	0.24	0.21	0.22	0.23	0.25
Wheat	0	0	0	0	0	0.48	0	0	0	0	0.45	0.69	0.37	0	0.55
Chick pea	0	0	0	0.50	0	0	0	0	0	0	0	0.37	0.25	0	0.35
Haricot bean	0	0.42	0.25	0.27	0.50	0.50	0	0	0.25	0	0	0	0	0	0.37
Noug	0	0	0	0	0	0	0.48	0	0	0.75	0.26	0	0	0.43	0.41
Enset	0.20	0.18	1.00	0.28	0	0	0	0.19	0.06	0	0	0	0	0	0.20
Sweet potato	0	0.25	0	0.21	0	0	0	0	0	0		0	0	0	0.22
Potato	0	0.14	0	0.37	0	0.14	0	0	0	0	0.06	0	0	0	0.14
Finger millet	0	0	0.05	0	0	0	0.25	0	0	0	0	0	0.35	0.46	0.34**
Linseed	0	0	0	0	0	0	0	0	0	0	0.2	0.07	0	0.21	0.14
Coffee	0.12	0	0	0.42	0	0	0	0.12	0.27	0.12	0	0	0	0.12	0.43
Chat	0.18	0.10	0.15		0	0	0	0.06		0.12	0	0	0	0	0.13
Faba bean	0	0.0	0	0	0	0	0	0	0	0.50	0.16	0.10	0.18	0	0.16
Sugar cane	0.19	0.12	0	0.25	0	0	0	0.12	0	0	0	0	0	0	0.17
Tomato	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04
Hot pepper	0	0	0.13	0.50	0	0.12	0.19	0.12	0	0.27	0	0	0.14	0	0.19
Papaya	0	0	0	1.50	0	0	0	2.50	0	0.50	0	0	0	0	1.50
Fenugreek	0	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0.25
Banana	0	0	0	0.25	0	0	0	2.62	0	0.75	0	0	0	0	1.25
Taro	0	0	0	0.25	0	0	0	0.25	0.23		0	0	0	0	0.24
Hopes	0	0	0	0	0	0	0	0	0	0	0	0.50	0	0	0.25
Avocado	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Mango	0	0	0	0	0	0	0	0	0	0.75	0	0	0	0	0.37
Field pea	0	0	0	0	0	0	0	0	0	0	0.12	0.27	0	0	0.21

Note: *, ** f-value for means among districts is significant at 1 and 10%, respectively.

Table 17. *Yield (t/ha) of major crops by agricultural potential and population density*

Crops	Agricultural potential and population density				Average
	H_aH_p	H_aL_p	L_aH_p	L_aL_p	
Wheat	1.79	1.96	1.00	2.00	1.84
Teff	0.75	0.73	0.75	0.62	0.72
Sorghum	0.65	0.59	0.56	0.57	0.62
Maize (total)a,b	2.12	2.38	1.49	1.97	2.05
Maize (dry)a,b	0.56	0.51	0.47	0.46	0.52
Nougc	0.41	0.60	0.60	0.29	0.45
Finger millet	1.44	1.16	0.80	0.58	1.28

Notes: a. H_a vs. L_a, $P < 0.01$.
b. H_p vs. L_p, $P < 0.08$.
c. Agricultural potential * Population density, $P < 0.05$.

The average yield of teff is about 0.72 t/ha which is not much different from the national average yield (0.87 t/ha) in 2001/02. The average yield of other major crops is low particularly for sorghum (0.62 t/ha), and *noug* (0.45 t/ha). As expected, dry maize yield was significantly higher in areas with high agricultural potential than in those with low agricultural potential.

The difference in yield was significant among the geographical location for teff, maize and *noug* (Table 18). On the other hand, there is little difference for wheat, sorghum and finger millet among the districts. The yield of maize ranges from about 0.8 t/ha in Boricha to 3.18 t/ha in Kersa. Yield of maize is high in western and northwestern parts of the country compared to the southern part that extends from Shashemene to Boricha. Similarly, teff yield is higher in Amhara where it is grown as a major crop and the yield ranges from 0.30 t/ha in Bako Tibe to 1.13 t/ha in Debre Elias. Except in Siraro, where the average teff yield is 0.80 t/ha, in all other districts of Oromia and SNNPR, the yield of teff is less than 0.60 t/ha. *Noug* is grown in only few districts and the yield in the two districts in Oromia where *noug* is grown (Bako Tibe and Gobu Sayo) is significantly lower compared to the two districts in the Amhara region.

Table 18. *Average yield (t/ha) of major crops by district*

District	Wheat	Teff	Sorghum	Maize	Noug	Finger millet
Awassa Zuria	–	–	–	1.28 abc	–	–
Boricha	–	–	–	0.8a	–	–
Alaba	–	0.46 ab*	0.67	1.52 abc	–	–
Badawacho	–	0.52 ab	0.30	1.42 abc	–	–
Siraro	–	0.80bc	–	1.14 ab	–	–
Shashemene	1.26	0.57 ab	0.73	1.42 abc	–	–
Gobu Sayo	–	0.32 a	0.45	2.89 de	0.21	0.60
Omo Nada	–	0.47 ab	0.50	2.08 cd	–	–
Kersa	–	0.44 ab	0.59	3.18 e	–	–
Bako Tibe	–	0.30 a	–	2.05 bcd	0.26	–
Debre Elias	1.83	1.13c	–	3.02 e	0.61	–
Baso Liben	2.17	1.00c	–	2.51 de	–	–
Bure	1.60	0.85bc	–	2.54 de	–	1.41
Mecha	–	0.86bc	–	2.86 de	0.47	1.36
Average	1.84	0.72	0.62	2.05	0.45	1.28

Notes: * Numbers followed with the same letter across districts are not significantly different at 5%.
– indicates that the crop is not produced in the district.

5 Maize production

5.1 Cultivars grown

As indicated in Chapter 4, maize is the dominant crop in the maize belt of Ethiopia covering on average about 47% of the cropland. It ranges from 14% in Baso Liben to 95% in Siraro. None of the sampled household reported the use of irrigation for maize production. The average area planted with maize per household in the study area is about 0.8 ha. Maize has relatively more suitable technologies released compared to other crops. Access to international research on maize has been important to develop more technologies than other crops, such as teff, where international experience is almost non-existent. Thus, the use of improved technologies particularly hybrids and open pollinated varieties (OPVs) is higher for maize than other crops.[1] There is also a tendency of increased use of improved cultivars over the period the data were collected. The proportion of farmers using improved cultivars increased from about 63% in 1999 to 69% in 2001 (Table 19).

Table 19. *Proportion (%) of farmers using different maize cultivars*

Cultivar	Years		
	1999	2000	2001
Local[1]	36.8	32.9	30.8
BH-140[2]	10.5	12.9	13.7
Katumani[1]	8.1	6.7	7.6
BH-660[2]	28.7	30.0	30.8
PHB-3253[2]	10.5	9.5	8.1
A511[1]	0.5	1.0	1.9
BH-540[2]	1.4	3.3	3.8
Other (improved)	3.3	3.8	3.3
N	209	210	211

1. OPV.
2. Hybrid.

In terms of individual cultivars, the proportion of farmers using the local variety decreased from 37% in 1999 to 31% in 2001. The decrease in use of local varieties corresponds to an increase in the use of improved cultivars including BH-140, BH-660, A511 and BH-540. The proportion of farmers using the most popular hybrid BH-660 was equal to those using the local variety in 2001. The hybrids BH-140 and PHB-3253 are also commonly used by farmers. The number of farmers using BH-140 has an increasing trend while that of PHB-3253 appears to be decreasing. There is a geographical distribution pattern where each cultivar has a niche to dominate (Table 20). The major improved hybrid BH-660 dominates

1. Wheat is the other crop, which has better improved seed technologies due to national and international efforts.

in western Oromia, except Omo Nada; and the Amhara region, except Mecha. On the other hand, the hybrid BH-140 dominates in Sidama and Omo Nada; while hybrid PHB-3253 is more common in southern Oromia and Badawacho. To some extent, PHB-3253 is also more common in Mecha. Apart from the ecological suitability, the domination of hybrids is also related to the seed supply, and the supply of fertilizer and credit.

Table 20. *Proportion (%) of farmers growing different maize cultivars in 2001*

District	Maize cultivar							
	Local	BH-140	Katumani	BH-660	PHB-3253	A511	BH-540	Others/ improved
Awassa Zuria	46.1	30.8	15.4	0	0	7.7	0	0
Boricha	49.9	37.5	6.3	0	6.3	0	0	0
Alaba	62.5	6.2	18.8	0	6.3	6.2	0	0
Badawacho	68.7	0	6.3	0	25.0	0	0	0
Siraro	12.6	0	43.7	12.6	24.9	0	0	6.2
Shashemene	28.7	7.0	7.2	0	28.5	7.1	7.1	14.3
Gobu Sayo	35.8	7.0	0	57.2	0	0	0	0
Omo Nada	6.1	68.7	0	25.2	0	0	0	0
Kersa	6.5	6.6	6.7	73.5	0	0	0	6.7
Bako Tibe	6.5	13.3	0	80.2	0	0	0	0
Debre Elias	33.4	0	0	53.3	0	0	0	13.3
Baso Liben	33.4	0	0	53.3	0	0	6.7	6.7
Bure	18.7	6.2	0	50.1	0	0	25.0	0
Mecha	21.4	7.0	0	28.8	21.4	7.1	14.3	0

The areas covered by maize cultivars are presented in Table 21. In high agricultural potential and high population density areas the local varieties and BH-660 are the most dominant cultivars covering about 35 and 31% of the maize area, respectively. The two cultivars cover almost similar proportion in the low agricultural potential and low population density areas. In H_aL_p the hybrid BH-660 alone covers about 41% of maize area, followed by the local varieties, which cover about 18%.

The maize area in the study districts is dominated by BH-660, a late maturing hybrid, covering about 31% of the maize area (Table 21). The area coverage of this hybrid ranges from 14.5% in Siraro, which is lowland to 75% in Bako Tibe. Next to BH-660, the maize area is dominated by the local varieties covering about 24.5% of the maize area. Unlike other cultivars, which are grown in some districts but not in others, the local varieties are grown in all districts with the specific cultivar depending on the location. The area allocated to the local variety in some districts like Omo Nada, Siraro, Kersa, Bako Tibe and Mecha is very small, less than 10% of the total maize area. In these areas, the improved cultivars usually dominate the maize production. The other hybrid, next to BH-660 is BH-140 which is relatively suitable to the lower altitude areas and it covers about 15% of the maize area. This hybrid covers about 74% of the maize area in Omo Nada and its coverage in Sidama zone is also considerable (33% in Boricha and 29% in Awassa Zuria). Katumani variety, which covers about 12% of the maize area, is more common in Siraro covering about 54% of the maize area in the district. In the adjacent district, Alaba, it also covers a relatively large area (15%). Other hybrids, PHB-3253 and BH-540 and the OPV A511 in total cover about 12.3% while the remaining 5.6% is covered by improved cultivars, which could not be identified by name.

Table 21. *Proportion (%) of maize area allocated to different maize cultivars by district*

Districts	Maize cultivars							
	Local	BH-140	Katumani	BH-660	PHB-3253	A511	BH-540	Other
Awassa Zuria	43.9	29.3	12.2	0	0	14.6	0	0
Boricha	54.1	33.1	5.1	0	7.6	0	0	0
Alaba	59.6	13.5	15.4	0	3.8	7.7	0	0
Badawacho	65.9	0	4.5	0	29.5	0	0	0
Siraro	4.7	0	54.5	14.5	19.6	0	0	6.8
Shashemene	30.1	16.4	8.2	0	15.1	5.5	11.0	13.7
Gobu Sayo	50.7	4.0	0	45.3	0	0	0	0
Omo Nada	2.9	73.7	0	23.4	0	0	0	0
Kersa	4.8	3.6	3.6	59.0	0	0	0	28.9
Bako Tibe	7.5	17.6	0	74.8	0	0	0	0
Debre Elias	28.4	0	0	61.7	0	0	0	9.9
Baso Liben	30.0	0	0	57.5	0	0	7.5	5.0
Bure	15.9	6.3	0	55.6	0	0	22.2	0
Mecha	7.9	6.3	0	20.6	23.8	9.5	31.7	0
Average	24.5	14.8	11.8	31.1	7.5	1.7	3.1	5.6

Comparing the proportion of farmers growing different maize cultivars and the areas in which they are grown, some differences could be observed particularly for the local, Katumani and an identified improved cultivars (Table 21). In 2001, the proportion of area allocated to local varieties was less than the proportion of farmers growing improved cultivars by about 6.3%. This is related to the average maize area in the districts where improved cultivars are more common. In Badawacho and Boricha, where the local varieties dominate, the average maize area and the coverage of improved cultivars are generally low.

The area coverage of different maize cultivars also varies by agricultural potential and population density (Table 22). The domination of BH-660 and the local variety is high throughout. In the high agricultural potential area, BH-660 is very important covering more than 34% of maize area. The local varieties dominate more in L_aL_p covering about 35% of the maize area and they also are second in L_aH_p and H_aH_p. In H_aL_p and L_aH_p, Katumani variety covers more than 21% of maize area.

Table 22. *Per cent of area coverage of different maize cultivars by agricultural potential and population density categories*

Cultivars	Agricultural potential and population density			
	H_aH_p	H_aL_p	L_aH_p	L_aL_p
Local	29	12	23	35
BH-140	22	6	11	14
Katumani	4	22	26	1
BH-660	34	36	19	27
A510	2	2	0	0
PHB-3253	4	4	12	18
A511	1	0	0	0
BH-540	4	2	0	4
Other improved	0	16	9	1
Total	100	100	100	100

A probit regression model was estimated in order to identify factors that influence the use of improved maize cultivars. The variables included in the probit model are given in Table 23. The same explanatory variables were used in models that predict use of fertilizer.

Table 23. *Descriptive statistics of variables included in the probit model of adoption of improved maize cultivars and commercial fertilizer*

Variables	Mean	Std. dev.	Min	Max
Age of household head (years)	46	15.42	25	102
Age square of household head (years)	2387	1691	625	10404
Education level of household head (years)	1.65	2.65	0	12
Active family member (15–60 years old)	3.51	1.73	1	10
Dependency ratio (number of dependents/ total family size)**	0.5	0.5	0	0.9
Walking distance to input shop (hours)	1.39	1.14	0	5
Walking distance to crop market (hours)	1.69	1.09	0.05	5
Per capita maize area (ha)	0.12	0.11	0.01	0.88
Per capita other crop area (ha)	0.26	0.21	0.02	1.54
Value of livestock sold (Ethiopian birr* × 10^2)	262	519.87	0	4020
If the household does not have ox (0/1)	0.25	0.43	0	1
If the household has only one ox (0/1)	0.21	0.41	0	1
If the household has more than 1 oxen (0/1)	0.55	0.5	0	1
If household is in H_aH_p (0/1)	0.50	0.50	0	1
If household is in H_aL_p (0/1)	0.21	0.41	0	1
If household is in L_aH_p (0/1)	0.16	0.37	0	1
If household is in L_aL_p (0/1)	0.13	0.34	0	1

* In May 2007, USD 1 = Ethiopian birr (ETB) 8.86.

