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ICARDA International Center for Agricultural Research in the Dry Areas

Characterization of indigenous breeding strategies of the sheep farming communities of Ethiopia

Solomon Gizaw, Tesfaye Getachew, Zewdu Edea, Tadele Mirkena, Gemeda Duguma, Markos Tibbo, Barbara Rischkowsky, Okeyo Mwai, Tadelle Dessie, Maria Wurzinger, Johann Solkner, and Aynalem Haile

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

BOKU

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A basis for designing community-based breeding programs

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Abbreviations

BOKU	Austrian University of Natural Resource and Applied Sciences
CSA	Central Statistical Authority
ICARDA	International Center for Agricultural Research in the Dry Areas
ILRI	International Livestock Research Institute
SNNPRS	Southern Nations, Nationalities and People’s Regional State

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This working paper is based on the results of collaborative PhD and MSc research projects between the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Livestock Research Institute (ILRI), the Austrian University of Natural Resource and Applied Sciences (BOKU), and Agricultural Research Systems in Ethiopia.

Executive summary

Sheep and goat production account for 40% of the cash income earned by farm households, 19% of the total value of subsistence food derived from all livestock production, and 25% of the total domestic meat consumption in Ethiopia (Hirpa and Abebe 2008). There are an estimated 26 million sheep (CSA 2008) and nine identified breeds in the country (Gizaw et al. 2007). However, sheep production and productivity in the country is low. Productivity is constrained, among other factors, by absence of planned genetic improvement programs. The few breeding programs initiated to improve the indigenous breeds had little or no consideration of farmers' and pastoralists' needs, perceptions, and indigenous practices nor have they involved farmers in the design and implementation of the breeding programs.

Cognizant of these deficits, ICARDA, ILRI, BOKU, and the Agricultural Research Systems in Ethiopia, initiated community-based sheep breeding programs in four regional states of Ethiopia. Two MSc and two PhD research projects were conducted to characterize the production systems and design community-based breeding programs in the project locations. The summary presented here is based on these studies.

This working paper synthesizes and analyzes the characteristics of the indigenous sheep production and breeding strategies and practices of four sheep farming communities located in pastoral (Amibara), sub-alpine sheep-barley (Menz), perennial crop-livestock (Bonga), and cereal-livestock (Horro) production systems. The paper also provides a model framework for characterizing the indigenous sheep production and breeding practices of traditional sheep producers in Ethiopia as a basis for designing suitable community-based breeding programs. Sections 1-3 of the paper present introduction to, objectives and study framework of the ICARDA-ILRI-BOKU research project. Chapters 4 and 5 give highlights, respectively, on sheep breeding strategies and the basis for designing community-based breeding programs in Ethiopia. Section 6.1 analyses indigenous sheep production and breeding strategies and practices of sheep farming communities. The paper closes with a synthesis of approaches to the design of community-based breeding programs including definition of breeding objectives, designing, optimizing and implementing community-based breeding programs in section 6.2.

1. Introduction

Sheep are the second most important species of livestock in Ethiopia. The estimated sheep population is about 26 million head (CSA 2008) and there are nine identified breeds (Gizaw et al. 2007). Livestock production generates between 30 and 35% of the Ethiopian agricultural GDP, 19% of total GDP, and more than 85% of farm cash income (Benin et al. 2006). Sheep and goats account for 40% of the cash income earned by farm households, 19% of the total value of the subsistence food derived from all livestock production, and 25% of total domestic meat consumption (Hirpa and Abebe 2008).

Sheep production and productivity in the country is constrained by feed shortages, diseases, poor infrastructure, lack of market information and technical capacity, and an absence of planned breeding programs and breeding policies. Institutions that are involved in research, extension, and services so far have failed to have a positive influence on traditional sheep husbandry practices. For instance, the carcass weight per slaughtered animal remained at the bottom of the low and unimproved category at about 10 kg, with an average annual off-take rate of approximately 32% for the period 2000 to 2009 (FAO 2010b).

Evidence indicates that breeds and populations that have evolved over the centuries in diverse, stressful, tropical environments have a range of unique adaptive traits (e.g. resistance to diseases, adaptation to heat and solar radiation, tolerance to water scarcity, ability to use low quality feed, etc.). These traits enable them to survive and be productive in harsh environments (Fitzhugh and Bradford 1983; Devendra 1987; Rege 1994; Baker and Gray 2004). Within-breed selection of the adapted indigenous genotypes is a viable and promising strategy for efficient, sustainable, on-farm conservation and use (Simon 1999; Ruane 2000; Olivier et al. 2002; Gizaw et al. 2008), which ensures a contribution to the economy of communities depending on them (Mueller et al. 2002; Mueller 2006).

Formulation of acceptable and viable breeding programs for low-input, traditional, and subsistence production systems requires characterization of the production systems, particularly the indigenous breeding strategies of communities, and include identification of their breeding objectives in a participatory and comprehensive approach.

2. Objectives

This working paper has two objectives:

- Develop a model framework for the characterization of the indigenous sheep production, breeding, management, and marketing strategies of traditional sheep producers in Ethiopia which can form the basis for the design of suitable community-based breeding programs
- Synthesise and document the characteristics of the indigenous breeding strategies of four sheep farming communities in Ethiopia.

3. Study framework

3.1 Study approach

This paper presents a model framework for characterizing the indigenous breeding strategies of sheep farming communities in Ethiopia by synthesizing and analysing two Masters' theses on sheep production systems in four locations in the country. A comparative analysis of the characteristics of the production systems in the four locations is made to reveal variations in the indigenous breeding strategies between communities under different production systems and production environments. Characterization of the indigenous strategies of the communities is presented in the context of sheep breeding strategies in Ethiopia and forms a basis for designing additional community-based sheep breeding strategies. For this purpose, a perspective on sheep breeding strategies in Ethiopia is outlined and two PhD theses on designing community-based breeding programs in the four locations are synthesised. The four theses (two MSc and two PhD) are products of an ICARDA–ILRI–BOKU sheep breeding project in Ethiopia (See Section 3.2).

ICARDA–ILRI–BOKU project

The project was initiated jointly by ICARDA, ILRI, the Austrian University of Natural Resources and Applied Sciences (BOKU), and the Agricultural Research Systems in Ethiopia. The objective was to design community-based sheep breeding strategies for Ethiopia.

The project operates in Afar, Amhara, SNNPRS, and Oromia regional states (Figure 1). The project sites are in Worer, Menz, Bonga, and Horro districts in the respective regional states. The project started by characterizing the production systems of the project areas, which were the MSc studies of Edea (2008) and Getachew (2008). Based on the characteristics of the production systems at the project sites and in-depth PhD studies by Duguma (2011) and Mirkena (2011), community-based breeding programs were designed. Implementation commenced half-way through the project life cycle and was part of the PhD studies.