** Dependents were those family members below 15 years or above 60 years of age.

The result of the model (Table 24) showed that variables including oxen ownership, active labour force and dependency ratio are statistically significantly associated with the use of improved maize cultivars. We find that the three variables affect the use of improved maize cultivars positively. The probability of using improved cultivars for those farmers who own a pair of oxen increase by about 25% over those who do not have oxen. This may show the importance of oxen in determining the capacity of farmer to adopt crop technologies. However, we find no difference between farmers who own no ox and those who own one ox. However, if the size of working labour force increases by one, the probability of using improved maize cultivars increase by about 4.6%. As the number of work forces increase, there is possibility to look for more intensive production to increase productivity. Improved cultivars usually require more labour inputs to accommodate management practices recommended for the use of improved cultivars. The other important variable that affects the use of improved cultivars is dependency ratio and as the level of dependency ratio increases by a unit, the probability of using improved cultivars of maize increases by about 22%. High dependency ratio could mean higher household consumption requirements and such households may have higher incentives for more intensive production.

5.2 Use of fertilizer

Sixty per cent of maize growers in 2001 used di-ammonium phosphate (DAP) and about 56% used urea (Table 25). In some districts (Omo Nada, Kersa, Bako Tibe) all maize growers use DAP. In Jimma zone, all maize growers used urea. In general, the use of DAP is more common in the districts found in western Oromia and Amhara as more than 60% of the farmers have used it. A few farmers (12.5–19%) use DAP in southern Oromia and Hadiya areas. The proportion of farmers using DAP in Sidama zone is also low (37.5% in Boricha and 46.2% in Awassa Zuria). Similar trend is also found for urea since as low as 6.3% of farmers in Siraro use urea, while in Amhara and western Oromia, more than 53% of the farmers used urea. In 1998, about 90% of maize growers in Ethiopia used commercial fertilizer (Tesfaye et al. 2001). Despite extension efforts to increase fertilizer use in the country there is still a considerable proportion of farmers who are not using it for several crops. Farmers in drought prone areas, such as Shashemene, are less likely to use fertilizer due to risk.

The use of fertilizer could also be related to the moisture availability as the response to fertilizer is very much related to the rainfall especially for urea. Areas in the Rift Valley usually receive low amount of rain compared to the western part of the country affecting the use of fertilizer besides other factors.

Table 24. *Factors affecting the use of improved maize cultivars, probit model estimate*

Variables	Coefficient	dF/dx	Z
Constant	–0.655		–0.78
Age of household head (years)	–0.011	–0.004	–0.29
Age square of household head (years)	0.00009	0.00003	0.27
Education level of household head (years of schooling)	0.007	0.002	0.18
Dependency ratio (dependent/total family size)	0.657	0.224	1.72*
Active labour size (15–60 years old)	0.135	0.046	1.83*
Walking distance to input supply shops (hours)	0.08	0.027	0.71
Walking distance to crop market (hours)	–0.148	–0.05	–1.28
Per capita maize area (ha)	0.225	0.077	0.20
Per capita other crop area (ha)	0.519	0.177	0.72
Value of livestock sold (ETB* × 10^2)	0.0003	0.0001	1.12
Oxen dummya			
Farmers with one ox§	0.458	0.143	1.60
Farmers with two or more oxen§	0.715	0.245	2.82***
Agricultural potential and population density dummy compared to L_aL_p			
H_aH_p§	–0.061	–0.021	–0.20
H_aL_p§	0.515	0.159	1.37
L_aH_p§	0.254	0.082	0.67
Regression diagnosis			
No.	209	Obs. P = 0.69	
LR x^2	27.07**	Pred. P = 0.71	
Log likelihood	–116.024		
Pseudo R^2	0.1045		
Per cent of positive values	69		

Notes: a. It is conceivable that oxen ownership may be dependant on adoption of improved cultivars, thus endogenous in this model. However, since farmers usually grow a number of crops, decision to acquire oxen may not necessarily be endogenous in a model of one particular crop.
* In May 2007, USD 1 = Ethiopian birr (ETB) 8.86.
§ dF/dx is for discrete change of dummy variable from 0 to 1.
*, **, *** are significant at 10, 5 and 1%, respectively.

There is a difference in the rate of fertilizer application through the different agricultural potential and population density (Table 26). The average rate of DAP use rate in the high agricultural potential areas is about 96 kg/ha, while it is 70 kg/ha for low agricultural potential areas. Similarly, the amount of urea fertilizer used per hectare was 91 kg/ha for high agricultural potential areas while it is 80 kg/ha for low agricultural potential areas.

Table 25. *Proportion of farmers and mean fertilizer used (kg/ha) by district in 2001*

District	DAP		Urea	
	% of farmers using	Mean amount of fertilizer (kg/ha)	% of farmers using	Mean amount of fertilizer (kg/ha)
Awassa Zuria	46	67.2	38	70.7
Boricha	37	71.1	189	73.9
Alaba	19	59.5	12	39.3
Badawacho	12	83.3	31	62.0
Siraro	19	63.3	6	40.0
Shashemene	14	66.7	21	41.1
Gobu Sayo	93	62.7	79	127.0
Omo Nada	100	70.3	100	66.4
Kersa	100	77.5	100	61.9
Bako Tibe	100	59.2	93	80.0
Debre Elias	93	157.1	80	141.7
Baso Liben	60	128.4	53	110.7
Bure	75	95.8	75	84.4
Mecha	79	111.4	79	100.0
Total	60	88.5	56	87.7
F-values		3.457***		3.464***

Note: *** Means are significantly different at 1%.

Table 26. *Use of fertilizer for maize in different agricultural potential and population density areas*

Agricultural potential and population density	DAP		Urea	
	% of users	Average kg/ha	% of users	Average kg/ha
H_aH_p	59	96	59	81
H_aL_p	64	95	59	114
L_aH_p	49	70	37	77
L_aL_p	73	69	61	82
Average	60	88.5	56	87.7

Factors that were hypothesized to affect the use of fertilizer in maize production were used in the analysis to identify which factors are important in determining the use of fertilizer. The descriptive statistics for those variables included in the probit model are given in Table 27.

Probit model results indicated that among the variables included, some of the variables were statistically significant in affecting the use of fertilizer (Table 27). These include value of livestock sold, education level of the household head, oxen ownership and distance to input supply shops. All these variables have the expected sign. Education level of the household head affects adoption of fertilizer positively, as expected. As year of schooling increases by one year, the probability of using fertilizer increases by about 5.6% confirming the importance of education in technology adoption. Distance to input supply shop was also found to affect adoption of fertilizer negatively. As walking time to reach the input supply shops increase by an hour, the probability of using fertilizer decrease by about 9%.

Table 27. *Factors that affect the use of chemical fertilizer, probit estimates*

Variables	Coefficient	dF/dx	Z
Constant	–1.139		–1.09
Age of household head (years)	0.059	0.02	1.47
Age square of household head (years)	–0.0006	–0.0002	–1.54
Active labour (15–60 years)	–0.015	–0.005	–0.21
Education level of household head (years of schooling)	0.161	0.056	3.29***
Dependency ratio (dependent/total family size)	–0.156	–0.054	–0.5
Walking distance to input supply shops (hours)	–0.266	–0.092	–2.22**
Walking distance to crop market (hours)	–0.088	–031	0.74
Per capita maize area (ha)	–1.41	–0.487	–1.12
Per capita total crop area (ha)	1.062	0.367	1.25
Value of livestock sold (ETB* × 10^2)	0.072	0.025	2.16**
Oxen dummy compared to no ox			
Farmers with one ox§	0.573	0.177	1.92*
Farmers with two or more oxen§	1.199	0.407	4.4***
Agricultural potential and population density dummy compared to L_aL_p			
H_aH_p§	–0.42	–0.144	–1.18
H_aL_p§	–0.60	–0.22	–1.45
L_aH_p§	–0.257	0.092	–0.6
Regression diagnosis			
N	209		Obs. P = 0.66
LR chi^2 (16)	64.25***		Pred. P = 0.70
Log likelihood	–102.46		
Pseudo R^2	0.2387		

Notes: * In May 2007, USD 1 = Ethiopian birr (ETB) 8.86.
(§) dF/dx is for discrete change of dummy variable from 0 to 1.
*,**,*** are significant at 10, 5 and 1% respectively.

Farmers who own oxen have higher probability of using fertilizer than those who do not own oxen. The marginal effect indicate that those farmers who own an ox have about 18% more probability to use fertilizer compared with those who do not own oxen. Moreover, as the number of oxen increases the probability of using fertilizer also increases. Those farmers who own a pair of oxen or more have about 41% more probability to use fertilizer compared with those who do not own an ox. Similarly, revenue from sale of livestock in the year positively influences the use of fertilizer. As cash income from livestock sale increase by ETB[2] 100,

2. In May 2007, USD 1 = Ethiopian birr (ETB) 8.86.

the probability of using fertilizer increases by 2.5%. This may show supplementary effect of livestock to crop production.

5.3 Grain harvesting

Maize harvesting starts in September and ends in January (Table 28). The peak harvesting time, however, is November where about 62% of the producers harvest their maize. In October and December, about 14 and 18% of the farmers harvest maize, respectively.

Table 28. *Proportion (%) of farmers harvesting maize by months and districts*

District	Month harvested					N
	September	October	November	December	January	
Awassa Zuria	0	61	39	0	0	13
Boricha	7	20	73	0	0	15
Alaba	0	0	87	13	0	15
Badawacho	19	6	69	0	6	16
Siraro	0	75	19	0	0	16
Shashemene	2	14	57	7	0	14
Gobu Sayo	0	0	13	67	20	15
Omo Nada	0	6	81	6	6	16
Kersa	0	0	93	7	0	15
Bako Tibe	0	0	57	43	0	14
Debre Elias	0	0	67	33	0	15
Baso Liben	0	14	79	7	0	14
Bure	0	0	50	50	0	16
Mecha	0	0	86	14	0	14
Average	3	14	62	18	3	

Maize harvesting extends over a long period not only because of different agro-ecological conditions but also because of the consumption pattern which starts while it is green. This is particularly true in districts located in the south including Shashemene where harvesting extend for three or four months in a given district. In the west and northwest, harvesting is mainly in November and December, except in districts like Omo Nada, Baso Liben and Gobu Sayo, where maize is harvested for three months.

The average maize yield in the study area is about 2.05 t/ha higher than the national average of 1.8 t/ha (CSA 2003). Variability exists with agricultural potential and population density (Table 29). The general linear model (GLM) result confirmed that the difference between agricultural potential is significant at 5% and that between population density is significant at 10%. Yield in low agricultural potential is 22% lower compared to the high agricultural potential areas, which is significant at 1%. The high maize yield in high agricultural potential over low agricultural potential is expected. Maize yield in high population density is lower by 10% compared to those areas with low population density and the difference is not statistically significant at 10%. Population density usually varies with the agricultural potential of the area and thus it would be expected that in areas where there is high population, yield would also be high. The result, however, does not support that and could be due to a number of reasons including rainfall distribution and use of fertilizer (61 and 93 kg/ha in high and low population density, respectively). It could also be hypothesized that the mining of farm land in low population density areas is low compared to high population densities where crop production is practised for a long time on the same plot. This, however, should be substantiated with field level soil fertility analysis.

Table 29. *Average maize yield (t/ha) by agricultural potential and population density*

Population density		Agricultural potential		
		High	Low	Average
	High	2.12	1.49	2.00
	Low	2.38	1.97	2.22
	Average	2.20	1.71	2.05

High vs. low agricultural potential, $P < 0.01$.
High vs. low population density, $P < 0.08$.
Agricultural potential * Population density, $P < 0.05$.

Grain yield of maize also varies across districts ranging from 0.80 t/ha in Boricha to 3.18 t/ha in Kersa. The general trend is that there is a higher maize yield in western and northwestern parts of the country. In these districts, the average yield ranges between 2.04 t/ha in Bako Tibe to 3.18 t/ha in Kersa, while in the districts found in SNNPR and southern Oromia, the yield is lower, about 1.52 t/ha.

Maize harvesting and consumption starts while the cob is green, depending on the consumption need of the family. The majority of farmers, more than 85%, harvest maize both as green and dry; while about 7.7 and 6.7% of the farmers harvest maize only as dry and green, respectively (Table 31). In the districts where green harvesting is common, like Awassa Zuria, Boricha and Shashemene, a considerable proportion of farmers, 33% in Awassa Zuria, 31% in Boricha and 29% in Shashemene, finish harvesting maize at green stage. Because fresh maize could not be stored for long, this may imply that more maize is sold at harvest. Double cropping and attractive market prices are other reasons for green harvesting. On the other hand, in Mecha about 31% of the farmers harvest their maize only after it dries. The average yield of maize harvested as green is 0.524 t/ha ranging from 0.309 t/ha in Siraro to 0.812 t/ha in Kersa. Green maize harvest account on average for about 25% of the total maize yield ranging from 12% in Mecha to 52% in Awassa Zuria.

Table 30. *Mean maize grain (fresh and dry) yield, t/ha, by district in 2001*

District	Yield t/ha	Dry grain yield, t/ha		Fresh grain yield, t/ha		
		N	Mean	N	Mean	% of total
Awassa Zuria	1.28	8	1	11	0.67	52
Boricha	0.80	11	0.55	13	0.40	49
Alaba	1.52	16	0.95	16	0.57	38
Badawacho	1.42	15	0.77	14	0.70	49
Siraro	1.14	16	0.83	16	0.31	27
Shashemene	1.42	10	1.12	14	0.62	44
Gobu Sayo	2.89	15	2.51	14	0.41	14
Omo Nada	2.09	16	1.75	14	0.39	19
Kersa	3.18	15	2.37	15	0.81	26
Bako Tibe	2.05	15	1.62	15	0.42	21
Debre Elias	3.02	14	3.29	14	0.51	13
Baso Liben	2.51	15	1.83	14	0.73	29
Bure	2.54	15	2.14	14	0.42	17
Mecha	2.86	13	2.62	9	0.35	12
Average	2.05	194	1.71	193	0.52	25
F-values	7.36***		5.95**		1.83*	

Note: *, ** means are significantly different at 5 and 1%, respectively across district.

Table 31. *Location difference of green maize harvest in the maize belt of Ethiopia*

Location		Total green maize harvested (t)	% of total harvest
Southern Ethiopia	Alaba, Badawacho, Awassa, Boricha, Siraro, Shashemene	0.369	36
Western Ethiopia	Omo Nada, Kersa,	0.511	16
	Bako Tibe, Gobu Sayo,	0.433	17
Northwestern Ethiopia	Debre Elias, Baso Liben, Bure, Mecha	0.158	13
Average		0.341	21

There is clear geographical difference regarding the per cent of maize harvested while green. Farmers in the southern Ethiopia including those in SNNPR and southern part of Oromia harvest higher proportion of their maize (on average 36%) while green (Table 28). On the other hand, farmers in western Oromia and northwest Ethiopia harvest 17% or less of their maize at green stage. This variability is important as it affects the time of harvesting and thus availability of quality maize stover for the animals.

The correlation coefficient between previous year per-capita major food crop production and the level of green maize harvested is negative (–0.427, significant at 1%). Those farmers who harvested more grain per capita the previous year harvest relatively smaller proportion of their maize output as green indicating the relative availability of food grain in this period.