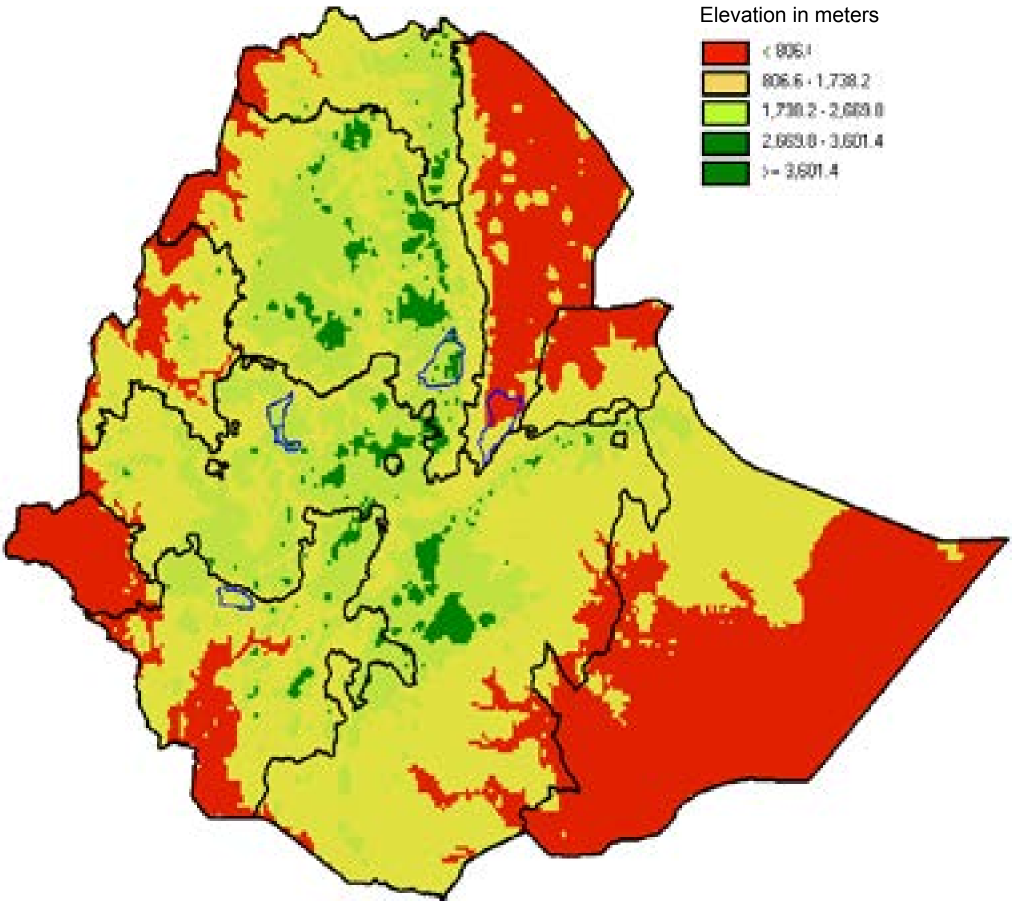

Figure 1. Project sites of the ICARDA–ILRI–BOKU sheep breeding project

4. Sheep breeding strategies in Ethiopia

4.1 Genetic improvement options

The sheep breeding strategies adopted in Ethiopia over the last several decades largely focused on importing exotic breeds for cross-breeding. Several efforts have been made to this end since the early 1960s (Tibbo 2006). These have included importing such exotic sheep breeds as Bleu du Maine, Merino, Rambouillet, Romney, Hampshire, Corriedale, and Awassi. However, these genetic improvement programs produced no significant effects on sheep productivity or on farmers' and pastoralists' livelihoods and the national economy at large.

The major drawback in the livestock cross-breeding programs in Ethiopia has been the lack of a clear and documented breeding and distribution strategy. There has been very little consideration of the needs of the farmers and pastoralists, their perceptions, and indigenous practices. Additionally they have had limited or no participation in the design and implementation of the breeding programs. Further, the breeding programs lacked breeding schemes to sustain cross-breeding at the nucleus centres and at the village level. The distribution of the improved genotypes of these programs was indiscriminate and unplanned, resulting in failure of the breeding programs and threatened to dilute the sheep genetic diversity in the country.

The indigenous livestock and poultry genetic resources of Ethiopia have high within-breed genetic variations (Dessie 2001; Abegaz 2002; Haile 2006; Tibbo 2006; Gizaw 2008; Dana 2011) and desirable characteristics. However, there has been little effort to improve the genetic merits of the local livestock and poultry resources using the within-breed genetic variation. The few sheep selective breeding programs initiated by the Institute of Agricultural Research in the 1980s, which included Afar and Horro sheep breeding programs, were limited to the formation of elite nucleus flocks and the programs have since been ended. There was no distribution scheme in place for the improved genotypes in the nucleus centres.

Currently, selective breeding as a genetic improvement strategy is gaining momentum. There are breeding programs underway for Menz, Horro, Bonga, Washera, and Afar sheep and for local chickens. Furthermore, a number of studies have been conducted to design suitable breeding schemes for implementing selective breeding in smallholder farming systems in Ethiopia (Wurzinger 2008; Gizaw and Getachew 2009; Gizaw et al. 2009; Duguma 2011; Gizaw et al. 2011a; Haile 2011; Mirkena 2011).

4.2 Selective breeding schemes

Conventional hierarchical breeding schemes

The design of selective breeding schemes is a major determinant of the success of breeding programs in smallholder livestock production systems. Designing a suitable breeding scheme for smallholder livestock production systems has remained a challenge hitherto. Until recently, livestock breeding programs in Ethiopia had adopted exclusively the conventional hierarchical breeding schemes. All the cross-breeding programs and the earlier Afar and Horro sheep breeding programs (see Section 4.1) were hierarchically structured. Cross-breeding programs inherently require a hierarchical structure as the improver breed needs to be imported, maintained, and multiplied at nucleus centres. However, livestock selection programs could be designed with a hierarchical structure involving two or three tiers or with only a single tier combining the breeding and production activities together.

The conventional hierarchical breeding schemes have several drawbacks (Gizaw and Getachew 2009). The major shortcoming is that they do not address fully the farmers' preferences under low-input systems (Gizaw et al. 2011a). The conventional approaches also fail to consider the different intangible, socio-economic, and cultural roles that livestock play in each situation. This usually leads to the wrong breeding objectives (Kosgey 2004). As a result, most conventional breeding programs have failed. Kosgey et al. (2006) cite the absence of any distribution of the improved genotype to farmers' flocks and inappropriate selection objectives for the failure of D'man sheep breed improvement in Morocco. Insufficient involvement of the farmers and the shortage of financial and logistical resources for sustaining the Peul, Touabire, and Djallonké sheep breeding program in Senegal are additional reasons for the lack of success.

The major advantage of the hierarchical breeding schemes is that they yield faster genetic progress as genetic improvement is carried out in a controlled environment at nucleus centres with advanced selection tools. These selection tools include selection on the basis of the best linear unbiased prediction (BLUP) of the breeding values of the selected candidates. In order for hierarchical programs to be successful, they need to accommodate breeding objectives and have a design based on the indigenous breeding strategies of the farmers and pastoralists. Attempts have been made to design breeding schemes to transform the conventional nucleus breeding approach into a sustainable participatory breeding scheme (Mueller 2006; Gizaw et al. 2011a; Haile et al. 2011).

Community-based breeding schemes

Failure of the conventional hierarchical breeding schemes has led to community-based breeding schemes being suggested as viable options for the genetic improvement programs of small ruminants in low-input, smallholder production systems (Sölkner et al. 1998; Kahi et al. 2005; Kosgey and Okeyo 2007; Gizaw and Getachew 2009). Some success stories of community-based breeding programs have been reported. These include. the significant involvement of a women's group in Northern Togo, involvement of farmers in the selection and control of inbreeding in south and Southeast Asia, and use of the indigenous Tzotzil selection criteria in southern Mexico (Perezgrovas 1995; Kosgey et al. 2006; Castro-Gámez et al. 2008).

A community-based breeding program refers to village-based breeding activities planned, designed, and implemented by smallholder farmers, individually or cooperatively, to effect genetic improvement in their flocks and conserve indigenous genetic resources. The process could be facilitated, coordinated, and assisted by outsiders (development and research experts in governmental and non-governmental organizations). Unlike the conventional top–down approach, community-based breeding strategies basically need a detailed understanding of the community's indigenous knowledge of farm animals regarding breeding practices and breeding objectives. The community-based breeding strategies also consider the production system holistically and involve the local community at every stage, from planning to operation of the breeding program (Baker and Gray 2004; Sölkner-Rollefson 2003). The breeding structure of such a program is commonly single-tiered with no distinction between the breeding and production tiers, i.e., the farmers and pastoralists are both breeders and producers.

Community-based breeding programs have recently been initiated in Ethiopia by research institutes. The current research concerned with community-based breeding programs is designing suitable breeding schemes that enable communities to implement breed improvement activities under uncontrolled village breeding practice. This includes procedures for the selection and use of superior breeding stock and prediction of genetic progress under village conditions. Currently a variety of village-based cooperative breeding schemes are used (Table 1). The most genetically efficient and operationally feasible scheme needs to be adopted.

Table 1. Characteristics of village-based breeding schemes and their feasibility under village conditions in Ethiopia

Breeding scheme	Description	Applicability/feasibility
Within flock selection (Croston and Pollot 1994)	• Program designed based on individual sheep/goat herders • Recording and selection takes place within each sheep/goat herder's flock • The sheep/goat herders produce breeding nucleus animals • Provide improved stocks to producers who do not practice selection • The scheme can operate with sheep/goat keepers having at least 150 breeding females	• Suitable for areas with large flocks and individual grazing • Requires that producer farmers and pastoralists appreciate genetic improvement and are willing to pay for breeding animals with higher genetic merit • Buying breeding stocks from breeders may not be feasible for poor farmers • Returns on investment for the breeder farmers may not be attractive
Ram circles (Croston and Pollot 1994)	• Farmers organize themselves into ram circles • Each year they use a significant proportion of the young males selected from their group • Breeding males are moved from farm to farm on a daily basis • Breeding males are evaluated based on the performance of their progeny in each participating farm	• High accuracy of selection is achieved • Operationally very DIFFICULT
Two tier cooperative scheme (Croston and Pollot 1994)	• The scheme involves cooperation among farmers • They form a nucleus flock by contributing their best females • Recording and selection takes place only in the nucleus • The nucleus produces replacement rams for the cooperating flocks	• Suitable for smallholder mixed crop–livestock systems with communal grazing • Operationally difficult • Requires land and barns and separate herding for the nucleus flock • Extra maintenance costs of the nucleus flock
Dispersed nucleus scheme (Mueller and James 1984)	• The scheme involves cooperation among farmers • Top females are identified within each member's flock • These females are mated to selected males • Male progeny are retained for evaluation and eventual replacement	• Requires hand mating of the best males and females in each flock • Nucleus flock has to be herded separately from the other flocks • Operationally not easy

Breeding scheme	Description	Applicability/feasibility
One tier cooperative scheme (Rodríguez and Quispe 2007; Gizaw et al. 2009; Haile et al. 2011)	• The scheme involves cooperation among farmers • In a one tier structure, no nucleus flock is established • All young males of the cooperating flocks are recorded • Breeding males are selected from among the young males born in the flocks of the cooperating farmers • Males can be evaluated within the cooperating flocks or maintained and evaluated in a separate place before being re-distributed among the farmers	• Suitable for smallholder mixed crop–livestock system with communal grazing systems • Suits the existing breeding structures in most parts of Ethiopia, particularly in mixed crop–livestock production systems • Extra cost of recording of the base flocks

Source: Gizaw et al. (2011b).

5. The basis for designing community-based breeding

The bases for designing community-based breeding programs are the farmers' and pastoralists' indigenous breeding strategies and the resultant mode of livestock production. Farmers' and pastoralists' strategies arise from their indigenous knowledge of animal breeding and management. Farmers' and pastoralists' strategies are expressed in their indigenous breeding and management practices, breeding/production objectives, and marketing strategies. The indigenous strategies of the farmers and pastoralists take into account the production environment, long-standing tradition of livestock production practices, management skills, socio-economic and cultural factors, and the availability of inputs and services.

The mode of livestock production practised by a farming community has a direct bearing on the design of livestock development strategies. Thus, the production system in a target area needs to be characterized and understood in order to design a suitable breeding program. Community-based sheep breeding requires a full description of the existing environment, the current level of productivity, breeding objectives, and the selection criteria of sheepherders, available indigenous knowledge and breeding practices, and the full participation from the beginning of the farmers and pastoralists (Sölkner et al. 1998; Kosgey et al. 2006). The approach to designing breeding programs should attempt to fit new breeding strategies into the indigenous breeding strategies of the target farmers and pastoralists, rather than forcing exotic methods and products as is the case with the conventional top–down design of breeding programs (See Section 4.2).

Sheep production in Ethiopia is generally of a subsistence nature. Sheep are reared in extensive systems with no or minimal inputs; they are kept virtually as scavengers, particularly in mixed crop–livestock systems. Extensive systems of production share common characteristics, such as small flock sizes, communally shared grazing, uncontrolled mating, absence of recording, low productivity per animal, relatively limited use of improved technology, and use of on-farm by-products rather than purchased inputs. Market-oriented or commercial production is almost non-existent. Livestock production systems in Ethiopia are crudely classified into mixed crop–livestock, pastoral, and agro-pastoral systems based on the contribution of livestock to the total household revenue, the type and level of crop agriculture, the type of livestock species, and the extent and length of movement. However, there are diverse production systems with diverse breeding, production, and marketing objectives and strategies among groups of farmers (Gizaw et al. 2011a). A summary of the characteristics of the major sheep production systems in Ethiopia and the types of sheep reared is described in Gizaw (2008).

6. A model framework

6.1 Characterization of the breeding strategies of four communities in Ethiopia

The characterizations of the breeding strategies of four sheep farming communities in four ICARDA–ILRI–BOKU project sites (See Section 3.2) are presented as a model approach for determining farmers' and pastoralists' indigenous breeding strategies in Ethiopia. The general characteristics of the four sites are presented in Table 2. A sample of 108 households in Worer, 120 in Menz, 114 in Bonga, and 115 in Horro were interviewed using structured questionnaires to characterize the production systems. A sample of 804 animals in Worer, 1242 in Menz, 795 in Bonga, and 802 in Horro were measured to characterize the sheep breeds.

Table 2. General characteristics of the project areas

Woreda	Altitude (m)	Rainfall (mm)	Production system	Crop production	Sheep (% of total)	Sheep breeds
Worer	750 – 812	588	Pastoral		23.9%	Afar
Menz	> 2800	900	Subalpine sheep–barley	Cereals; low potential	84.8%	Menz
Bonga	1800 – 2835		Perennial crop–livestock	93% perennial crops; high potential	21.9%	Bonga
Horro			Cereal crop–livestock	Cereals; high potential	20.1%	Horro

Characteristics of the communities

Understanding the characteristics of the target community has relevance to the success of the genetic improvement programs and to adoption of improved technologies in general. Characterization of a community includes understanding the culture and traditions, economic circumstances as well as demographic characteristics– age and sex structure, education level, and labour profile. The level of literacy is of particular importance. The majority of the pastoralists in the Afar community (97.2%) have been found to be illiterate. In Menz 33.3% of household heads are illiterate, in Bonga 22.8%, and in Horro 19.1%. Improving the educational background of the farmers and pastoralists participating in genetic improvement enhances the success of breeding programs which depend heavily on record keeping.

Understanding the labour profile also has a bearing on the success of breeding programs. Women are less frequently involved in activities related to breeding management (selection, castration, culling, and mating) in Bonga (9%) as compared to their counterparts in Horro (47.3%). In Bonga, it is a cultural taboo for women to be involved in mating or breeding activities.

Agricultural production strategies

The farmers' and pastoralists' production strategy is expressed in their choice of alternative agricultural enterprises and the level of management and resources (such as land and inputs) they allocate to the different enterprises in mixed crop–livestock systems. It is, therefore, important to understand the relative contributions of the alternative agricultural enterprises to the household economies in order to design successful genetic improvement programs.

The relative contributions of agricultural enterprises to farm revenues are presented in Table 3. For communities in the subalpine sheep–barley and pastoral production systems, livestock production is the major or sole contributor to the families' cash incomes. Similarly, of the 114 farmers interviewed in Bonga and the 115 interviewed in Horro, 93.9% and 74.8% reported livestock as their main source of income. Livestock production is commonly a side-line in most mixed crop–livestock production systems, particularly in high potential crop areas such as perennial crop–livestock systems. Livestock holdings in such situations are small indicating the focus given to livestock production. This is in contrast to the situation in the subalpine areas. Crop production is unreliable in the subalpine, Menz region where rainfall is unreliable and frost is a common problem. Livestock production in such areas is a major source of food security. Furthermore, surveys show that Menz farmers devote a quarter of their land to grazing (Getachew 2008). The contribution of livestock as a source of family food also determines the farmers' and pastoralists' choice of enterprises. Livestock production is the major source of food for the pastoralist and contributes to family food in the other production systems. The contribution of livestock production to the diets of pastoralists is also documented for Ethiopian Somali pastoralists (Gizaw 2008).

Table 3. Importance of major farming activities as a source of family income in four agricultural production systems in Ethiopia

Farm activity	Rank indexes of farm activities by production systems			
	Subalpine sheep–barley	Pastoral	Perennial crop–livestock	Cereal–livestock
Sheep	0.63	0.20	0.45	0.45
Cattle	0.29	0.24	0.35	0.34
Crop	0.08			
Goat		0.37	0.04	0.05
Camel		0.15		
Chicken		0.06		0.06
Horse		0.08		0.09
Mule		0.02		0.0

Index = [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for each species of each production system]/[(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for all species for a production system].