On the other hand, those farmers who produced smaller per capita grain in the previous year harvested more maize at green stage.

Determinants of maize grain yield

Description of the variables included in the determinants of yield regression equation is given in Table 32 and the result of OLS estimates of the parameters of maize yield equation is presented in Table 33. Most of the variables included in the model are socio-economic variables and a few variables directly related to agronomic management of the field were included. To check if the exclusion of these variable have a serious effect on prediction power of the model, omitted variable test was done after running the model and the hypothesis that the model has omitted variable bias was rejected (F = 0.60).

Table 32. *Descriptives of variables used in the determinants of grain yield model*

Variables	Mean	Std. Dev.	Min.	Max.
Age of household head (years)	47.0	37.32	38.0	59.0
Education level of household head (years)	1.7	2.7	0.0	12.0
Active labour size (15–60 years)	3.26	1.67	1.0	10
Dependency ratio (dependent/total family size)	0.5	0.5	0.0	0.9
Distance from input shop (hour)	1.4	1.1	0.0	5.0
Walking distance to crop market (hour)	1.7	1.1	0.1	5.0
Walking distance to livestock market (hour)	1.9	1.1	0.1	6.0
Area of maize (ha)	0.89	0.81	0.06	6.0
Total crop area (ha)	2.42	1.81	0.25	13.5
Population density (person/km^2)	6.2	5.4	1.7	26.3
Fertilizer rate (kg/ha)	103.4	110.0	0.0	800.0
If the household used improved cultivar (0/1)	0.7	0.5	0.0	1.0
If the household has no ox (0/1)	0.2	0.4	0.0	1.0
If the household has only one ox (0/1)	0.2	0.4	0.0	1.0
If the household has more than 1 oxen (0/1)	0.5	0.5	0.0	1.0
If household is in H_aH_p (0/1)	0.5	0.5	0.0	1.0
If household is in H_aL_p (0/1)	0.2	0.4	0.0	1.0
If household is in L_aH_p (0/1)	0.2	0.4	0.0	1.0
If household is in L_aL_p (0/1)	0.1	0.3	0.0	1.0

The major variables affecting maize yield included maize area owned, total crop area and fertilizer rate used. Area under maize has significant negative effect on yield of maize indicating that as the area under maize increases production tends to be more extensive and thus the yield decreases. As area of maize increased by 1%, yield of maize decreased by 24%.

On the other hand, the total area of crop has positive elasticity which may probably indicate the impact of diversification on the productivity of maize. As the total crop area increased by 1% the yield of maize increase by 26%. As expected, the rate of fertilizer use on maize has significant and positive effect on the yield. For 1% increase of fertilizer use per hectare on maize, yield increases by 6%.

Table 33. *Determinants of maize yield in the maize belt of Ethiopia, OLS estimates*

Variables	Coefficient	t-value
Constant	3.53	5.06***
Age of household head (years)[1]	–0.276	–1.53
Education level of household head (years)	0.017	0.90
Dependency ratio (dependent/total family size)	–0.002	–0.06
Active labour size (15–60 years)	–0.06	–0.54
Distance from input shop (hours)	0.01	0.33
Walking distance to crop market (hours)	–0.011	–0.12
Walking distance to livestock market (hours)	0.051	0.54
Maize area (ha)	–0.239	–3.5***
Total crop area (ha)	0.257	2.3**
Population density (person/km^2)	–0.093	–0.95
Fertilizer rate (qt/ha)a	0.061	4.53***
If the household used improved cultivar (0/1)a	0.058	0.48
Oxen dummy compared to no ox		
If the household has only one ox (0/1)	–0.097	–0.60
If the household has more than 1 oxen (0/1)	0.041	0.26
Agricultural potential and population dummy compared to L_aL_p		
If household is in H_aH_p (0/1)	0.061	0.39
If household is in H_aL_p (0/1)	0.196	1.12
If household is in L_aH_p (0/1)	–0.041	–0.21
Regression diagnosis		
N 191		
F(17, 173) 5.33***		
R-squared 0.34		
Adj R-squared 0.28		
Root MSE 0.66		

Note: 1. Both the dependent and continuous independent variables are in natural log.
a. Use of fertilizer and adoption of improved cultivars could be endogenous in this model. However, endogeneity test failed to reject the null hypothesis of no endogeneity.
***,* indicate statistical significance at 1 and 10%, respectively

6 Livestock production in the maize belt of Ethiopia

6.1 Livestock ownership

Livestock are an important component in the livelihood of the farming communities that grow maize in Ethiopia. Data at community level indicate that with the exception of donkeys and to some extent oxen, which have shown some increasing trends, the number of livestock in the communities decreased from 1999 to 2001 (Table 34). On average, the population of livestock per peasant association decreased from about 5589 TLU in 1999 to 4594 (by about 995 TLU) in 2001 while the average human population per peasant association increased from 1119 to 1217 during the same period. This reduces the average livestock holding of the household from about 5 TLU in 1999 to 3.8 TLU in 2001. The major decline in cattle population in the Rift Valley and partly in western Oromia is perhaps due to environmental factors such as drought and feed shortage.

Cattle are the dominant livestock type in the study area accounting for about 75% of TLU and owned by about 88% of the households (Table 35). The average number of cattle owned by households is 4.5 heads ranging from 2.3 in Awassa Zuria to 8.7 in Omo Nada. About 72% of the households have at least one ox and similarly about 75% of the households have one cow, pointing to the importance of both oxen and cows in the household economy. For those households who own oxen, on average oxen constitute about 42% of the cattle ranging from 25% in Siraro to 63% in Bure. The average number of oxen and cows owned by households is 1.6 and 1.7, respectively. In terms of animal value per household, the average is ETB 2268 ranging from ETB 1004 in Awassa, to 3531 ETB in Debre Elias indicating the low value per animal probably due to the domination of young animals in districts like Omo Nada, Kersa and Siraro. The variation in average number of cattle owned by households among the districts is significant (5% level) ranging from 2.3 in Awassa Zuria to 8.7 in Omo Nada. On the other hand, the difference in livestock ownership did not show significant difference by the agricultural potential and population density categories, (the average number of livestock owned by households in H_aH_p is 7, L_aL_p is 6.6, H_aL_p is 6 and L_aH_p is 4.7).

Table 34. *Trends in livestock population (TLU) by location and species, (average per PA) during 1999–2001*

Livestock species	Year	Awassa Zuria	Boricha	Alaba	Badawacho	Siraro	Shashe-mene	Gobu Sayo	Omo Nada	Kersa	Bako Tibe	Debre Elias	Baso Liben	Bure	Mecha	Mean
All cattle	1999	8399	4725	2340	2358	10951	11110	2400	4440	5799	4386	3605	3509	2080	6242	5167
	2000	7542	3221	1905	2049	8133	6850	3041	4223	5178	3781	4476	3621	2515	6417	4496
	2001	6383	2381	1568	2203	6455	6346	3493	3846	4720	3271	4726	3710	2664	6626	4171
Cows	1999	3899	2182	750	711	3771	3691	939	1411	2258	1114	934	1121	503	1665	1782
	2000	3431	1376	615	665	2830	3268	1182	1269	1957	948	1209	1160	596	1701	1586
	2001	3001	904	492	694	2176	2949	1363	1142	1736	808	1290	1161	617	1746	1434
Oxen	1999	158	340	489	523	1589	842	473	899	1158	833	1388	989	771	2045	893
	2000	172	319	412	445	1214	945	629	1033	1097	778	1636	1081	1007	2101	919
	2001	158	312	334	456	942	1072	753	976	1041	727	1747	1130	1101	2166	922
Sheep	1999	31	33	49	37	52	189	10	40	67	13	105	100	28	48	57
	2000	27	24	36	30	33	198	12	42	63	13	136	103	36	44	57
	2001	22	19	30	24	22	208	11	44	60	12	143	108	45	41	56
Goats	1999	48	82	85	76	539	136	13	28	27	20	19	37	18	12	81
	2000	39	51	63	60	472	99	17	26	25	21	17	35	23	12	69
	2001	36	34	52	61	423	85	20	24	23	21	19	34	26	12	62
Donkeys	1999	38	148	233	139	835	784	75	114	231	99	187	183	120	319	250
	2000	49	156	188	131	779	941	83	114	230	96	200	198	152	334	261
	2001	75	143	162	156	736	1140	95	108	243	94	217	216	160	350	278
Horses	1999	24	3	9	3	58	35	0	0	20	1	1	24	1	5	13
	2000	34	3	7	2	39	36	0	0	18	1	1	32	1	5	13
	2001	48	6	5	2	26	39	0	0	14	1	0	29	1	7	13
Mules	1999	0	4	5	2	9	1	5	53	91	6	0	3	0	30	15
	2000	0	3	3	2	6	1	5	53	88	7	0	1	0	30	14
	2001	0	4	1	2	5	1	5	53	84	8	0	1	1	36	14

Table 35. *Average livestock holding (TLU/household) (proportion of owners) among sample households*

District	All cattle§	Oxen	Cows	Sheep	Goats	Horses	Donkeys	Mules
Awasa Zuria	2.3 (81)	0.7#	0.8 (88)	0.4 (6)	0.4 (13)	0	0	0
Boricha	3.5 (94)	1.0 (56)	2.0 (75)	0.4 (13)	0.5 (38)	0	0.7 (19)	0
Alaba	2.9 (88)	1.3 (56)	1.2 (69)	0.5 (13)	0.3 (25)	0	0.7 (19)	0
Badawacho	3.9 (62)	1.4 (38)	1.6 (56)	0.7 (6)	0.4 (25)	4.8 (6)	1.2(38)	1.4 (6)
Siraro	5.8 (81)	1.3 (81)	2.2 (88)	0.5 (13)	0.6 (69)	2.4 (6)	1.0 (69)	0.7 (12)
Shashemene	3.2 (81)	1.2 (56)	1.3 (63)	0.3 (13)	0.3 (13)	0	1.1 (25)	0
Gobu Sayo	3.9 (94)	1.4 (88)	1.2 (88)	0.3 (13)	0.5 (6)	0	0.6 (38)	0
Omo Nada	8.7 (94)	1.7 (94)	3.0 (94)	0.3 (6)	0.3 (6)	0	0.7(44)	0.7 (13)
Kersa	6.2 (94)	2.2 (94)	2.0 (81)	0.3 (13)	0.8 (6)	0	0.9 (25)	0.7 (19)
Bako Tibe	5.6 (81)	1.7 (75)	2.1 (75)	0	0.3 (6)	0	0.8 (19)	0.7 (6)
Debre Elias	5.4 (100)	2.3 (100)	2.0(63)	0.4 (56)	0.6 (6)	0	0.9 (25)	0
Baso Liben	4.8 (100)	1.9 (81)	1.6 (88)	0.4 (50)	0	1.6 (6)	0.7 (50)	0
Bure	2.8 (100)	1.5 (100)	1.0 (50)	0	0	0	0.6 (31)	0
Mecha	4.3 (87)	1.6 (88)	1.3 (69)	0.3 (13)	0.7 (6)	0	0.7 (50)	0.7 (6)
Average	4.5** (88)	1.6** (72)	1.7 (75)	0.4 (15)	0.5 (16)	3.0 (1)	0.8 (32)	0.8 (4)

Note: **means are significantly different among the districts at 5%.
( ) numbers in parentheses are per cent of owners.
§ Cattle include oxen and cow, among others.
# Only one respondent owned oxen in Awassa Zuria.

Only 15 and 16% of the households own at least one sheep and one goat, respectively. The average number owned by households is about 0.4 TLU for sheep and 0.5 for goat. Relatively more farmers in Debre Elias (56%) and Baso Liben (50%) owned sheep, and in all other districts, the proportion of owners was very low, 6 to 13%. In Siraro, 69% of the farmers owned six goats on average. In many of the districts of SNNPR, except Awassa, at least more than one-quarter own goats. But in all other districts, not more than 6% of the households own goats. The average number of sheep owned ranges from 0.3 TLU in many districts to 0.7 TLU in Badawacho. Similarly, the average holding of goat ranges from 0.3 TLU in four districts to 0.8 TLU in Kersa. The difference among the districts as well as among the agricultural potential and population density categories for ownership of small ruminants is not statistically significant, unlike for cattle.

Population of equines is very low particularly for horses, which are owned only by 1% of the households. The average number of horses for the owners is about 3 TLU and the difference among the district as well as the agricultural potential and population density categories is not significantly high. Among the equines, donkey ownership accounts for about 85% of the equine population. In 6 of the 14 studied districts, the equines reported are only donkeys. This indicates the dominance of donkeys as pack animals. Moreover, shortage of grazing land may be forcing farmers to keep donkeys rather than other pack animals as donkeys withstand hardship better. About 32% of the households own at least one donkey. None of the sample households own donkeys in Awassa Zuria; while in Siraro the majority of farmers (69%) own donkeys, which may be due to the unavailability of water and in this area, where often farmers use donkeys to transport water from distant places. The average number of donkeys owned ranged from 0.6 TLU in Bure to 1.2 in Badawacho with an overall average of 0.8 TLU. About 61% of the households own one donkey and about 30% have two donkeys and the remaining 9% of the households own more than two donkeys.

6.2 Purpose of keeping livestock

Livestock kept by farmers have multiple purposes. Every categories of livestock are kept at least for five purposes (Table 36). This may partly reflect the subsistent nature of agriculture in the area. However, some animal species are more important for certain purposes than others. Keeping livestock for cash generation is more common across different groups.

Table 36. *Purpose of keeping livestock**

Purpose	% of users for each livestock group				
	Sheep	Goats	Donkeys	Cows	Oxen
Draught power*	–	–	89	7	99
Milk	–	37	–	96	–
Meat	56	63	0	8	51
Cash	79	89	92	97	97
Manure	6	9	8	69	67
Savings	32	37	25	57	52
Prestige	–	3	3	32	38
Reproduction	76	80	31	97	–

Note: *Transport for donkey.
* Mules and horses are omitted because of their small number.

Some specific purposes are associated with specific animals, such as oxen for draught power, cows for milk and equines as pack animals. Keeping small ruminants for prestige and manure production is not common in the maize producing areas. In addition to the proportion of farmers that keep certain animals for different purposes, the way they rank the purposes is also important. The multiple purposes were ranked for the different groups of animals in Tables 37–40.

Oxen are predominantly kept for draught power with 99% of the farmers ranking draught power as most important (Table 37). The second major purpose of keeping oxen is for cash generation indicating that after some years of traction services, farmers sell their oxen. About 96% of the farmers ranked cash generation to be the second and the remaining 4% ranked cash generation to be the third. The third major purpose of keeping oxen is for meat which is ranked 3^{rd} and 4^{th} by 59 and 26% of the farmers, respectively, which is in fact related to cash generation.

Table 37. *Purpose of keeping oxen (1 = most important)*

Purpose	% of farmers for the ranks						Total farmers responded
	1	2	3	4	5	6	
Draught power	99	1	0	0	0	0	170
Cash	0	96	4	0	0	0	168
Prestige	0	5	25	34	30	7	61
Saving	0	4	59	19	15	3	95
Meat	0	1	59	26	9	5	92
Manure	0	1	25	59	13	3	117

The three most important purposes of keeping cows, in order of importance, are milk, breeding and cash income (Table 38). About 55 and 42% of the farmers who keep cows ranked milk as the first and second most important purpose respectively. Similarly, about 40 and 35% of the farmers who keep cows ranked breeding as first and second respectively. Among those farmers who keep cows 65 and 21% ranked cash as the third and second purpose respectively.

Table 38. *Purpose of keeping cows*

Purpose	% of farmers for the ranks								Total farmers responded
	1	2	3	4	5	6	7	8	
Draught power	16	16	53	11	5	0	0	0	19
Milk	55	42	3	0	0	0	0	0	192
Meat	0	1	19	46	22	7	3	1	69
Cash	5	21	65	9	0	1	0	0	188
Manure	0	1	4	34	50	8	3	0	150
Saving	1	1	3	56	26	11	3	0	110
Prestige	0	0	9	16	35	33	9	0	58
Reproduction	40	35	16	5	2	<1		1	189

Sheep are mainly kept for cash and breeding purpose and a considerable proportion of farmers also keep sheep for meat (Table 39). About 80 and 10% of the farmers ranked breeding as the first and second purpose respectively. Similarly, 25 and 59% of the farmers ranked keeping sheep for cash as the first and second priority, respectively.

The ranking of purpose of keeping goats is also similar with that of sheep with the exception of milk (Table 40). Breeding purpose was ranked first by majority of the farmers (57%), and cash generation was ranked as first and second by 29 and 50% of the farmers, respectively. The third purpose of keeping goats was milk production, although by few farmers.

Table 39. *Purpose of keeping sheep*

Purpose	% of farmers for the ranks					Total farmers responded
	1	2	3	4	5	
Meat	9	39	42	9	0	33
Cash	25	59	16	0	0	44
Manure	0	0	0	0	100	5
Saving	0	4	61	35	0	23
Breeding	80	10	5	5		41

Table 40. *Purpose of keeping goats*

Purpose	% of farmers for the ranks						Total farmers responded
	1	2	3	4	5	6	
Milk	47	29	12	12	0	0	17
Meat	4	30	30	26	11	0	27
Cash	29	50	19	2	0	0	42
Manure	0	0	33	33	33	0	3
Saving	0	5	68	16	5	5	19
Reproduction	57	16	11	14	3	0	37

Equines are kept for two purposes (as pack animals and for cash generation). About 95% of the farmers ranked the use of equine as a pack animal as the most important purpose.

Table 41. *Average annual amount of livestock products produced and sold*

Livestock product	Production			Sale			
	N	Quantity	Value (ETB)	N	Quantity	Value (ETB)	% of production
Cattle whole milk (litre)	93	307	457	4	156	207	9
Butter (kg)	92	17	245	35	9	132	74
Cheese (kg)	39	18	33	6	15	42	18
Hide (number)	18	2	16	6	1	10	43
Dung cake (number)	40	399	45	1	180	18	6
Goat milk (litre)	8	23	23	1	10	20	29
Skin (goats/sheep) (number)	26	2	46	23	2	41	95

Animal products commonly used by farmers include milk and milk products, and hides/skins. For cattle, milk is the major product produced by 56% of the cow owners and almost the same proportion makes butter (Table 41). Hides/skins are a by-product of meat consumption and/or if the animal dies as a result of disease or accident. The average value of livestock products ranged from ETB 16.47 for hides to 457.5 for cattle milk. The proportion of farmers selling the animal products varies from 6% for milk to 88% for skins. Milk is mainly consumed in the household but 38% of the farmers sell butter. The proportion of farmers selling cheese and hides is 15 and 33%, respectively. The average proportional sale of animal products ranges from 6% for dung cake to 95% of skin. The most sold products are thus skins followed by butter (74%) and hides (43%).

6.3 Livestock production services

Availability and access to livestock services and infrastructure

Some of the infrastructure and services for livestock management include veterinary services, artificial insemination (AI) and access to water in different seasons. A large majority of the farmers (84.4%) use veterinary services. The majority of the farmers use veterinary services provided by the district offices of agriculture (97.3%) and only very few (4.7%) used private veterinary services. The districts where the private veterinary services providers are found include Shashemene, Boricha and Awassa Zuria.

Veterinary services are usually found only in district towns and farmers are expected to go to town from their respective villages to get the services. The time it takes to reach the veterinary services centres on average is about one and half walking hour ranging from 0.38 in Omo Nada to 2.45 in Siraro (Table 42). Besides the significant variation in the distance the farmers have to travel in the districts, there are also differences among the agricultural potentials and population density categories. The low agricultural potential areas are usually far from the service centres. As a result, it took 60% more time to reach L_aL_p areas compared to H_aH_p areas. Such a difference will increase the disparity in terms of development if attention is not given to those areas with low agricultural potential.

Fifteen per cent of farmers used artificial insemination (AI), which is only provided by the district offices of agriculture. Badawacho, Siraro and Shashemene are some of the districts where AI service is relatively more common. In some districts like Omo Nada and Baso Liben, not a single household used AI and in many others (Boricha, Gobu Sayo, Kersa and Mecha) only about 6% use AI. It also appears that more farmers in high agricultural potential and high population density areas use AI services compared to the other categories. About 20% of households in H_aH_p used AI services compared to 13.6% in H_aL_p and less in the others. Those few farmers who look for the AI services on the average walk almost 2 hours to get the services. This ranges from about 30 min. in Awassa Zuria to more than 3:25 hours in Siraro.

Only about 1 and 2.2% of farmers reported using watering trough for livestock during the wet and dry seasons, respectively. Livestock are mainly watered in rivers and streams.

Table 42. *Average walking time (hours) to the veterinary services in the study areas*

District	Agricultural potential and population density				Average
	H_aH_p	H_aL_p	L_aH_p	L_aL_p	
Awassa Zuria	1.19		1.50		1.35
Boricha	1.02		1.37		1.48
Alaba	0.25	1.30	1.33	2.15	1.25
Badawacho	1.54				1.54
Siraro	2.20	2.30	2.08	4.20	2.45
Shashemene	1.20	0.40	0.53	1.55	1.10
Gobu Sayo	1.55	1.00		2.30	1.59
Omo Nada	0.44	0.21			0.38
Kersa	2.02	0.56			1.44
Bako Tibe	0.32	1.16	0.41	1.23	0.58
Debre Elias	2.00	2.23	1.45	1.26	1.53
Baso Liben	1.11	0.59			1.08
Bure	1.57	1.30			1.35
Mecha	1.00	1.15			1.04
Average	1.26	1.18	1.33	2.16	1.32*

Note: F-value for the districts (4.96) and for agricultural potential and population density (5.85) are significant at 1%.

Credit

The use of credit for livestock production is very low and this is not different from the rest of the country. Not more than 25% of the sampled households perceive the need for credit in any of the three years showing that credit for livestock management is not common in the study areas. Most of those who did not show an interest in taking credit lacked awareness about the availability of credit services for livestock (54%). About 31% of them fear risk of not being able to repay the credit. Moreover, only less than half of those farmers who actually want credit applied (21% to formal sources and 24% to informal sources) showing lack of interest by farmers to make use of the available opportunities. This may be related to the low level of success as only 30 and 43% of the applicants to formal and informal sources, respectively, in 2001 obtained the credit, mainly in cash. The major purpose for wanting credit among those who sought credit was to purchase livestock (52%), which is usually an investment.

6.4 Livestock production inputs

Livestock production inputs include mainly feeds, health care and labour for management (herding, watering, feeding, milking and cleaning). In subsistence oriented crop–livestock production, where open grazing is more common and stall feeding is almost non-existent, actual input use for livestock is difficult to measure accurately. Only in some cases, farmers attempt to consider the various inputs as real inputs. The majority of the farmers were not able to estimate the amounts of residue they have used.

Feeds

Livestock feeds in the study area could be categorized into grazing, on-farm produced crop residues, on-farm produced hay, purchased crop residue, purchased hay, industrial/local beverage by-product and minerals/salt. Weeds are also used as feed. Planting forages is not common. Only three sample households planted improved forage crops in 1999 and only one planted in 2000. Only 4.5% of the sample households have been trained on forage production and less than 1% has been trained on improved livestock and poultry management.

Natural pasture

The increased population pressure in the country, which has brought more and more land under crop production has greatly reduced area left for grazing. Use of communal grazing was reported in 64, 52 and 29% of the sample PAs in the wet, harvest and dry seasons, respectively. It was indicated above that grazing land account for 10% of the land mass in the survey area. Such grazing lands usually do not go beyond concentrating the livestock on small areas to prevent damage to crops during the cropping season.

Districts where communal grazing was reported in dry season include Gobu Sayo and Omo Nada in Oromia and all districts in Amhara region. During the harvest season the same districts in Amhara, and districts in Jimma zone and Badawacho reported to have communal grazing. The average grazing hours in the reporting villages is 9 hours/day in the wet season and 7 hours during harvesting when livestock also feed on stubble. During dry season, when there is no pasture, the time of grazing on communal fields is increased to 9 hours/day. This turns the communal grazing fields into resting places.

On-farm produced crop residues

Residues of almost all crops are fed to animals and the use depends on the location and farming system. The major crop residues fed to the animals by the majority of farmers are teff, maize, finger millet and *enset*. Maize residue is fed to the animals both at green stage, during harvest and in dry season after harvest. Dry and green maize stover was used as feed by 79 and 58% of sample households. Similarly, all teff producers used teff straw for animal feed. However, the amount used was difficult to estimate particularly for maize. While 55 and 67% of teff straw users were able to estimate the amount of teff straw used for livestock in the wet and dry seasons, respectively, only about 8.7 and 6.4% of maize growers were able to estimate the amount of green and dry maize stover they fed to their animals in the wet and dry seasons, respectively.

The households that were able to estimate the total amount of stover used as a feed in a season are shown in Table 43. On average they have used 0.86 t of green maize stover and 0.8 t of dry maize stover as feed in the wet and dry seasons, respectively. A higher proportion of teff growers reported using about 1.39 and 1.1 t of teff straw as feed in the wet and dry seasons per household, respectively. About 33% of *enset* growers have used *enset* as feed for animals in the dry season, although there are few farmers using *enset* for animal feed in other seasons. In the dry season, where feeding *enset* is more common, farmers have used on average about 1.35 t of *enset* as feed per household. The other crop residue which is commonly used by growers is finger millet residue which is used by about 22 and 15.6% of finger millet growers in the wet and dry season, respectively. On average, they have used about 0.46 and 0.27 t, in the wet and dry seasons, respectively.

Table 43. *Average amount (t) of on-farm produced crop residues used by farmers in different seasons*

Residue type	Wet		Harvest		Dry	
	N	Mean	N	Mean	N	Mean
Maize dry			1	1.90	14	0.80
Maize green	19	0.864	0	0	0	0
Barley*	6	1.30	3	1.32	4	3.16
Wheat	6	0.27	4	1.20	6	3.19
Teff	59	1.39	2	1.10	72	1.96
Haricot bean	2	0.025	4	2.10	7	.46
Enset	5	0.58	5	1.94	22	1.35
Finger millet	10	0.46	0	0	7	0.27

Note: * Cartload of barley straw.

Purchased feed

Besides on-farm produced feed, which is common to all farmers, some farmers also buy feeds. The most common purchased supplementary feed is salt which was used by about 27% of the farmers, only during wet season. The number of farmers supplementing with salt in the other seasons is low. This also indicates the need of supplementing with minerals. Only about 4% of farmers in dry season and 2% of farmers in wet season purchased hay. In general, less than 12% of the livestock owners bought livestock feed of any type in any one season. Although there is some practice of selling crop residues, farmers usually do not sell to other farmers. Most of the sale is for town dwellers mostly for dairy and equines. During the wet season when farmers have natural pasture, they only purchase supplementary feeds and also rent pasture field. In the harvest season, farmers do not purchase any feed except salt. It is in the dry season that a range of feeds are purchased, although by a few farmers.

Health services

Despite unavailability of animal health services in rural areas, some farmers travel the required distance to get treatment for their animals. The proportion of farmers using animal health services is more in the wet season (31%), with an average expense of ETB 21.48 per household. In the dry season, only about 17% of the households received health services with average cost of about ETB 18.91 per household. In the harvest season, only about 9% of farmers used health services. In general, about 45% of the farmers who own livestock received animal health service in 2001.

Labour

Herding and watering are the major activities that require labour in livestock management. About 93–95% of the livestock owners used family labour for herding and watering while only 3–4% used hired labour. Farmers rely heavily on family labour for milking and barn cleaning. Almost all households having livestock (93–96%) used family members for barn cleaning and milking. The other activity where labour is important is feeding of crop residue, hay, and supplements.

6.5 Livestock feeds and feeding

Sources

Livestock feeds mainly include natural pasture, crop stubble, crop residue and hay. Natural pasture and stubble are the most widely used feed resources as these resources were used by 97 and 93% of the farmers, respectively. Most farmers use crop residues as stubble as they do not collect and feed their animals. Crop residues (collected and fed to the livestock) are usually used when there is shortage of natural pasture and stubble. With the expansion of cropland, which has reduced the availability of natural pasture, crop residues are becoming increasingly important. As a result, more than 62% of the crop residue produced by smallholders is used for livestock feed.

The most common crop residue is maize stover, which is available as dry stover in about 79% of the sample households and as green stover in more than 58% of the households. The second most common crop residue next to maize is teff, which was used by about 48% of the sample households in the study area. *Enset*, tree legumes and hay are available for about 10% of the households. There are other feed sources, which are available to some farmers during the year including the sown pasture, which is available only for 3.1% of the households and commercial feed, which is available for about 1% of the sample households.

Only one or two of the sample households planted improved forages during 1999–2001. The major reason for not planting improved forage is lack of awareness as reported by about 76% of the respondents indicating the low promotion activity for this technology. Some 13% of the respondents also indicate shortage of land to plant forage as a reason for not planting improved forage.

Seasonality of feed availability

Because of the heavy dependency of the agricultural system on rainfall, the availability of feed for livestock follows a seasonal pattern both in type and quantity. In terms of type, some feeds are available at specific period and some could also be stored temporally. In order to know the relation between the type of feed and seasonality, the five most common sources of feed were considered. For each feed, farmers' responses on its availability was analysed (Figure 4). The pattern of availability is directly related to rainfall. During May–October, natural pasture constitutes the larger portion of feed available compared to other feed sources for many farmers, but contributes the smallest share during the dry period, i.e. November to March. During this period the larger proportion of the feed available are stubble and crop residues. The availability of stubble extends from September to March depending on the type of crop and harvest time. However, during the months of November to January, stubble provides most of the feed for the livestock. This role is taken up by crop residue in the three months that follow (February–April). Dry maize residue is available for many farmers between January and March, although its availability is almost throughout the year. Teff straw is available mainly in the dry season, January–May, being highest in March and gradually decreasing.