The importance of sheep production among the other livestock enterprises is shown in Table 4. Sheep production is the most important livestock farming activity in all systems except for the Afar pastoralists, where goat production is the major activity. The highest contribution to family food and the income of smallholders and pastoralists in the Menz area is made by sheep. Goats, cattle and sheep make the highest contributions in the Afar area. These two different emphases indicate the production strategies of the communities. Improvement strategies need to focus on these enterprises rather than on crop production.

Table 4. Relative importance of livestock enterprises as a source of income in mixed crop–livestock and pastoral systems

Species	Rank index of species by production system			
	Subalpine sheep–barley	Pastoral	Perennial crop–livestock	Cereal–livestock
Sheep	0.63	0.20	0.45	0.45
Cattle	0.29	0.24	0.35	0.34
Goat		0.37	0.04	0.05
Camel		0.15		
Chicken	NA	NA	0.06	0.06
Horse	NA	NA	0.08	0.09
Mule	NA	NA	0.02	0

Sheep production and breeding objectives

Sheep production objectives

Finding out the production objectives for sheep of the farmers and pastoralists gives an indication of their breeding objectives. Defining the production objectives identifies the tangible and intangible uses of the sheep breeds reared by a community. The uses are equivalent to 'gross trait categories' which form the basis for identifying specific breeding objective traits.

Table 5 presents the sheep production objectives of farmers and pastoralists in the mixed crop–livestock and pastoral systems. The results show that sheep play multi-functional roles in all production systems and that the reasons for keeping sheep are rational and related to the farmers' and pastoralists' needs in the long- or short-term. The particular importance of multiple varieties of indigenous livestock breeds in low-input traditional systems has been widely established in Ethiopia (Mekoya 1999; Wuletaw et al. 2006; Gizaw et al. 2010) and elsewhere (Kosgey 2004; Mwacharo and Drucker 2005; Wurzinger et al. 2006).

Table 5. Ranking of the sheep production objectives by smallholder farmers and pastoralists

Production objectives	Rank index of sheep production objectives by production system			
	Subalpine sheep–barley	Pastoral	Perennial crop–livestock	Cereal–livestock
Meat	0.63	0.24	0.179	0.109
Hair	0.29	–		
Religious				
Ceremony	–	0.01	0.010	0.007
Wealth	–	0.05		
Skin		0.01		
Manure			0.003	0.077
Saving			0.030	0.088
Income		0.23	0.776	0.718
Milk		0.45		

Index = [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for each objective]/[(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for all purposes of keeping sheep in a production system].

There are differences in the production objectives of farmers and pastoralists in the four production systems. The primary sheep production objectives of smallholder farmers in mixed crop–livestock systems are as regular sources of income, meat, and manure. However, the Afar pastoralists primarily keep sheep for their milk followed by their meat and for income generation.

Breeding objectives

Knowledge of the reasons for keeping animals is a prerequisite for deriving operational breeding goals (Jaitner et al. 2001). Based on the reasons for keeping sheep, the breeding goals of farmers and pastoralists can be defined. The main breeding goal of farmers in the subalpine sheep–barley system for Menz sheep is to improve their market value through increased meat production (improved growth rates and conformation). The same is true for farmers in the perennial crop–livestock system for the Bonga breed and for farmers in the cereal–livestock system for the Horro breed. The breeding goals of the Afar pastoralists are to increase milk yield and meat production.

The specific breeding objective traits can be deduced from the farmers' and pastoralists' selection criteria gathered through the interviews conducted in these studies. The breeding objective traits are presented in Table 6.

Table 6. Community breeding objective traits for the Menz, Bonga, Horro, and Afar sheep breeds

Breeding objective traits for sheep breeds	Rank indexes of breeding objective traits			
	Menz	Bonga	Horro	Afar
Breeding rams				
Appearance/conformation/size	0.290	0.349	0.412	0.350
Colour	0.200	0.282	0.216	0.150
Horn	0.030	0.009	0.007	0.006
Ear	0.020			0.005
Growth rate	0.240	0.052	0.014	0.170
Fleece yield	0.004			
Mating ability	0.040	0.027	0.002	0.110
Tail size and shape	0.180	0.273	0.280	0.210
Temperament		0.005	0.002	
Breeding ewes				
Appearance/size	0.080	0.279	0.403	0.150
Coat colour	0.120	0.238	0.233	0.100
Mothering ability	0.220	0.075	0.046	0.160
Age at first lambing	0.030	0.020	0.101	0.030
Lambing interval	0.310	0.076	0.006	0.120
Twining	0.160	0.124	0.024	0.090

Breeding objective traits for sheep breeds	Rank indexes of breeding objective traits			
	Menz	Bonga	Horro	Afar
Tail size and type	0.050	0.137	0.089	0.090
Milk yield for family				0.220
Ear size	0.010			0.000
Longevity	0.020	0.003	0.0	0.040

Index = [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for each selection criteria]/[(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for all selection criteria for a production system].

Source: Adapted from Getachew (2008) and Edea (2008).

Breeding management

Controlled breeding activities are the basis for designing genetic improvement programs. The primary purpose of characterizing farmers' and pastoralists' breeding management practices is to assess the possibility of introducing controlled breeding activities under existing traditional practices. Breeding activities that influence implementation of controlled breeding activities include the size, structure, and ownership patterns of the flocks, the herding practices, and breeding ram ownership and use patterns.

Flock characteristics

Flock sizes reflect a community's sheep production strategies. Large flock sizes usually indicate extensive sheep breeding and production of a large number of lambs for sale. The strategy is based largely on the sale of non-fattened yearling lambs because of the high dependence on sheep production for food security (Gizaw et al. 2010). Communities practicing such production are rich in indigenous breeding knowledge and are more likely to participate in genetic improvement programs. The large flock sizes in the subalpine sheep–barley and pastoral systems characterize the extensive mode of production described above, whereas the strategy in high potential cropping areas (particularly in Bonga) is maintenance of small flocks and production of lambs for fattening (Table 7).

Table 7. Flock size and structure

Class of animal	Mean flock size and size of each age class as proportion of the total flock							
	Subalpine sheep–barley system		Perennial crop–livestock system		Cereal–livestock system		Pastoral system	
	Mean ± SD	%	Mean ± SD	%	Mean ± SD	%	Mean ± SD	%
Over all	31.4 ± 15.1		11. 3 ±1.3		8.2 ± 2.1		23.0 ± 16.5	
Lambs	6.3 ± 4.2	19.9	4.0 ± 1.6	35.8	1.9 ±1.3	23.5	5.4 ± 4.7	23.6
Ram lambs†	3.0 ± 2.0	9.5	2.3 ± 1.6	20.1	1.8 ±1.9	20.0	1.2 ± 0.9	5.4
Ewe lambs	4.5 ± 2.8	14.2					4.2 ± 4.00	18.1
Rams	1.8 ± 1.2	5.6	0.6 ± 1.5	5.8	0.3 ± 0.8	3.6	0.6 ± 0.8	2.8
Ewes	14.7 ± 8.6	46.8	3.7 ± 2.7	32	3.9 ± 2.8	48.1	11.3 ± 7.8	49.2
Castrates	1.2 ± 1.3	3.9	0.7 ± 1.7	5.9	0.2 ± 0.9	2.9	0.2 ± 0.6	0.8

† The flock size for 'ram lambs' in Bonga and Horro includes both ram and ewe lambs.

Similarly, flock structures reflect production objectives and breeding practices. For instance, the maintenance of castrates and a larger number of intact males (particularly in Menz) is related to the objective of meat production. Wilson (1986) noted that the higher proportion of males in the traditional systems indicates the objectives of wool, hair, or meat production. The lower proportion of ram lambs in Menz compared to other locations in the crop–livestock system indicates the tradition of marketing young ram lambs because of the greater dependence on sheep production.

The study of flock characteristics helps in the design of tailor-made breeding programs. Unbalanced flock structures and small flock sizes hinder genetic improvement activities. For instance, the practice of maintaining limited numbers of breeding ewes (e.g. Bonga and Horro) results in a small number of lambs being produced (selection candidates) thus limiting the effectiveness of selective breeding because of the low selection intensity. Another traditional practice, which is a challenge to the effectiveness of selective breeding at the village level, is maintaining multiple breeding rams, including those rams that need to be culled because of their inferior genetic merits (e.g. Menz area). Flock characteristics should be addressed in the design of genetic improvement programs. Farmers and pastoralists have their own indigenous breeding strategies when adopting a given flock size and structure. Thus, the approach should be to design breeding programs that suit their strategies and practices and which do not impose an exotic practice in an attempt to introduce exotic breeding strategies.

Flock ownership patterns and the traditional exchange of animals between flocks should also be considered when designing breeding programs. Multiple ownership of a flock and the movement of animals between flocks affect the decisions regarding breeding management. Multiple ownerships are common in traditional communities and there are several arrangements between farmers in this regard (see Edea 2008). In Bonga, 31.8% of the flocks are owned by one person, 37.7% by two, 20.2% by three, and 13.2% by four or more. Similar patterns are observed in Horro (23.6, 44.1, 28.3, and 20.5%) and Menz (48.9, 45.27, 4.73, and 1.12%) (Mekoya 1999). The exchange of animals between farmers is more common in Bonga, accounting for 1.4% of flock entries and 2.1% of flock exits.

Herding practices

The flock herding and grazing strategies of farmers and pastoralists reflect their breeding management and have serious implications for the design of controlled breeding activities. The farmers' and pastoralists' herding practices in all the study sites follow seasonal patterns (Table 8). The data show that there are seasons when the flocks within a village are herded together for free grazing. Although individual flocks are herded by their own shepherds in some communities (e.g., Menz), there is a possibility of mixing, as reported by 82% of Menz farmers. However, there is less chance of mixing between the flocks of different villages. Tethering is a commendable practice for controlling breeding activity (e.g. Bonga area), but it can only be adopted in areas with very small breeding flocks as tethering is labour intensive.

Table 8. Herd management

Herding practice by season	Respondents (%)			
	Subalpine sheep–barley system	Cereal–livestock system	Perennial crop–livestock system	Pastoral system
Rainy season				
Separate herding		62.6	10.5	
Mixed herding/free grazing	62.5		2.6	64.8
Tethering		5.3	53.5	
Dry season after crop harvest				
Separate herding	11.8 – 14.7	12.1	21.9	
Mixed herding/free grazing	81.7	37.4 – 50.5	43.9	33.6
Tethering		0.9	1.8	

Ranging for feed and water was practised by all the transhumant pastoralists interviewed in Afar. The time when ranging can occur, the place to be grazed, and which species of livestock are to move are determined by tribal leaders after careful assessment of the new area. Pastoralists that settle in a village are usually relatives and they move and settle together at the new place.

Although mixed herding poses a problem for implementing breeding programs designed on the basis of controlled mating practices, it has its own advantages as it allows communal use of rams. Farmers without rams benefit from the communal use of breeding rams. This communal use of breeding rams also helps minimize the unavoidable inbreeding in the small individual flocks of smallholders. Furthermore, mixed herding practices can be exploited to increase selection intensity in village breeding programs. Studies on the details of the movements and flock herding strategies and practices are of utmost importance for designing community-based breeding programs.

Ram utilization practices

Indigenous breeding ram utilization practices, including ownership patterns, reasons for keeping rams, and ram management, need to be described in order to design suitable community-based breeding programs. This is because ram use practices significantly affect the implementation of controlled breeding activities. The use patterns of breeding rams in the study areas are presented in Table 9.

Table 9. Breeding ram ownership and use by production system

	Proportion (%)			
	Subalpine sheep–barley	Cereal–livestock	Perennial crop–livestock	Pastoral system
Breeding ram ownership				
Farmers having no ram	20.6			51.7
Farmers having own ram		29.6	56.3	
Farmers having one ram	17.6			36.7
Farmers having two or more rams	61.8			11.6
Source of breeding rams				
Rams born on-farm	90.0	75.8	84.2	100.0
Rams brought in	7.1	24.2	15.8	
Purpose of keeping rams				
Farmers keeping for breeding only	24.1			49.0
Farmers keeping for breeding and fattening	65.5			33
Farmers keeping for breeding and socio-cultural reasons	3.5			7.0
Farmers keeping for breeding, fattening and socio-cultural reasons	6.9			11.0

Ram use and breeding is generally uncontrolled in most traditional production systems. However, there are some indigenous practices for controlling breeding and it is important to build upon them. For instance, the Afar sheep owners exercise some control over breeding by avoiding close sire-daughter mating (4.6% of pastoralists interviewed), indiscriminate mating (11.1%), and dry season lambing (86%). Methods like ram isolation, castration, and tying a cord around the neck of the scrotum are used to control mating in the Afar area. An apron made of skin, tied in front of the genitals, as practised by Maasaitribes in Kenya, could improve the latter practice (Getachew et al. 2010).

Despite the absence of controlled mating practices, 62.5% of the Menz farmers and 77.4% of the pastoralists claim that they are able to identify the sire of a new born lamb by comparing the lamb with the colour and conformation of the rams in the flock. However, such methods of pedigree recording are rather unreliable. Farmers (68%) and pastoralists (89%) are also not aware of the adverse effects of inbreeding.

Removing unwanted rams, making rams available, and managing them appropriately determines the genetic progress of the breeding programs. There are encouraging indigenous practices to this end. For instance, the majority of Menz (96.7%), Afar (97.2%), Bonga (98.2%), and Horro (58%) sheep owners practice castration. However, the purpose of castration could be either to improve fattening or to avoid unnecessary mating or both. Management of breeding rams also varies among groups of farmers and pastoralists. Another important aspect of ram use that needs to be described is the length of time that the ram is available for use in a flock and/or the age at castration. This could serve as a basis for designing breeding programs, specifically in determining the frequency of breeding stock replacement, which determines the rate of genetic progress.

Genetic improvement strategies

Choice of breeds

It is important to understand the indigenous genetic improvement strategies of communities, as the success of new breeding strategies depends on the communities' preferences. The primary focus in this regard is farmers' and pastoralists' choice of breeds. Traditional farming communities commonly prefer to keep their own traditional breeds to meet their multiple breeding objectives. However, farmers' and pastoralists' preferences are usually influenced by market forces to adopt cross-breeding. Besides, farmers' and pastoralists' preferences for breeds are influenced by their perceptions of their breeds and previous genetic improvement projects in the area. Positive evaluation of traditional breeds by their owners creates a favourable ground for introducing selective breeding programs (see subsection on characterization of breed resources below). In contrast, the existence of cross-breeding projects has a negative effect. For instance, 93% of the farmers interviewed in the Menz region expressed their preference for Awassi sheep, which were introduced into the area by the Awassi sheep cross-breeding project. Maintenance and improvement of the indigenous breeds through selective breeding in such situations is challenging.

Traditional selection practices

Selective breeding is a long-standing genetic improvement practice among most communities. Identifying the indigenous, selective breeding practices of farmers and pastoralists facilitates introduction of modern breeding methods. It is more feasible to improve the traditional selection practice than introduce a completely novel approach. Selective breeding has been a long-standing practice of farmers and pastoralists. For instance, between 79.7 and 94.7% of the farmers in Bonga and Horro, 90% of the Menz farmers, and 80% of the Afar pastoralists practice selection.

Selection practices, including selection criteria used in villages, and the selection age of replacement rams and ewes need to be described. For instance, in Bonga males are selected at 7.5 ± 3.0 months, while in Bonga they are 4.39 ± 2.2 months. Comparable ages for females were Bonga 7.4 ±3.01 months and Horro 4.5 ± 1.9 months. The mean (standard deviation) of the age at selection for rams in Menz was 9.9 (0.46) months and in Afar was 7.5 (0.47) months. The selection criteria used by the farmers and pastoralists are presented in Table 5.

Characterization of breed resources

Two important aspects of characterizing breed resources maintained by a target community are eliciting the community's perceptions of their sheep and describing the sheep population (breed type, adaptive features, and production traits). This is so that the community's preferences are accommodated and the desirable characteristics of the indigenous breeds are maintained when designing genetic improvement programs.