Availability in terms of percentage of farmers using specific feed and the length of the period in which that feed is available does not necessarily indicate the sufficiency of the feed, i.e. the amount available in relation to the livestock owned. To highlight how much the available feed is sufficient, farmers' responses are presented in Figure 5. Seasonal trend in the level of availability of the feed could be clearly seen. The year is divided into quarters of almost equal period. The first quarter, January–March, is the period of severe feed shortage. For most part of this season more than 50% of the farmers reported the severity of feed shortage. In the second quarter, April–June, the level of severity reduces as there is some grass as a result of the short rains. The proportion of farmers reporting severe shortage drops in this period while those farmers reporting moderate shortage of feed increases. Because of the main rains, feed is relatively abundant in the third quarter, July–September. At least 50% of the farmers reported excess feed indicating availability of better amount of feeds compared to other periods. As the rains stop, feed availability also decreases but it is sufficient to sustain the animals. The cyclical trend directly follows the rainfall, although there could be lags.

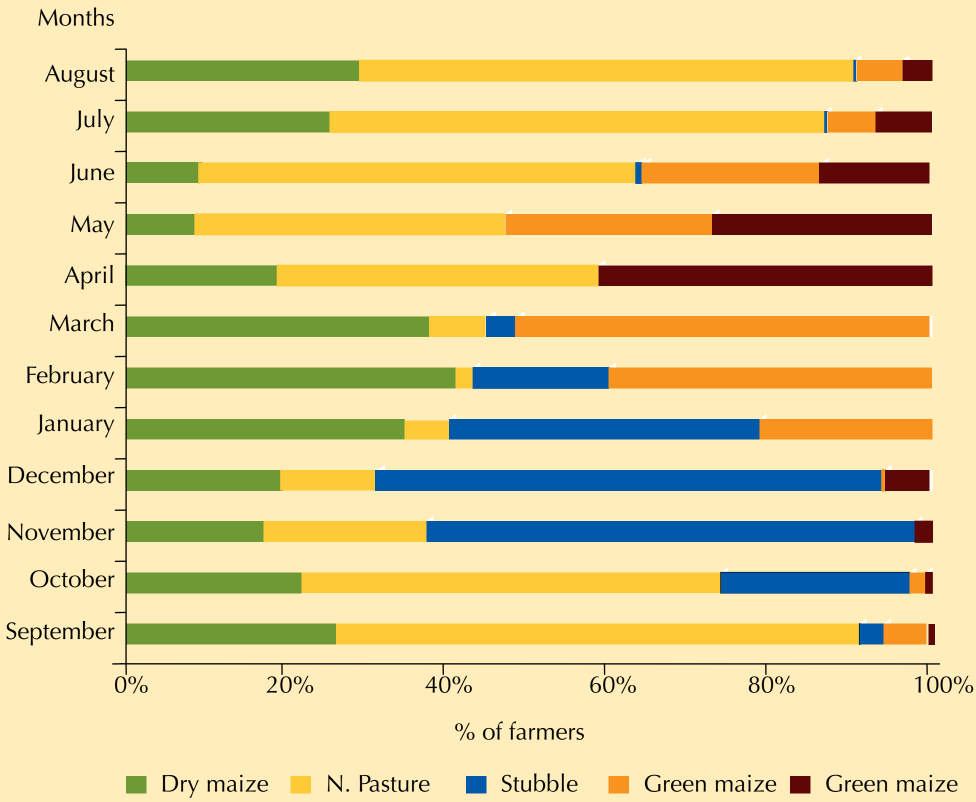

Figure 4. *Feed availability by type and months.*

By overlapping Figures 4 and 5 (availability and level of availability) it is possible to elucidate the importance of each of the major feed sources. Year-round feeding of animals is based on a dynamic integration of feed resources at the farm level. In the first quarter, where there is severe shortage of feed, the major component of the feed is crop residues. On the other hand, in the third quarter, where feed is reported to be in excess, natural pasture dominates the feed available in the period. In the fourth quarter too, where feed is sufficient, natural pasture dominates in October and stubble dominates in the other two months. This may show the importance of natural pasture in the feed supply system. Stubble grazing is also important as it still supplies partly green feed for the animal. Thus, crop residue is mainly used during the period where natural pasture is unavailable.

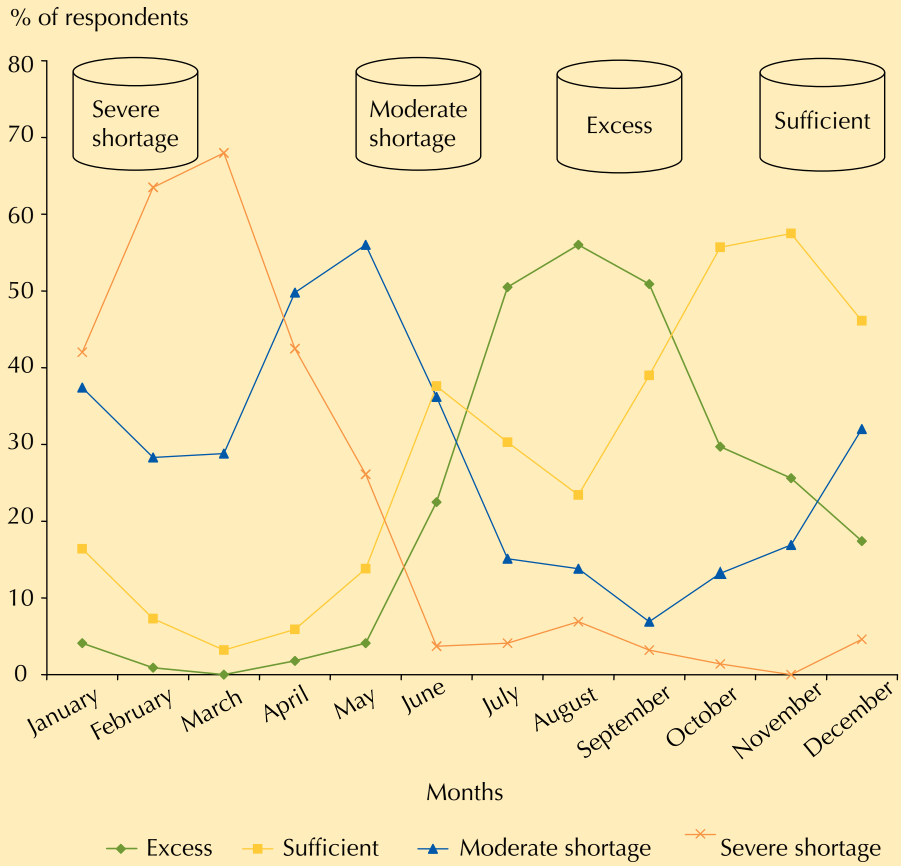

Figure 5. *Level of feed availability throughout the year (all types of feed considered)*

Use of available feeds

Almost all farmers who have livestock use free grazing mainly on herding throughout the year. However, grazing as such is less common in the wet and harvest seasons mainly because of shortage of grazing land and animals graze on roadsides, pathways and around the home stead. Although these types of grazing are becoming more common because of land shortage, most farmers did not report such system as a pasture grazing. Stubble grazing after grain harvest is used by the majority of the farmers particularly for draught oxen and milking cows.

Use of feeds for different livestock groups

Different livestock groups have different level of access to different sources of feed. Moreover, there is seasonal variability within the same group. In the dry and wet seasons, all cattle groups except calves have better access to private grazing land, which in most cases fallowed from cropland, communal grazing and crop residue (Table 44). They have less access to other sources of feed. The availability of crop residue after grain harvest is low for most of the cattle groups. This is because of the availability of stubble, which will be lost if not used soon after grain harvest. Crop residues are stored for dry and wet period, particularly for draught oxen and milking cows. In the wet season, calves do have better access to private grazing land and weeds. Calves are not usually taken to communal grazing fields and are not also given crop residue. Equines and small ruminants depend more on communal grazing and private grazing land than other sources of feed in both the dry and wet seasons. During the grain harvest season, the majority of the livestock groups have access to stubble and private grazing land except small ruminants, which concentrate more on the stubble grazing. Dry season is similar to wet season for almost all livestock group.

Table 44. *Use of various feeds to feed different livestock species by season, per cent of farmers*

Livestock group	Season	Crop residues	Communal grazing	Private grazing	Stubble grazing	Hay	Thinning (maize & sorghum)	Grass & Weeds	Tree leaves
	Wet	68.4	69.6	74.9	4.7	3.5	31.0	21.6	
Draught oxen	Harvest	28.1	35.1	48.0	97.1	–	–	3.5	–
	Dry	56.7	72.5	55.0	19.3	2.9	1.8	–	2.3
	Wet	65.8	65.2	76.1	4.2	3.0	38.3	22.1	5.4
Milking cows	Harvest	32.4	43.7	79.0	67.7	0.0	0.0	2.4	0.0
	Dry	54.5	69.1	57.6	17.6	4.9	1.2	1.2	4.2
	Wet	37.3	16.2	63.6	1.0	1.0	24.2	61.7	0.0
Calves	Harvest	31.0	12.0	59.0	55.1	1.0	2.1	29.9	1.0
	Dry	58.7	17.5	72.1	9.3	4.1	2.1	16.6	1.1
	Wet	60.0	67.7	76.8	2.6	–	21.3	14.8	0.6
Other cattle	Harvest	38.5	34.0	50.0	94.2	–	–	1.3	–
	Dry	58.8	75.2	57.5	21.6	2.6	0.7	0.7	0.7
	Wet	20.0	63.6	56.4	–	–	1.8	5.5	30.9
Small ruminants	Harvest	15.1	26.4	37.7	83.0	–	–	1.9	24.5
	Dry	13.5	65.4	50.0	9.6	–	1.9	–	32.7
	Wet	30.1	68.5	74.0	1.4	–	5.5	2.7	–
Equines	Harvest	31.1	39.2	54.1	85.1	–	1.4	–	–
	Dry	40.8	71.8	50.7	19.7	–	–	–	–

Farmers' perception on feed quality of different residues

The most important crop residues in terms of feed quality as perceived by farmers are maize stover and teff straw (Table 45). The majority of the farmers ranked maize first (67%) and about 52% ranked teff second and 50% also ranked *enset* leaves as second in terms of quality. Maize stover and teff straw in that order are better in terms of quality, while crop residues such as wheat and haricot bean are not considered as high quality feed by farmers.

Table 45. *Farmers ranking of crop residue quality as feed (1 = best quality)*

Residue types	% of farmers for each rank					Overall rank*
	1	2	3	4	5	
Maize (green and dry)	67	26	5	2	0	1
Teff	38	52	9	1	0	2
Enset	19	50	27	4	0	3
Sorghum	4	46	50	0	0	4
Haricot bean	0	41	50	5	5	6
Wheat	0	29	38	29	5	7
Finger millet	33	29	29	10	0	5

* Cumulative figures were used to estimate the overall rank.

Priority of feeding

Feed resources are not abundant throughout the year and thus all animals do not have equal access to the limited feed available. Thus, farmers give priority depending upon the purpose and contribution of the livestock group to the livelihood of the family. The priority for the different animal species is almost uniform throughout the seasons.

Cattle are generally given high priority and oxen get the first priority followed by milking cows. This may be related to the high contribution of oxen for crop production to sustain the household. Even during non-working time, oxen get priority as it is felt that it influences their performance during ploughing. Milking cows are also important both as breeding animal and for their milk. Third feeding priority is given to other cattle, followed by calves. Small ruminants and equines (mainly donkey in this case) are usually given low priority for feed. In general, equines get priority compared to small ruminants.

Level of consumption

As indicated in Tables 46 and 47, grazing is the most widely used feeding system. Average grazing day varies more among seasons than either among animal groups or between the private and communal grazing areas, but draught oxen have significantly lower grazing day during the wet season. While other animals except equine (91 days) graze for more than 110 days, oxen graze for 74 days during this season. In general oxen grazing duration is lower, followed by equines, perhaps because of the work load on these two animal groups. The trend is similar on the private grazing land. In the wet season, small ruminants have more grazing days in both communal and private grazing land. Stubble grazing is usually for short period and average grazing days range from about 35 days for equines to 42 days for small ruminants. It is more widely used for cattle than for equines and small ruminants.

Table 46. *Average grazing days on communal grazing land in different seasons**

Livestock group	Wet	Harvest	Dry
Draught oxen	74 (68)	31 (32)	82 (76)
Milking cows	113 (61)	35 (26)	101 (67)
Other cattle	110 (57)	35 (27)	100 (63)
Small ruminants	118 (62)	33 (27)	96 (67)
Equines	91 (67)	31 (29)	83 (74)

Note: *numbers in parentheses are number of farmers/users.

Table 47. *Average grazing days on private grazing land in different seasons**

Livestock group	Wet	Harvest	Dry
Draught oxen	74 (80)	32 (55)	77 (64)
Milking cows	114 (74)	31 (51)	92 (60)
Other cattle	113 (168)	33 (47)	88 (56)
Small ruminants	128 (75)	37 (52)	90 (65)
Equines	102 (85)	29 (63)	75 (78)

Note: *numbers in parentheses are number of farmers/users.

The most common crop residues fed to animals are those of maize, teff and wheat (Table 48). Maize residues are fed to livestock almost throughout the year and are used by a large number of farmers and in larger quantities than other feeds. Green maize stover is used during wet season and dry maize stover is used after grain harvest and during the dry seasons. Relatively few households, not more than 7%, use the green maize stover that is only available during wet season. The green maize forage is only used for feeding oxen and milking cows. The average value of green maize stover provided to the animals range from ETB 7.5 to 22.1 per household during the wet season.

Dry maize stover is used starting from harvest. During grain harvest, the number of households using dry maize stover is relatively low, not more than 11% for a given type of animal. Yet the amount fed is relatively higher with the average value of ETB 11.8 for oxen, ETB 11.5 for equines and ETB 9.8 for milking cows. The number of users is low mainly because there is stubble to be grazed in this period. In the dry season the proportion of farmers using dry maize stover was 37% for oxen, 33% for other cattle and 32% for cows.

The value of the residue used also increased to ETB 19.8 for oxen, ETB 12 for milking cows and ETB 10.6 for other cattle. The use increases because of the declining availability of other feeds (stubble and grass). In this period, relatively other animal types, goats and equines are also included, for it is critical for the animal to reach the wet season where they can have relatively enough grass. In the wet season, the proportion of farmers feeding maize was 35% for other cattle, 38% for milking cows and 42% for oxen. During the rainy season, the average value of the dry maize feed was ETB 18.2, 22.1 and 25.4 for other cattle, milking cows and oxen, respectively.

Table 48. *Average value (ETB/farmer) of feeds for different animal groups in different seasons*

Feed	Livestock type	Wet		Harvest		Dry	
		N*	Mean	N	Mean	N	Mean
Green maize	Oxen	14	22	–	–	–	–
	Milking cows	13	11	–	–	–	–
	Other cattle	14	8	–	–	–	–
Dry maize	Other cattle	78	18	–		72	11
	Oxen	93	25	23	12	83	20
	Small ruminants	–§	–	1	2	1	2
	Equines	–	–	9	12	4	3
	Milking cows	86	22	24	10	72	12
Teff	Oxen	–	–	–	–	63	42
	Equines	–	–	–	–	2	8
	Milking cows	–	–	–	–	33	22
Wheat	Oxen	–	–	3	1	–	–
	Milking cows	–	–	1	9	–	–
Enset	Milking cows	–	–	1	16	–	–
	Oxen	–	–	1	24	–	–
Salt	Oxen	34	6	–	–	–	–
	Milking cows	29	3	–	–	–	–
	Small ruminants	3	2	–	–	–	–

Note: * Number of farmers.
§ – not used.