Determining the community's perceptions involves listing what they like and what they do not like about their breed(s). For instance Menz farmers listed the following as the positive aspects of their sheep compared to the Afar, Wollo, and Awassi-Menz crossbred sheep they are aware of:

- Delectable meat
- Disease tolerance

- Ability to thrive under feed shortages and cold climates
- Presence of horns
- Shorter lambing interval
- Denser fleece.

The downside of Menz sheep according to Menz farmers include

- Small size
- Slow growth rate
- Short tail
- Short ear.

Similarly, Afar sheep owners believe that their breed is the best because of its larger fat tail, good appearance, and tolerance to water shortage. The morphological characters and performance and adaptive characteristics of Menz, Afar, Horro, and Bonga sheep are presented in Appendices 1–5.

The production environment and management practices

Livestock genetic improvement programs should incorporate improvements in the production environment and the traditional management practices. Characterization of the production environment consists of a description of the climatic conditions, feed resources, prevalence of diseases, input levels, and constraints to increases in productivity. Characterization of the management practices requires describing the community's indigenous coping strategies and management practices. The purpose is to ensure that the environment supports new genotypes resulting from genetic improvement activities.

Feed resources and feeding practices

The major feed resource in the Bonga, Afar, and Menz areas is natural pasture lands. Fallow lands are the major grazing resources in Horro, during both dry and the wet seasons. Almost all farmers and pastoralists reported that they faced feed shortages during the dry seasons. In Menz, the strategies for coping with feed shortages included provision of on-farm produced supplementary feeds (38.6% of farmers), purchased feeds (6.7% of farmers), irrigation of private grazing lands (8% of farmers), and reduction of flock sizes (7.2% of farmers). Most of the farmers in Bonga (97%) and Horro (86.8%) provide supplementary feed for their sheep during the dry season. For pastoralists in the Afar area, flock mobility is the main coping mechanism in addition to supplementing the feed with the leaves and seeds of trees, mainly A*cacia* spp. and *Prosopis juliflora* during times of feed shortage.

New strategies to improve feed resources include improving the use of available crop residues, hay making, and forage development by allotting part of the cropping lands for these purposes or during periods when the crop lands remain ideal. For the Afar area, containing the expansion of *invasive Prosopis juliflora* in the grazing areas is a priority strategy. Pods of *Prosopis juliflora* could make up to 20% of the rations and can be used as a concentrated supplement.

Diseases and control practices

Major diseases and parasites and their relative importance according to farmers' and pastoralists' rankings in the Menz, Afar, Bonga, and Horro areas are presented in Table 10. Farmers and pastoralists possess long-standing, and in some cases, proven traditional medical practices. However, the current studies identified some unproven and probably harmful practices, such as dipping sheep affected with coenurosis in the river in the Menz area. Most of the farmers and pastoralists use modern drugs to treat sick animals. However, there is a concern about the use of drugs from illegal open markets and the improper use of medications. Yet, legal veterinary services are not available to 91.2% of the Bonga farmers. Instead, they have to travel 25 km to the nearest veterinary clinic. Therefore, breeding programs need to consider the delivery of proper and cost effective disease control strategies, the training of livestock keepers, and the strengthening of veterinary services. Community–based, animal health worker programs could be an option.

Table 10. Ranking of sheep diseases by communities

Local name*	Common name	Ranking of diseases by location			
		Afar	Menz	Bonga	Horro
			2		
Sal	Lung worm		5	4	1
	Liver fluke	1			2
Nitosh/Engib/wozwuz	Pasteurellosis	3	1	1	
	Skin diseases	2			
Fentata	Sheep pox		4		
Baryawz	Coenurosis		3	2	3
Dengetegna	Sudden death		7		
Kezen	Diarrhea		6	3	
Yesanba mich	Pneumonia		6		
	External parasite		7		
	Difficult urination		6		

*Local names are for the Menz area only.

Constraints to improved productivity

Good understanding of the relative importance of the different constraints is fundamental for initiating any genetic improvement program. The major constraints to improving sheep productivity, according to farmers' and pastoralists' rankings, are presented in Table 11.

Table 11. Ranking of sheep production constraints by farmers and pastoralists

Constraints	Ranking of constraints by production system			
	Pastoral	Subalpine sheep–barley	Perennial crop–livestock	Cereal–livestock
Genotype	5	4	8	6
Feed shortage	1	1	4	2
Water shortage	3	6	8	8
Disease	2	2	1	1
Market	6	5	5	7
Predator	4	6	3	3
Labour shortage	6	5	2	5
Money	5	3	6	0
Drought			8	4
Lack of education			8	10
Theft			7	9

Marketing strategies

Breeding programs need to adopt a value chain approach. The success of a breeding program is determined by

- The suitability of the breeding design to the target community's breeding practices
- Provision of appropriate extension services to improve the production environment
- Existence of a mechanism for accessible and affordable input supply
- Availability of market incentives for products.

Though marketing was not mentioned as the top constraint across the study sites, appropriate market incentives are particularly necessary drivers for genetic improvement (Seleka 2001). However, any marketing interventions have to fit into farmers' and pastoralists' marketing strategies.

Culling and disposal strategy

Understanding the farmers' and pastoralists' culling and disposal strategy is important in designing breeding programs. They are specifically important for determining breeding stock replacement rates, which affect the rate of genetic progress from selection. There are marked variations between communities in their strategies. The average culling ages for breeding males and females in the sheep–barley system are 2.8 and 6.9 years, in the pastoral system 5.6 and 7.6 years, in the perennial crop–livestock system 3.2 and 7.8 years, and in the cereal–livestock system 3.8 and 8.2 years.

Communities have their own selling priorities for the different classes of sheep. Under normal circumstances, the Menz farmers dispose of their animals in the order aged ewes, castrates, and ram lambs. The Afar community's priority is to first sell castrates then aged rams, ram lambs, and old ewes. However, these strategies can be overridden in pressing situations.

Reasons for, and seasons of sale

The farmers' decision to sell animals is frequently dictated by immediate financial needs, although they prefer to sell their sheep during holidays and festivals when the prices are high. Farmers at the Bonga and Horro sites stated that mostly they (86.4%) sell sheep primarily to meet their cash needs with only 16.6% of the farmers selling just to cull unwanted animals.

The Afar pastoralists have a broader objective for the disposal of their animals. They sell sheep to buy food (45.3%), to reduce their stock during feed shortages (37.9%), and to exploit the better condition of the sheep and the availability of better markets (16.8%). The majority of the pastoralists (89.2%) sell their sheep during the dry seasons and only 2% of the sales occur at a time when they need money. Selling sheep in the pastoral system is closely associated with the dry seasons when milk production (the main food of the family) declines.

Most sales in the Menz area occur during festivals, with 34.2% of sales occurring the Ethiopian Christmas and Epiphany, 18.5% during, Ethiopian New Year, and 18.3% during the Ethiopian Easter. The remaining sales occur in October–November (20.3%), when the farmers exploit the better condition of the sheep resulting from the availability of pasture, and in May–July (8.8%) when there is a pressing need for money to purchase the inputs for crop production.

6.2 Developing community-based breeding programs in four communities in Ethiopia

Defining breeding objective traits

Sheep breeding objectives were defined for the four communities rearing four different breeds in the subalpine sheep–barley, pastoral, perennial crop–livestock, and cereal–livestock production systems. These objectives were based on the producers' priority attributes identified in subsection 6.1. Although, characterizations of sheep breeding by and the management strategies of the communities detailed in Section 6.1 include definitions of their livestock breeding objectives, during this exploratory and descriptive stage, breeding objectives are identified based on a simple ranking of traits. Thus improvement and fine-tuning of crudely defined breeding objectives may be required. Duguma et al. (2011) suggested that a combination of methods be used to elicit producers' breeding objectives. The available tools and methods for defining livestock breeding objective traits include participatory rural appraisal (Chambers 1994; Bhandari 2003; Gizaw et al. 2010), choice experiments (Scarpa et al. 2003; Wurizinger et al. 2006; Ouma et al. 2007; Omondi et al. 2008a, 2008b; Roessler et al. 2008; Kassie et al. 2009), ranking of animals from own flock (Warui and Kaufmann 2005), and a phenotypic ranking method (Ndumu et al. 2008).

The methods employed in defining the breeding objectives were choice experiments (Duguma 2011) and own-flock and group-animal ranking experiments (Mirkena 2011). The relative importance of ram and ewe traits using choice experiments for the four communities is presented in Tables 12 and 13 (Duguma 2011). Ram attribute preferences across the different production systems are heterogeneous. Libido is the most preferred attribute for breeding ram selection by Horro and Menz sheep farmers and the second most preferred trait, next to tail, for Bonga sheep owners. In Afar, ram attributes influencing breeding candidate selection were colour, body size, tail type, and libido in that order. Tail type was the least preferred trait for choosing breeding rams in the Menz sheep breed while colour was the least preferred trait for the Horro sheep breed.

Table 12. Maximum likelihood estimate and standard error for ram traits in the Afar, Bonga, Horro and Menz sheep breeds

Parameter	DF	Estimates ± standard error			
		Afar	Bonga	Horro	Menz
Size	1	1.09 ± 0.130***	1.35±0.163***	1.10±0.128***	0.92 ± 0.123***
Colour	1	1.29 ± 0.085***	1.43±0.106***	0.50±0.076***	0.74 ± 0.076***
Tail	1	0.98 ± 0.129***	2.94±0.176***	1.53±0.130***	0.21 ± 0.121^{NS}
Horn	1	0.67 ± 0.128***	0.15±0.146^{NS}		0.64 ± 0.122***
Libido	1	0.77 ± 0.128***	2.30±0.173***	1.79±0.136***	1.70 ± 0.129***
Pseudo-R^2		0.38	0.56	0.34	0.29

*** = p < 0.001; NS = p > 0.05

Table 13. Maximum likelihood estimate and standard error for ewe traits in the Afar, Bonga, Horro and Menz sheep breeds

Parameter	DF	Estimates ± standard error			
		Afar	Bonga	Horro	Menz
Milk	1	1.32 ± 0.141***			
Size	1	0.79 ± 0.136***	–0.68 ± 0.159***	0.92 ± 0.154***	0.60 ± 0.132***
Colour	1	0.99 ± 0.097***	–0.40 ± 0.098***	–0.31 ± 0.096***	0.23 ± 0.080**
Tail	1	0.62 ± 0.129***	1.80 ± 0.182***	0.73 ± 0.150***	0.85 ± 0.143***
Lambing interval	1	–0.03 ± 0.136NS	1.41 ± 0.172***	1.04 ± 0.150***	1.85 ± 0.145***
Twinning rate	1	0.51 ± 0.138***	–0.04 ± 0.160NS	0.97 ± 0.149***	0.74 ± 0.135***
Mothering ability‡	1	2.32 ± 0.143***	3.98 ± 0.188***	3.30 ± 0.161***	2.39 ± 0.145***
Psuedo-R2		0.40	0.62	0.54	0.42

*** = p < 0.001; ** = p < 0.01; NS= p>0.05

Designing and optimizing breeding programs

The information generated in the definition of breeding objectives was used to design four community-based selective breeding programs for the four communities rearing the four sheep breeds described above (Mirkena 2011). Designing breeding programs mainly involves optimizing genetic progress from selection activities by comparing alternative breeding plans. Optimization of the design of the current breeding programs focused on the intensity of selection and duration of ram use or the ram replacement rate. To this end, among the 18 alternatives simulated (Mirkena 2011), four alternative scenarios of ram selection and ram use were compared and presented for choice to the target communities. Optimization of breeding programs essentially entails employing modern animal breeding methods. Thus, the four scenarios were evaluated via a deterministic simulation of the breeding plans using the computer program ZPLAN (Willam et al. 2008). However, the choice of a specific scheme for implementation entirely depended on the decision of each community. Farmers and pastoralists opted for a high intensity of selection and a short use of rams for breeding and the expected genetic gains are satisfactory for the breeding plans selected by the communities.

Implementing breeding programs

The breeding plans agreed upon by the communities (see subsection on designing and optimizing breeding programs above) laid the basis for developing community-based breeding programs in the four ICARDA–ILRI–BOKU project locations (See Figure 1). At the Afar site 1364 animals were involved, at the Bonga site 1074, at the Horro site 2248, and at the Menz site 2411. Baseline information, including flock structures, husbandry practices, and live weight measurements for all the animals, were recorded. Breeding ram selection in all areas was generally based on phenotypic appearances, such as tail type, coat colour, body size, conformation, and libido. Enumerators were hired to assist the farmers and pastoralists in data recording. The database is managed centrally at the participating research centres. To date three rounds of ram selection have been carried out and animal shows have been organized.

7. Concluding remarks

A comparative analysis of the breeding strategies of four sheep farming communities in Ethiopia shows that there are variations in the breeding strategies of the different communities. This underlines the need to characterize the breeding practices and objectives of a community as a basis for designing breed improvement programs. The model framework for characterizing community strategies illustrates the need for characterizing a range of aspects, including the characteristics of the communities, breeding, production, and marketing strategies, and the production environment.

The model framework covers four major sheep production systems, four sheep breeds and varying agro-ecologies in Ethiopia. Much of the information provided in this document can be used to design breeding programs in similar production systems and agro-ecologies in Ethiopia. The framework can also be adopted to characterize sheep production systems, particularly indigenous breeding strategies of communities, for other production systems and agro-ecologies that are not covered in this study. It is important that such studies be conducted in other systems and agro-ecologies as a basis for designing breeding programs. However, description of production systems need not necessarily involve extensive surveys, which commonly take a long time. This can result in a late start to the actual breeding program in the project lifetime and result in disappointment for the communities. Survey techniques, such as rapid rural appraisal, and quick informal surveys could be considered as applicable.

The ICARDA–ILRI–BOKU breeding programs are now underway. The contributions of the breeding programs to a model for designing breeding programs in similar situations could be enhanced if a comprehensive guide to the whole process of designing breeding programs is documented. Research on the evaluation of different community-based breeding schemes, in terms of efficiency of genetic progress and operational feasibility, is still required.

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Appendices

Appendix 1. Ranking of species based on some adaptive features

Adaptive features	Crop–livestock		Pastoral			
	Cattle	Sheep	Cattle	Sheep	Goat	Camel
Disease tolerance	(0.59)1	(0.43)2	(0.29)1	(0.17)4	(0.24)3	(0.29)1
Tolerance to internal parasite	(0.60)1	(0.40)2	(0.29)2	(0.19)4	(0.20)3	(0.32)1
Tolerance to external parasite	(0.56)1	(0.44)2	(0.30)1	(0.24)3	(0.17)4	(0.28)2
Heat	(0.50)1	(0.50)1	(0.19)4	(0.20)3	(0.23)2	(0.37)1
Cold	(0.37)2	(0.63)1	(0.20)4	(0.24)2	(0.24)2	(0.28)1
Drought	(0.41)2	0.59)1	(0.21)3	(0.14)4	(0.26)2	(0.39)1
Feed	(0.39)2	(0.61)1	(0.21)3	(0.15)4	(0.26)2	(0.39)1
Water	(0.35)2	(0.65)1	(0.17)3	(0.24)2	(0.16)4	(0.40)1
Adaptability	(0.35)2	(0.65)1	(0.23)3	(0.18)4	(0.31)1	(0.28)2

Index = [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) given for each species within adaptive features within a production system]/[(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for both/all species within each adaptive features of a production system].

Numbers in parenthesis are index values; numbers not in parentheses are rankings.

Appendix 2. Reproductive performance of Menz and Afar sheep breeds

Breed and reproductive traits	Crop–livestock			Pastoral		
	NO.	Mean	SD	NO.	Mean	SD
Age at sexual maturity male (months)	115	10.47	3.44	110	7.10	2.49
Age at first lambing (days)	115	470.10	106.60	83	405.60	91.60
Lambing interval (days)	112	255.10	54.80	103	270.50	72.30
Number of lambs per ewe per lifetime	111	9.31	2.56	106	12.06	4.29
Twining rate (%)	115	1.04	1.44	106	5.49	4.38

NO. = number of observation; SD = standard deviation.

Appendix 3. Milking frequency, yield and lactation length of Afar sheep

Parameter	NO.	Mean	SD
Milking frequency per day	107	2.0	0.10
Milk yield per day (ml)	106	224.0	52.00
Lactation length (months)	102	3.8	0.81
Milk yield per lactation (liter)	100	25.5	8.00

NO. = number of observation, SD = standard deviation.