The other residue used by many farmers (28% for oxen and 15% for milking cows) is teff straw, which is used during the dry season only. The average value used is about ETB 42.4 for oxen and ETB 22.4 for milking cows. Very few farmers feed equines a small amount of teff straw. *Enset* leaves and wheat straw are rarely used by farmers. Moreover, these two crops are limited in their geographical distribution within the maize producing areas. Additional/supplementary feed that farmers commonly use is salt, especially during the wet season.

The level of 'feed security' varies across livestock types and seasons (Figure 6). In most cases, relatively a higher proportion of farmers reported enough feed for cattle compared to small ruminants and equines.

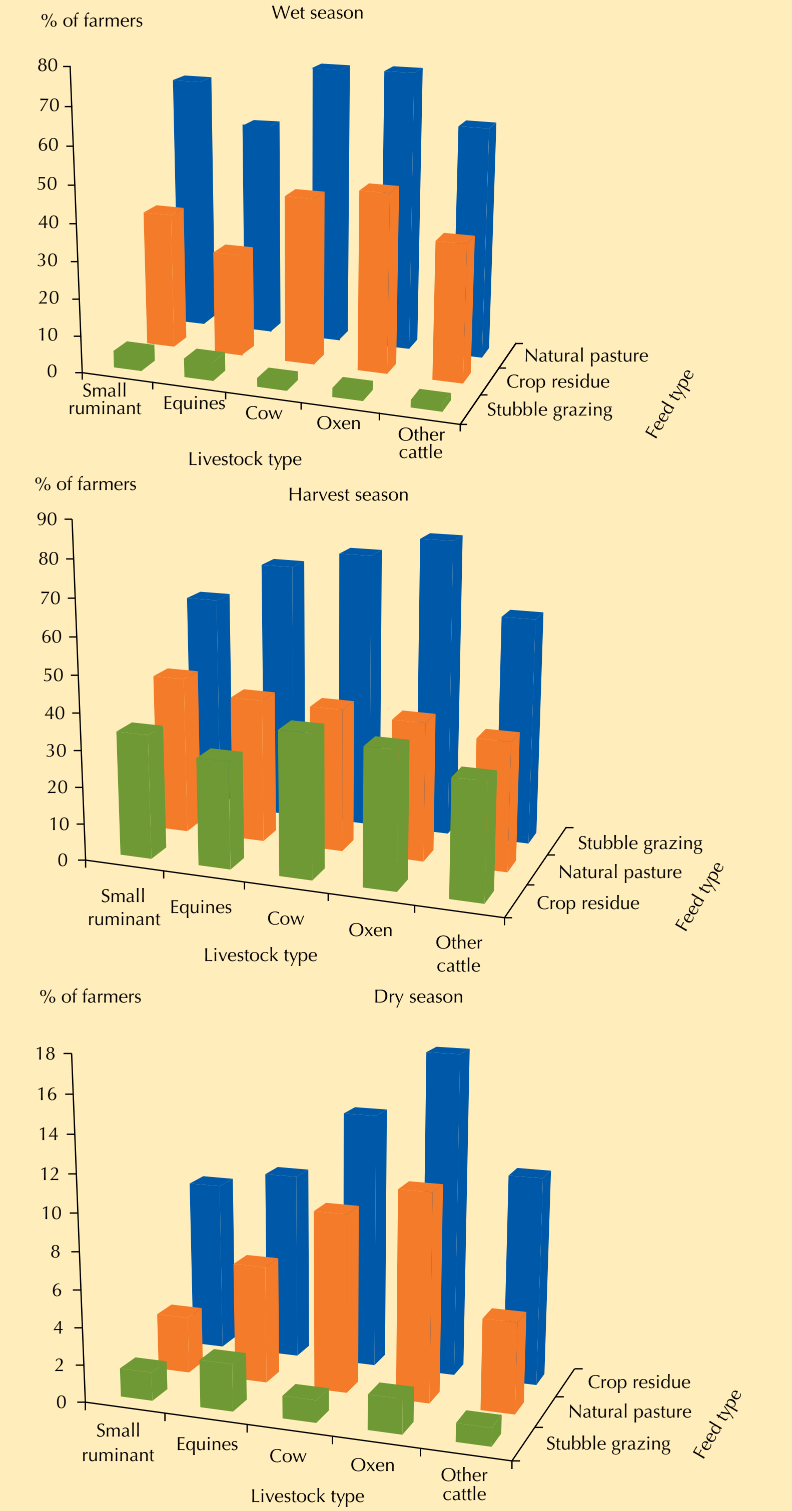

Figure 6. *Level of feed security for livestock species in different seasons.*

The amount of feed resources available varies by season and the feed type. Crop residues are normally available in the dry season. However, in this season, not more than 18% of the farmers reported sufficient feed from various sources for any livestock group. The maximum proportion of farmers who reported sufficient feed in the dry season were referring to crop residues used for oxen (17%). The contribution of other feed sources is low during the dry season. Even for oxen, which usually get priority, less than 10% of the owners reported sufficient natural pasture. Natural pasture is the second major source of feed in the dry season.

In the wet season the majority of farmers (more than 60%) reported that available natural pasture is enough for their livestock. The contribution of crop residues is also high, as 20–40% of the farmers reported enough crop residues for different livestock groups in the season. This shows that farmers store crop residue to be used during the wet season. The maximum level of feed security is reported during the grain harvest season. The majority of farmers (60–80%) reported that stubble grazing is sufficient for different livestock groups in this season. The contribution of both natural pasture and crop residue is also high in this period. About 25–40% of the farmers reported sufficient natural pasture in the harvest season for different livestock group. Moreover, 20–30% of the farmers have also reported that crop residue is sufficient for different livestock groups in the harvest period.

In general, the maximum level of feed security (60–80% of farmers reporting) occurs during the grain harvest season. This is followed by the wet season (reported by about 55% for milking cows and slightly more than 70% for oxen). In the dry season, very few farmers reported that crop residues are enough for livestock (9–16%) and less than 10% reported that natural pasture is sufficient for livestock. This shows the seasonality in the amount of feed available for the livestock in the study area.

Consequences of feed shortage and mitigation strategies

The consequence of feed shortage is well recognized by farmers (Table 49). The most common effect is weight loss and weakness, which are recognized by more than 80% of the farmers for all livestock groups. Weight loss is more serious for small ruminants and equines, probably due to less attention given to them by farmers compared to cattle. Similarly, the incidence of weakening of the animal is reported more for small ruminants and equine than cattle. Most farmers (more than 70%) also reported that feed shortage increases mortality. The decrease in milk yield by cows and extended calving for cows and equines were also mentioned by 86 and 85% of the respondents, respectively. For equines, the most important impact of feed shortages was reported to be weight loss, weakness and mortality. Reproductive effects were not reported for equines possibly, at least in part, due to the fact that the equines were not disaggregated into males and females. The effect of feed shortage on the incidence of diseases was reported by less than 10% of the sampled households for the different groups of animals.

Table 49. *Proportion (%) of farmers recognizing impact of feed shortage*

Consequence	Oxen	Milking cows	Other cattle	Small ruminants	Equines
Weight loss	83	87	90	99	100
Low milk	–	86	–	–	–
Increased mortality	74	75	78	–	88
Weakness	82	85	88	99	100
Delayed calving	–	85	–	–	31
Predisposition to disease	8	6	5	–	2

The effect of feed shortage in order of importance is given in Table 50 for the different groups of animals. The most important effect across animal groups is weight loss. Weakening, except in case of milking cows and equines, is the second most important. In the case of milking cows, less milk is more common than weakening. Similarly, mortality is more important compared to weakening in the case of equines. Mortality is the third most important effect of feed shortage for oxen and other cattle.

Table 50. *Ranking of impacts of feed shortage on different livestock group (1 = most important)*

Rank	Oxen	Milking cows	Other cattle	Small ruminants	Equines
1	Weight loss	Weight loss	Weight loss	Weight loss	Weight loss
2	Weakening	Less milk	Weakening	Weakening	Mortality
3	Mortality	Weakening	Mortality		Weakening
4	Susceptibility to disease	Delayed calving	Susceptibility to disease		Delayed calving
5		Mortality			Susceptibility to disease
6		Susceptibility to disease			

The order of priority of the different effects of feed shortage, therefore, is weight loss followed by weakness, mortality, low milk and extended calving. This shows that farmers easily recognize the visual effects like weight loss and weakness while the second level effects, such as reduction in milk yield, reproductive wastage and exposure of the animals to the diseases are less perceptible.

Farmers employ several strategies to overcome the problem of feed shortages. Table 51 shows the different mitigation strategies followed by livestock owners and their preference whenever there is a problem. One strategy that is used by about 68% of livestock owners is de-stocking. Among those farmers who opt for de-stocking, 48% ranked it as the first option; 28% ranked it as second and the remaining 24% ranked de-stocking as the third option. The second strategy used by about 62% of the household is purchase of feed, which is ranked second by majority of the farmers (57%) and ranked as first option by about 20% of the farmers. Other options include moving the animals to other places, renting pastureland, storing hay and straw. As feed is not widely available in the market in times of feed shortage and hence the purchase strategy is rarely realized. Whenever there is shortage of feed, farmers usually rent grazing plots in other areas. Transferring the stock to another person is practised by less than a third of the livestock owners. However, the majority of those farmers who opted for moving the animals to other places and those who opted to store hay and straw ranked these as their first options.

Table 51. *Importance of feed shortage mitigation strategies*

Mitigation strategy	% of farmers for each rank				% of livestock owner
	1	2	3	4	
De-stocking	48	28	23	0	68
Purchase feed	20	57	19	5	62
Moving the stock to other places	66	15	19	0	30
Renting grass land	6	33	57	4	26
Store hay and straw	53	25	22	0	24
Transferring stock to other people	41	39	21	0	19
Others*	40	40	20	0	3

*Planting forage and asking relatives feed for free.

6.6 Constraints to livestock production

The major constraints to livestock production, according to farmers, are listed in Table 52 for the different districts. The majority of farmers reported problems of feed availability as the most important constraint. On average, about 62% of the farmers reported feed shortage as the most important problem, ranging from 38% of farmers in Bure and Bako Tibe to 94% in Baso Liben. Some of the districts where feed problem is serious include Baso Liben, Debre Elias, Kersa and Awasa Zuria where more than 75% of the farmers reported feed shortage. In districts like Bure, Bako Tibe and Siraro, feed shortage is less important since only less than 45% of the farmers reported it. In other districts, the problem is moderate and 50–69% of the households reported the problem.

The second important constraint is disease, which on average was reported by about 12% of the households. However, the problem is more serious in Wellega zone where many farmers, 38% in Bako Tibe and 44% in Gobu Sayo reported the problem. About 19% of the farmers in Alaba and Badawacho also reported the problem of livestock disease. The next problem in order of importance is cash shortage. This is true as there is no credit for purchasing livestock input unlike for crop inputs where credit is usually available for fertilizer and seed. Water is a problem in only two districts particularly in Siraro where about 19% of the farmers reported the problem. Siraro is the driest districts among the districts included in this study.

Table 52. *Major problems of livestock management in the maize belt of Ethiopia (per cent of farmers reporting the problem)*

District	Feed shortage	Disease	Labour shortage	Water shortage	Cash shortage	Land shortage	Others
Awassa Zuria	75	6	0	0	13	0	0
Boricha	69	0	0	0	13	0	0
Alaba	56	19	0	0	13	0	0
Badawacho	50	19	0	0	19	0	0
Siraro	44	6	0	19	0	6	0
Shashemene	50	0	6	0	13	0	0
Gobu Sayo	50	44	0	0	0	0	0
Omo Nada	69	6	0	0	6	0	0
Kersa	81	6	0	0	0	0	0
Bako Tibe	38	38	0	0	13	0	0
Debre Elias	88	0	0	0	6	0	0
Baso Liben	94	0	0	0	6	0	6
Bure	38	13	0	6	25	0	0
Mecha	63	13	0	0	0	6	0
Average	62	12	0	2	9	1	0

7 The multiple roles of maize

7.1 Use of maize as food

Ethiopian agriculture is mainly subsistence oriented and most of the production is for household consumption. About 67% of cereal grain produced is consumed at the household level and the surplus is either sold or used as seed (Table 53). Among the cereals, maize and sorghum have highest proportion consumed by producers (74–76% of produce consumed by producers), followed by finger millet, oats and rice (Table 53).

Table 53. *Use of cereals in Ethiopia, (per cent of production), 2001/02*

Cereals	Household consumption	Seed	Sale	Wage in-kind payment	Animal feed	Others
Teff	57	13	26	1	0	3
Barley	66	18	11	2	1	3
Wheat	59	17	20	1	0	3
Maize	76	9	11	1	1	2
Sorghum	74	9	11	1	1	3
Finger millet	69	10	13	1	0	4
Oats	68	19	9	3	2	2
Rice	65	12	19	1	0	2
Total	67	13	16	1	1	3

Source: CSA (2003).

The role of maize as a source of cash income is low compared to other cereals except oats and barley as indicated in Table 53. Only about 10.9% of the maize grain produced was marketed in 2001/02 compared to 25.8% for teff and 19.5% for wheat. Thus, the major role of maize in Ethiopia is for household consumption.

In this study area, about 60% of the cereal produced by smallholder was used for direct household food consumption (Table 54). This is in line with the CSA information given in (Table 53) that shows 67% of the cereal produced is consumed at home. The slightly higher consumption at national level is due to the fact that the national data also include remote areas where almost the entire production is used for home consumption. About 35% of the cereal produced in the area is also used for generating household cash income (Table 54). Maize, being the major cereal produced in the study area, accounting for 57% of total cereal production, is the major crop for both household consumption and cash generation.

In terms of individual crop use in the study area, a high proportion of the sorghum (89%) goes to household consumption followed by maize, 65% (Table 55). However, the share of sorghum in total household production is only 2% (Table 54). On the other hand, among the cereals, wheat is mostly produced for the market (44%), followed by teff where about 37% of the produce is marketed. About one-third of barley and maize is also sold.

Table 54. *Contribution of cereals to different uses in the study area (per cent of total production)*

Uses	Crops					Total
	Barley	Wheat	Teff	Sorghum	Maize	
Food	1	7	13	2	37	60
Feed	0	1	0	0	0	1
Sale	1	7	8	0	19	35
Seed	1	1	1	0	1	4
Total	3	16	22	2	57	100

Table 55. *Use of cereals for different purposes in the study area, per cent of production*

Use	Barley	Wheat	Teff	Sorghum	Maize
Food	54	44	57	89	65
Feed	0	3	0	0	0
Sale	33	44	37	9	33
Seed	13	9	6	2	2
Total	100	100	100	100	100

In the maize belt of Ethiopia, maize is the staple food for the majority of the farmers; hence, the household consumes about 65% of the maize produced. Farmers consume maize by preparing different dishes (Table 56). These include *injera*, thick porridge, bread, boiled maize and local beer. About 93% of the maize growers make bread out of maize, and *injera* (92%). About 83% of the farmers boil maize, 72% make thick porridge and about 64% use maize to make the local beverage, *tella*.

Table 56. *Types of food prepared from maize and their ranks*

Types of food	% of maize grower	% of farmers for each rank				
		1st	2nd	3rd	4th	5th
Injera	92	30	44	18	8	0
Thick porridge	72	4	21	37	20	19
Local beer	64	31	16	10	31	12
Bread	93	49	22	18	11	1
Boiled maize	83	3	17	41	36	3

In some instances, there are differences in the consumption patterns of maize across the different geographical locations. For instance, local beer is not very common in the districts found in the southern part of the country and Jimma area, perhaps because of religion; boiled maize is not known by farmers around Shashemene; *injera* is not common in Awassa Zuria; thick porridge is rarely used in the northwestern parts of the country. These are related to the consumption habit of the society in different parts of the country.

From the proportion of farmers using maize for different purposes and the ranks they have given, it could be seen that the major use of maize is for bread and *injera* (Table 56). They have both comparable number of users as well as similar ranking pattern. In general, maize is used more for bread followed by *injera*. Among the remaining food types, the majority of households (82.5%) consume boiled maize and a considerable proportion ranked it third. Hence, boiled maize grain (*nifro)* is the third most important use of maize, followed by local beer and thick porridge.

7.2 Use of maize as livestock feed

Maize forage is derived from green stover (obtained from thinning, leaf stripping, plant tops and entire green plant) and dry stover (Reynolds 1999). Thinning does indeed introduce a significant benefit in terms of fodder availability and quality, during the rainy season, thereby promoting an increase in milk production. The immature plant thinning contains up to six times the crude protein content of dry stover, and it has been reported that it can produce up to 4 t DM/ha of high quality feed without significantly affecting the final grain yield (Onim et al. 1991; Methu 1998). Thinning is practised in Western Kenya by a dual-purpose goat project in the highlands of Kenya, the Kilimanjaro region of Tanzania and in the Ethiopian highlands on smallholder dairy farms (Franzel and van Houten 1992; Getz and Onim 1993; Shirima 1994). Early thinning (8 weeks) has been recorded to contain a crude protein of 17% DM compared to late thinning (14 weeks) of 10–11% DM.

Dry maize stover available after grain harvest is the most widely used (Reynolds 1999). The major limitation to the use of dry maize is its high lignification and low protein content, which varies from 55 to 66 g/kg DM (Methu 1998). Dry maize stover accounts for 15% of the annual ruminant diet in the low veldts of Zimbabwe, to 40% in the cut and carry dairy systems in the Tanzanian highlands (Shirima 1994). In West Africa, overall annual contribution is as low as 16% and during the peak of dry season it could go up as high as 80% in other areas (Sandford 1989). Part of the difference between West and East Africa can be explained by rainfall pattern; two growing seasons per year in the east African highlands, produce more stover than a single growing season in South Africa (Reynolds 1999).

Methu (1998) reported that yields of up to five t/ha of dry maize stover are common in the Kenyan highlands. Abate (1990) reported maize stover yields of 2.2–3.8 t/ha (DM basis) on station. Despite the large volume, dry and mature maize stover with low N and digestible organic matter contents is at best maintenance feed. Dry matter digestibility of maize forage decreases from 65 to 55% in four weeks and protein content from 19 to 10% in 10 weeks (Abate and Lukuyu 1985). Nevertheless, dry stover is of considerable importance during dry seasons when forage of any kind may be in short supply.

7.3 Production of maize stover

The use of maize grain for feed is insignificant in the study area, although few farmers reported its use. The major part of maize used for feed is its stover both as green and dry. Maize stover production for different purposes depends on the farmers' circumstances. About 66% of maize growers produced green maize stover and 89% produced dry maize stover (Table 57).

Table 57. *Per cent of household producing maize stover and average annual maize stover production per household by districts (2001)*

District	Green		Dry		Total	
	Amount (t)	% of producers	Amount (t)	% of producers	Amount (t)	% of producers
Awassa Zuria	0.53	92	0.83	67	1.04	100
Boricha	0.50	88	0.43	75	0.81	94
Alaba	1.82	94	1.15	94	2.98	94
Badawacho	0.90	88	0.84	88	1.74	88
Siraro	2.34	94	4.21	88	5.87	100
Shashemene	1.44	93	2.70	79	3.46	100
Gobu Sayo	0.40	7	1.82	67	1.69	73
Omo Nada	0.80	69	1.56	94	2.15	94
Kersa	0.72	73	1.83	100	2.36	100
Bako Tibe	1.03	33	1.82	100	2.16	100
Debre Elias	2.46	47	0.67	100	0.78	100
Baso Liben	2.98	93	0.75	100	1.03	100
Bure	0.53	27	1.18	87	1.25	93
Mecha	0.19	23	1.27	100	1.31	100
Mean	1.00	66	1.51	89	2.09	95

Ninety five per cent of maize growers produced either of the two stover types or both. On average, farmers produced about 1 t and 1.51 t of green and dry maize stover per year, respectively and this varied among districts. In some districts like Gobu Sayo, Bure, Mecha and Bako Tibe, very few farmers produce green maize stover, which may also be related to the level of green maize harvest. The differences were also observed in terms of green stover harvest between the agricultural potentials. The amount of green maize stover harvested in high agricultural potential area (0.83 t) is significantly lower compared to what is harvested in low agricultural potential (13.1 t). The difference is not high for dry maize stover, which is 1.4 t for high agricultural potential and 1.6 t for low agricultural potential.

On the other hand, in districts like Alaba, Siraro, Shashemene, Badawacho, Boricha and Baso Liben the majority of the farmers produce green maize stover. Average production of green maize stover per household per year ranged from 0.19 t in Mecha to 2.34 t in Siraro. The majority of farmers (>67%) in all districts produced dry maize stover.

Figure 7. *Storage of maize stover around Shashemene.*

Figure 8. *Stubble grazing of a maize field in western Oromia.*

Average dry maize collected and stored by a household is 1508 kg per annum ranging from 0.43 t in Boricha to 4.21 t in Siraro. The total maize stover collected and stored for different purposes is on average 2092 kg per household per year ranging from 0.78 t in Debre Elias to 5.87 t in Siraro. In terms of total maize stover production, southern Oromia and Alaba take the lead, collecting more than 2.9 t/year per household. This is followed by districts in western Oromia, which collect between 1.69 t to 2.36 t/household per year. Districts in Amhara region and Sidama zone produce smaller amount ranging between 0.78 t to 1.31 t, which could also be due to the smaller average land under maize in these areas.

Differences among locations in terms of amount of maize stover produced were significant ($P<0.05$) as indicated in Table 57. If the districts are grouped into some homogenous groups then the difference is pronounced. Southern Oromia produced the highest maize stover (4.75 t), while West Gojam and Sidama produced on average 0.91 t and 0.89 t, respectively. East Gojam produced about 1.25 t which is more than West Gojam (0.91 t), West Oromia (2.12 t) and Hadiya (2.38 t). The analysis shows in general, the existence of high spatial variability in maize stover production.

On the other hand, the variability that exists among agricultural potential and population density is relatively low (Table 58). Green maize stover production ranged from 0.79 t in H_aH_p to 1.53 t in L_aL_p. Similarly dry maize stover harvest ranged from 1.27 in H_aH_p to 2.09 in L_aL_p, leading to the total maize stover production that range from 1.82 t in H_aH_p to 3 t in L_aL_p. The increasing trend from H_aH_p to L_aL_p shows the relative scarcity of feed in L_aL_p forcing farmers to harvest and store all available stover unlike in the high potential areas where there could be other sources of feeds.

Table 58. *Maize stover production per household by agricultural potential and population density*

Agricultural potential and population density	Green		Dry		Total	
	N	Amount (t)	N	Amount (t)	N	Amount (t)
H_aH_p	70	0.79	94	1.36	101	1.82
H_aL_p	24	0.96	37	1.69	40	2.14
L_aH_p	28	1.24	30	1.27	33	2.20
L_aL_p	16	1.53	24	2.09	25	2.99
Average*	138	1.00	185	1.51	199	2.09

* Means are different at 5%.

7.4 Use of maize residues

Not all produced/collected stover is used for livestock feed as there are also other uses of crop residue. The major ones, however, are animal feed and fuel. About 69% of the residue produced is used for livestock feed followed by fuel which consumes about 25% of the residue (Table 59). Sale and construction account for very small amount of crop residue. In the case of animal feed, maize account for about 77% of the total residue fed to the animals and about 99% of the total crop residue used for fuel. Thus, the two major uses of maize stover, animal feed and fuel, account for about 59 and 40% of the maize stover produced by smallholders, respectively. The amount used for sale and construction is less than 1%.

Table 59. *The contribution of maize in crop residue utilization*

Stover use	Total crop residue used (t)	Contribution of maize for each use, %
Feed	322.46	76.6
Construction	167.27	17.5
Fuel	17.62	99.1
Sale/gift	9.72	44.3
Total	517.07	

Maize residue has multiple purposes as indicated in Table 59. However, its use as a livestock feed dominates the other uses including construction and fuel. Maize residues are also used for soil amendment. However, the relative importance of this use was difficult to assess, as this is mostly achieved by incomplete removal. Cobs are normally used as feed. In terms of the feed use, the majority of farmers fed maize residue to milking cows and oxen. As a result, among those farmers who produced green maize stover, 84% fed it to milking cows and about 79% fed it to draught oxen (Table 60). In the case of dry maize stover, 69% of the farmers fed it to milking cows and 65% fed it to draught oxen. Many farmers (69%) also used dry maize residue as firewood indicating the shortage of fire wood in many of these areas. The use of the stover to feed other cattle and small ruminants is very low as less than 20% of those households who produced the residue used to feed small ruminants and other cattle.

Table 60. *Proportion (%) of farmers using maize residue for different purposes*

Purpose	Dry	Green
Feed for milking cows	69	84
Feed for oxen	65	79
Feed for small ruminants	13	17
Feed for other cattle	11	19
Fuel wood	69	–
Construction	6	0
N	175	144

More than two-thirds of the maize stover collected is used for livestock feed. However, it varies from location to location and the variability in the proportion of maize stover use is high ranging from 43% in Kersa to 92% in Boricha (Table 61). In the south including the districts from Oromia, more than 75% of the collected maize is used for livestock feed. In Amhara, on average 61% of the collected maize stover is used for livestock feed ranging from 51% in Bure to 72% in Baso Liben.

The proportion of maize stover used for livestock feed in western Oromia is very low (on average 45%). Multiple linear regression model was used to identify some of the factors that affect the proportional use of maize stover for livestock feed. The description of variables used in the analysis is given in Table 62. The use of maize residue for livestock feed as indicated in Table 63 is influenced by the amount of teff residue produced, amount of maize residue produced, distance to livestock market, distance to input supply shop, population density and oxen ownership.

Figure 9. *Use of green and dry maize stover for livestock feed.*

Table 61. *Average production and proportion of maize stover used as livestock feed by district*

District	Average production (t) per household	Number of farmers	% of stover used for feed
Awassa Zuria	0.938	13	88
Boricha	0.809	15	92
Alaba	4.518	16	79
Badawacho	1.791	13	75
Siraro	5.056	13	90
Shashemene	3.396	14	80
Gobu Sayo	0.675	11	44
Omo Nada	1.231	16	48
Kersa	1.722	15	43
Bako Tibe	1.543	15	44
Debre Elias	0.769	15	55
Baso Liben	1.020	15	72
Bure	1.179	15	51
Mecha	1.160	13	67
Average	1.854	199	68

Distance to livestock market has negative elasticity as expected. As the farmer is nearer to the livestock market by one hour (walking time), the proportion of maize stover used for livestock increases by 3.3%, probably indicating the market value of well-fed animals. On the other hand, distance to input supply shops affect the proportion of maize stover used as livestock feed negatively. As walking distance to input supply shop increase by an hour, the proportion of maize stover used for livestock increases by about 4%. Similarly, the effect of using improved cultivars is negative. The proportion of maize stover used by those farmers who used improved maize cultivars is 6.5% less than those who do not use improved maize cultivars. The effect of these two variables may show that those who have access to input and use improved maize cultivars concentrate more on crop production than livestock management. As a result, they may have more cropland and less livestock, which could lead them to less proportional use of stover. It may also be possible that this effect of using improved cultivars on the proportion of stover used as feed is related to the perception that stover of improved cultivars is less nutritious compared to local varieties. Participatory rural appraisal (PRA) studies in western Oromia and in Sidama and Wolayita found that farmers preferred maize stover for their cattle from their local maize varieties, *Burre* and *Asemera*, respectively to that of their improved maize cultivars (Degu et al. 2006; Hassena et al. 2006). Oxen ownership also affected the proportion of maize stover used for livestock feed, where those farmers who have more oxen tends to use lower proportion of maize stover for feed. As farmers concentrate more on crop production, they may have more oxen than other animals, which will lead to lower number of total livestock. As a result they may use proportionally less maize stover for livestock feed.

Table 62. *Description of sample statistics of variables used in the estimation of maize stover model*

Variables	Mean	Std. Dev.	Min	Max
Proportion of maize stover used for feed (%)	68	22	16	100
Age of household head (years)	47.26	15.45	25	102
Age square of household head (years)	2471	1714	625	10404
Education level of household heads (years of schooling)	1.48	2.46	0	12
Active labour size (15–60 years)	3.46	1.69	1	10
Dependency ratio (dependent/total family size)	0.49	0.52	–5	0.93
Walking distance to input supply shops (hours)	1.35	1.08	0.01	5
Walking distance to livestock market (hours)	1.77	1.06	0.05	5
Per capita maize area (ha)	0.11	0.10	0.01	0.75
Livestock owned (TLU)	5.16	5.43	0.7	50.3
Total maize residue produced (qt)	14.96	22.63	0.44	170.5
Total teff residue produced (qt)	7.84	9.73	0	47.81
Population density (person/km^2)	6.52	5.62	1.66	26.29
If the farmer used improved cultivars (0/1)	0.70	0.46	0	1
If the farmer does not have an ox (0/1)	0.20	0.40	0	1
If the farmer owns one ox (0/1)	0.23	0.42	0	1
If the farmer owns a pair or more oxen (0/1)	0.57	0.50	0	1
If household is in H_aH_p (0/1)	0.52	0.50	0	1
If household is in H_aL_p (0/1)	0.20	0.40	0	1
If household is in L_aH_p (0/1)	0.17	0.38	0	1
If household is in L_aLp (0/1)	0.10	0.31	0	1

Teff straw is the substitute feed for livestock and the model correctly showed that those farmers who produced more teff residue used less proportion of maize residue for livestock feed. As production of teff stover increased by one quintal (100 kg), the proportion of maize stover used for livestock feed decreased by about 0.5%. On the other hand, the elasticity of the amount of maize residue produced is positive showing that those farmers who produce more maize residue use more of it for livestock feed compared to those farmers who produces less maize stover. As the production of maize stover increased by one quintal (100 kg), the proportion of maize stover used for livestock increased by about 0.3%. In areas where population density is high, the use of maize stover for livestock feed increases. As population density increase by one person per km^2, proportion of maize stover used for livestock also increased by 1.1% indicating more intensification of livestock management compared to low population density areas.