Appendix 4. Least squares mean and standard error of body weight (kg), body condition score and other body measurements (cm) for the effects of sex, age, and sex by age for Menz sheep

Effects and	Body weight		Body length		Chest girth		Wither height		Pelvic width		Body condition	
level	NO.	LSM ± SE	NO.	LSM ± SE	NO.	LSM ± SE	NO.	LSM ± SE	NO.	LSM ± SE	NO.	LSM ± SE
Overall	1072	20.6 ± 0.15	1095	53.5±0.17	1095	65.1 ± 0.22	1095	58.4 ± 0.16	1095	18.1 ± 0.07	1095	1.9 ± 0.03
CV (%)	1072	15.0	1095	6.3	1095	7.1	1095	5.7	1095	8.3	1095	29.8
R2	1072	36.0	1095	27.0	1095	28.0	1095	19.0	1095	22.0	1095	6.0
Sex		**		NS		**		**		*		**
Male	858	22.0 ± 0.27	871	53.9 ± 0.29	871	65.7 ± 0.39	871	59.6 ± 0.28	871	18.2 ± 0.13	872	2.1 ± 0.05
Female	217	19.3 ± 0.13	224	53.7 ± 0.15	224	64.5 ± 0.20	224	57.1 ± 0.14	224	17.9 ± 0.06	224	1.8 ± 0.02
Age group		**		**		**		**		**		**
0 PPI	264	17.2 ± 0.19^{a}	271	51.3 ± 0.22^{a}	271	61.4 ± 0.28^{a}	271	56.1 ± 0.20^{a}	271	17.0 ± 0.09^{a}	271	1.7 ± 0.03^{a}
1 PPI	202	21.0 ± 0.23^{b}	204	54.3 ± 0.26^{b}	204	66.1 ± 0.35^{b}	204	59.0 ± 0.25^{b}	204	18.4 ± 0.11^{b}	204	2.0 ± 0.04^{b}
≥ 2 PPI	609	23.6 ± 0.32^{c}	620	55.9 ± 0.35^{b}	620	67.7 ± 0.48^{c}	620	60.0 ± 0.34^{b}	620	18.9 ± 0.16^{b}	621	2.1 ± 0.06^{b}
Sex by age group		**		Ns		**		Ns		Ns		**
Male, 0 PPI	127	18.0 ± 0.28^{a}	133	51.7 ± 0.31	133	62.2 ± 0.40^{a}	133	57.4 ± 0.29	133	17.1 ± 0.13	133	1.7 ± 0.05^{a}
Male, 1 PPI	65	22.9 ± 0.39^{bc}	66	54.7 ± 0.43	66	67.7 ± 0.57^{b}	66	60.8 ± 0.41	66	18.6 ± 0.19	66	2.3 ± 0.07^{b}
Male, ≥ 2 PPI	25	24.9 ± 0.67^{b}	25	55.5 ± 0.71	25	67.3 ± 0.93^{bc}	25	60.8 ± 0.67	25	18.9 ± 0.30	25	2.3 ± 0.11^{b}
Female, 0 PPI	137	16.5 ± 0.27^{d}	138	50.8 ± 0.30	138	60.7 ± 0.40^{a}	138	54.8 ± 0.28	138	16.8 ± 0.13	138	1.7 ± 0.05^{a}
Female, 1 PPI	137	19.1 ± 0.27^{e}	138	53.9 ± 0.30	138	64.5 ± 0.40^{c}	138	57.3 ± 0.28	138	18.2 ± 0.13	138	1.8 ± 0.05^{ac}
Female, ≥ 2 PPI	584	22.3 ± 0.14^{c}	595	56.4 ± 0.14	595	68.2 ± 0.19^{b}	595	59.2 ± 0.14	595	18.8 ± 0.06	596	1.9 ± 0.02^{c}

Means with different superscripts within the same column and class are statistically different. Ns = Not significant; *significant at 0.05; **significant at 0.01; 0 PPI = 0 pair of permanent incisors; 1 PPI = 1 pair of permanent incisors; ≥ 2 PPI = 2 or more pairs of permanent incisors.

Appendix 5. Least squares mean and standard error of body weight (kg), body condition score and other body measurements (cm) for the effect of sex, age, and sex by age for Afar sheep

Effect and	Body weight		Body length		Chest girth		Wither height		Pelvic width		Body condition	
level	NO.	LSM ± SE	NO.	LSM ± SE	NO.	LSM ± SE	NO.	LSM ± SE	NO.	LSM ± SE	NO.	LSM ± SE
Overall	779	22.76 ± 0.26	792	60.58 ± 0.28	792	66.50 ± 0.31	792	61.37 ± 0.23	793	20.55 ± 0.13	793	2.04 ± 0.04
CV (%)	779	14.0	792	5.5	792	5.7	792	4.6	793	7.4	793	27.4
R2	779	33.0	792	22.0	792	30.0	792	21.0	793	23.0	793	9.0
Sex		**		**		**		**		Ns		**
Male	46	24.3 ± 0.50	46	61.3 ± 0.52	46	67.3 ± 0.58	46	62.1 ± 0.44	46	20.5 ± 0.24	46	2.3 ± 0.08
Female	733	21.2 ± 0.16	746	59.9 ± 0.17	746	65.7 ± 0.19	747	60.7 ± 0.14	747	20.7 ± 0.08	747	1.8 ± 0.02
Age group		**		**		**		**		**		NS
0 PPI	102	19.4 ± 0.40a	102	57.3 ± 0.41[a]	102	62.4 ± 0.46[a]	102	58.6 ± 0.35[a]	102	19.3 ± 0.19[a]	102	2.1 ± 0.06
1 PPI	117	22.1 ± 0.53[b]	121	61.2 ± 0.56[b]	121	66.5 ± 0.62[b]	121	61.6 ± 0.47[b]	121	20.8 ± 0.26[b]	121	1.9 ± 0.08
≥ 2 PPI	560	26.8 ± 0.42[c]	570	63.2 ± 0.44[c]	570	70.5 ± 0.49[c]	570	63.9 ± 0.37[c]	570	21.6 ± 0.21[c]	570	2.1 ± 0.06
Sex by age group		Ns		Ns		Ns		*		Ns		**
Male, 0 PPI	21	20.3 ± 0.71	21	57.3 ± 0.74	21	62.5 ± 0.82	21	58.6 ± 0.62[a]	21	19.2 ± 0.34	21	2.2 ± 0.11[a]
Male, 1 PPI	10	23.5 ± 1.02	10	62.4 ± 1.07	10	67.6 ± 1.20	10	62.4 ± 0.90[bcd]	10	20.9 ± 0.50	10	2.2 ± 0.15[a]
Male, ≥ 2 PPI	15	29.0 ± 0.84	15	64.2 ± 0.87	15	71.9 ± 0.97	15	65.3 ± 0.74[b]	15	21.3 ± 0.41	15	2.4 ± 0.12[a]
Female, 0 PPI	81	18.5 ± 0.36	81	57.2 ± 0.38	81	62.4 ± 0.42	81	58.6 ± 0.32[a]	81	19.41 ± 0.18	51	2.1 ± 0.05[a]
Female, 1 PPI	107	20.8 ± 0.31	111	60.1 ± 0.32	111	65.4 ± 0.36	111	60.9 ± 0.27[c]	111	20.7 ± 0.15	111	1.7 ± 0.05[b]
Female, ≥ 2 PPI	545	24.5 ± 0.13	555	62.3 ± 0.14	555	69.2 ± 0.16	555	62.6 ± 0.12[d]	555	21.8 ± 0.07	555	1.7 ± 0.02[b]

Means with different superscripts within the same column and class are statistically different (at least $p < 0.05$). Ns = not significant; * significant at 0.05; **significant at 0.01; 0 PPI = 0 pair of permanent incisors; 1 PPI = 1 pair of permanent incisor; ≥ 2 PPI = 2 or more pairs of permanent incisors.

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ICARDA

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ICARDA has a global mandate for the improvement of barley, lentil and faba bean, and serves the non-tropical dry areas for the improvement of on-farm water use efficiency, rangeland and small-ruminant production. In the Central and West Asia and North Africa (CWANA) region, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming systems. It also works on improved land management, diversification of production systems, and value-added crop and livestock products. Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.

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