Table 63. *Factors affecting the use of proportion of maize stover for livestock feed (OLS estimate)*

Variables		Coefficient	t-value
Constant		98.382	6.37**
Age of household head (years)		–0.752	–1.32
Age square of household head (years)		0.006	1.1
Education level of household heads (years of schooling)		–0.641	–1.0
Dependency ratio (dependent/total family size)		2.819	0.62
Active family size		–0.718	–0.66
Walking distance to input supply shops (hours)		–4.108	2.42**
Walking distance to livestock market (hours)		–3.261	–1.82*
Per capita maize area (ha)		–29.749	–1.58
Livestock owned (TLU)		0.430	1.38
Total maize residue produced (qt)		0.256	3.58***
Total teff residue produced (qt)		–0.475	–2.73***
Population density (person/km^2)		1.143	3.85***
If the farmer used improved cultivars (0/1)		–6.486	–1.95*
Oxen dummy compared to no ox			
If the farmer owns one ox (0/1)		–7.445	–1.54
If the farmer owns a pair or more oxen (0/1)		–9.030	–1.91*
Agricultural potential and population density dummy compared to LL			
If household is in H_aH_p (0/1)		–1.463	–0.28
If household is in H_aL_p (0/1)		–5.039	–0.85
If household is in L_aH_p (0/1)		1.956	0.32
Regression diagnosis			
N	162[a]		
F(20, 141)	5.69***		
R-squared	0.42		
Adj R-squared	0.34		
Root MSE	18.08		

Note: ***,**,* are significant at 1, 5 and 10%, respectively.
a. In the sample, 25 households did not harvest maize stover and 26 households did not own cattle. Data on use of maize stover as livestock feed are missing for these households.

8 Feed marketing in the maize belt of Ethiopia

Feed marketing includes the sale and purchase of different feed types (crop residues, hay, industrial by products, salt and natural pasture). Feed marketing is related to the level of market orientation of the production system. In more market oriented livestock production systems, supplementing own feed with purchased inputs is common. In subsistence oriented production systems, farmers resort to producing all necessary inputs, hence the use of purchased feed is less likely. We found that the number of farmers participating in the feed marketing in the study area is very limited. Their participation is also more geared towards selling feed to generate income than purchasing animal feed.

Figure 10. *Transporting green maize stover to market in Awassa.*

8.1 Demand for livestock feed

Farmers were asked if they had a plan in those years to buy any of the animal feeds. Very small proportions of farmers reported planning to buy animal feeds (Table 64). Despite considering purchase of feed as mitigation strategy by more than 60% of the farmers, the real demand for feed is very low which could be due to unavailability of the feed during the critical feed shortage in the market. Comparing the residues and grasses (pasture and hay), farmers look more for grasses than residues. This is probably because the quality of dry crop residues as feed is very low compared to that of grasses.

In addition to the low demand, the supply in terms of both quantity and quality is also low. The few farmers that wanted to buy animal feed reported that they did not get the required amount. The most important feeds for which not more than a quarter could get the demanded quantity are natural pasture, maize stover and teff straw (Table 64). The quality of these residues are, however, better as more than 50% of the farmers reported to have the required quality. While the industrial by-products are found from markets, the residues are mainly obtained from other farmers. Most of the farmers know the sources of these feeds and the remaining farmers also get information mainly from neighbours (Table 65).

Table 64. *Per cent of farmers demanding to buy different feed types by year*

Type of feed	Year		
	1999	2000	2001
Maize residue	1.8	1.3	1.8
Teff residue	1.3	1.8	3.6
Sorghum residue			0.4
Finger millet residue			0.4
Hay	4.5	4.0	6.3
Bran	3.1	2.7	2.2
Oilseed cake	2.2	1.8	2.7
Pasture*	2.2	1.8	4.0

Note: * Purchase of pasture is renting grass land for limited months.

Table 65. *Sources and availability (quantity and quality) of the feed in the market, per cent of farmers*

Feed type	Obtained		Source		
	Quality demanded	Quantity demanded	Other farmers	District market	Nearest market
Maize residue	50	25	100	–	–
Teff residue	57	25	100	–	–
Sorghum residue	100	–	–	–	100
Finger millet residue	100	100	100	–	–
Hay	77	46	86	7	7
Bran	100	–	40	–	60
Oilseed cake	100	20	33	–	67
Natural pasture	67	22	75	12.5	12.5

There are generally three sources of feed: traders, input supply shops, and other farmers. Traders and input supply shops are sources of industrial by-products and farmers are sources of farm products. The traders are the main source of bran and oilseed cake.

Although many farmers do not buy livestock feed, they have information on prices. The role of development agents and traders as sources of feed price information is low. Farmers might have not participated in the feed market because of a number of reasons. However, the availability of information about the market and prices could be used as an opportunity to strengthen feed marketing.


Figure 11. *Marketing of different crop residues in Shashemene market.*

The major marketing problem cited by farmers (44%) was high prices particularly for natural pasture, bran and hay (Table 66). This could be the reason behind the very low number of farmers purchasing livestock feed. The second factor, also related to the price, is the fluctuation of price particularly for salt and hay and to some extent also for teff residue. Unavailability of the sellers and shortage of supply were cited as problems by about 24% of the farmers.

Table 66. *Major marketing problems for different feed types as reported by purchasers, per cent of farmers*

Feed types	% of purchasers reporting				
	High price	Supply shortage/ feed seller unavailability	Price variation	Lack of transport	No problem
Maize residue	6	3	–	–	–
Teff residue	3	2	3	–	–
Finger millet residue	–	2	–	2	–
Hay	10	8	5	–	–
Bran	10	–	–	–	–
Salt	2	–	6	–	14
Oilseed cake	5	–	–	–	–
Natural pasture	10	10	2	–	–
Total	44	24	16	2	14

8.2 Supply of livestock feed

Only three respondents reported having supplied crop residue to the market in 2001. This confirms the shortage of supply reported by buyers. Moreover, only very small proportion of farmers confirmed the availability of maize stover in the market in different seasons. In the wet season, when it is only green maize stover, about 29% of the farmers reported the availability of maize stover in the market. The figure is very low for harvest (14%) and dry (16%) seasons. This may confirm the sale of green maize stover most commonly than the dry maize stover. Teff straw could be sold throughout the year as it is also used for construction.

8.3 Storage of crop residues

Storage of crop residues is important to utilize the available residue efficiently over the seasons. However, not all farmers store the residue and thus increased feed fluctuation is observed widely. Sorghum stover and wheat straw are some of the residues, which the majority of the farmers (57% for sorghum and 43% for wheat) do not collect for future use. This could be related to the low use of the stovers for animal feed. More than 20% of the farmers also do not collect finger millet, barley and maize residue. Teff is the most stored residue as about 98% of the producers stored it using different storage methods. Both stalking and piling are used for many of the residues stored by farmers. However, stalking is more commonly used for maize, barley and finger millet; and piling is most commonly used for wheat, sorghum and teff residue. Other residues are also piled. Only very few farmers store crop residue under shade (Table 67).

Table 67. *Storage methods used for different types of residue (per cent of farmers using)*

Feed type	Storage methods by importance		N
	Stacking/piling	Under shade	
Maize	80	0	159
Teff	97	2	111
Finger millet	62	14	21
Barley	64	7	14
Wheat	57	0	14
Sorghum	43	0	14
Others	30	10	30

Farmers recognized the loss of residue due to improper storage (Table 68). This is more prevalent for maize, barley and wheat. The average loss for major crops residue ranged from 12% for sorghum to 23% for maize. The perceived loss of *enset* as feed due to storage is 25%. About 40% of the farmers reported storage loss of teff residue of about 14%. For many other crops, the proportion of growers that have recognized storage loss of stover is low.

Table 68. *Farmers' perceptions of feed loss due to storage and level of loss for major crops*

Feed type	Feed loss due to storage		Per cent of loss
	Yes (%)	N	
Maize	80	140	23
Barley	60	10	17
Teff	40	110	14
Sorghum	75	10	12
Enset (false banana)	75	6	25

9 Conclusion and implications

The cultivated area in the maize belt of Ethiopia accounts for 69% of the total land area and grazing land accounts for 10% of the total land, followed by forest/wood lots (9%) and homestead (7%). The proportion of cultivated land is higher in the H_aL_p areas (accounting for 80% of the available land), followed by H_aH_p (accounting for 71%). The average land holding in the study area is about 1.68 ha.

Maize is grown by about 97% of households in the study area, followed by teff (grown by 48%), and sorghum (grown by about 25%). Maize accounts for 47% of the cultivated area, followed by teff (16%). All other crops individually occupied less than 6% of the cropped land. The average area allocated to maize is 0.8 ha/household.

The average maize yield is about 2.11 t/ha. Because of international and national research efforts, there is a wide variety of technological options for maize and maize has received high attention by the extension service. The use of improved technologies particularly hybrids and open pollinated varieties (OPVs) is higher for maize than other crops. The proportion of farmers using improved cultivars increased from about 63% in 1999 to 69% in 2001. The importance of maize in the crop choices of households in the study areas is increasing, perhaps because of both its food and feed value. This implies that the attention given to maize in research and development needs to be strengthened.

In the H_aH_p areas, the local varieties and BH-660 are the most dominant cultivars covering about 35 and 31% of the maize area, respectively. These two cultivars cover almost similar proportion in the L_aL_p areas. In the H_aL_p areas, the hybrid BH-660 alone covers about 41% of maize area followed by the local varieties, which covers about 18%. The local varieties dominate more in the L_aL_p areas covering about 35% of the maize area. In H_aL_p and L_aH_p, Katumani variety covers more than 21% of the maize area.

We find that oxen ownership, active labour force and dependency ratio are statistically significantly and positively associated with the use of improved maize cultivars. In 2001, 60% of maize growers used DAP and about 56% used urea. Amount of livestock sold, education level of the household head, oxen ownership and distance to input supply shops explained commercial fertilizer use on maize statistically significantly. Education level of the household head increases probability of fertilizer use positively. Distance to input supply shop affect adoption of fertilizer negatively. Farmers who own oxen have higher probability of using fertilizer more than those who do not own oxen. Household traction capacity is clearly an important factor for more intensive maize production, as is labour supply. These results suggest that interventions to improve oxen ownership, such as through credit services, could improve maize productivity. Our results also imply that developing input supply centres could reduce transaction cost in procuring fertilizer, thus enhancing adoption of commercial fertilizers for maize production.

Maize yield is explained significantly by maize area, total crop area and fertilizer rate used. While maize area is inversely related with yield, total crop area and use of fertilizer are positively associated with maize yield. These results imply that maize is responsive to fertilizer at the current average rate farmers are applying it, reinforcing the need for more efforts to promote fertilizer for maize production.

Cattle account for about 75% of livestock population in the study area and are owned by about 88% of the households, with an average holding of 4.5 per household. Households reported that every categories of livestock are kept at least for five different purposes. Oxen are predominantly kept for draught power. The major purposes of keeping cows are milk, saving and cash income. Sheep are mainly kept for cash and saving purposes.

About 84.4% of the farmers reported using veterinary services, mostly from the district offices of agriculture (97.3%) but also from private sources (4.7%). Only 15% of farmers used AI, which is provided only by the district offices of agriculture. There was a tendency that more farmers in the H_aH_p areas use AI services compared to the other categories. Only about 1 and 2.2% of farmers reported using watering trough for livestock during the wet and dry seasons, respectively. Livestock are mainly watered in rivers and streams. The use of credit for livestock production is very low. The major purpose of wanting credit among those who sought credit was to purchase livestock (52%), which is an investment. These results imply that the extension service needs to accord better attention to the livestock sector. The demand for credit for livestock is high, implying that credit services with appropriate terms and repayment arrangements could contribute to welfare of livestock keepers.

The major livestock feeds in the study area are natural grazing, own produced crop residues, stubble grazing, and own produced hay. Residues of almost all crops are fed to animals and the use depends on the location and farming system. The most common crop residue used as feed in the study area is maize stover, followed by teff, finger millet and *enset*. Maize residue is fed as green and dry stover, during the growing season, harvest and the dry season. Majority of the farmers use maize residue as feed for milking cows and oxen.

Green maize stover is derived from thinning, leaf stripping, plant tops and entire green plant. Dry maize stover is available after harvest. The use of maize grain for feed is insignificant in the study area, although few farmers reported its use. On average, farmers produced about 1 and 1.51 t of green and dry maize stover per year, respectively. Maize stover is used as feed, fuel and for construction purposes. About 69% of the residue produced is used for livestock feed followed by fuel which accounts for about 25% of the residue. Sale and construction account for very small amount of the crop residue. Cobs are used as fuel. Our results imply that interventions to improve maize as food and feed crop could contribute significantly to the alleviation of feed shortage.

Purchased crop residue and hay, and industrial by-products are rarely used. About 4 and 2% of farmers purchased hay, in the dry and wet seasons, respectively. In general, less than 12% of the livestock owners bought livestock feed of any type in any one season. Farmers participate in the feed market more as sellers than as buyers. Farmers are more likely to buy grasses (pasture and hay) than crop residues. In addition to the low demand, the supply in terms of both quantity and quality is also low. The few farmers that wanted to buy feed reported that they could not get the required amount.

Only one or two of the sample households reported planting improved forage during 1999–2001 period. The major reason for not planting improved forage is lack of awareness as reported by about 76% of the respondents indicating the low promotion activity of this technology. These results imply the need for interventions to develop feed markets and promote improved forage technologies to alleviate the feed shortage problem.

According to farmers, the first quarter, January–March, is the period of severe feed shortage. In the second quarter, April–June, the level of severity reduces slightly because of the short rains. The highest level of feed security (60–80% of farmers reporting) occurs during the grain harvest season, followed by the wet season. Different livestock groups have different level of access to different sources of feed. Cattle are generally given high priority and oxen get the first priority followed by milking cows.

This study points to the multiple roles of maize in the livelihoods of people in the Ethiopian highlands. In spite of these multiple roles, research and development efforts have focused on the importance of grain for food security and have neglected the importance of crop residues as livestock feed, and soil amendments. Since maize accounts for over 50% of the feed supply in the area, improving the availability and feed value of maize stover can enhance the contribution of maize–cattle production to the well-being of farmers and their families. Although farmers use all maize cultivars as animal feed, in general they prefer local maize varieties in terms of feed quality of the stover. Hence, there is need for maize breeders to study the traits of local varieties in order to incorporate them in their breeding programs. Agricultural research aimed at developing improved maize cultivars needs to make explicit consideration for the stover value. Quantitative assessments of the economic loss due to under nutrition of livestock and the trade-offs among the competitive use of maize stover should inform this effort. In addition, attention needs to be given to improved storage of maize stover and its utilization.

Research also needs to investigate the link between maize stover, livestock productivity and farm income. Although initial results indicate that performance of animals is influenced by the feed quality of the stover as determined by cultivar (Fernandez-Rivera and Twumasi-Afriyie 2005) this is a question that requires further investigation, in particular in terms of the potential tradeoffs between use of stover as feed, grain yield and availability of residues for soil amendment. These studies should ultimately address the question on whether grain yield and feed quality of the stover are related to higher incomes per unit of land and how increased maize stover can lead to poverty reduction.

Planting of improved forages can alleviate the problem of feed shortage but only about 24% of the sample farmers were aware of this technology. Extension services need to focus on promoting improved forages as well as on efficient management and utilization of crop residues.

Our results imply that the contributions of maize to the welfare of farmers in the maize–cattle belt could be enhanced if policy, research and extension interventions place maize in a broader agricultural development context.

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