

Review of sheep research and development projects in Ethiopia



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Review of sheep research and development projects in Ethiopia

Solomon Gizaw,¹ Solomon Abegaz,² Barbara Rischkowsky,³ Aynalem Haile,³ Ally Okeyo Mwai¹
and Tadelle Dessie¹

1. International Livestock Research Institute, ILRI
2. Institute of Biodiversity Conservation, Addis Ababa, Ethiopia
3. International Centre for Agricultural Research in the Dry Areas, ICARDA




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ILRI is a member of the CGIAR Consortium

Box 30709, Nairobi 00100, Kenya
Phone: + 254 20 422 3000
Fax: +254 20 422 3001
Email: ILRI-Kenya@cgiar.org

Box 5689, Addis Ababa, Ethiopia
Phone: +251 11 617 2000
Fax: +251 11 617 2001
Email: ILRI-Ethiopia@cgiar.org

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Acronyms

ARARI	Amhara Regional Agricultural Research Institute
BHS	Black Head Somali sheep
BoA	Bureau of Agriculture, Ethiopia
CADU	Chilalo Agricultural Development Unit
CGIAR	Consultative Group on International Agricultural Research
DAD-IS	Domestic Animal Diversity Information System
DAGRIS	Domestic Animal Genetic Resource Information System
EIAR	Ethiopian Institute of Agricultural Research
ESAP	Ethiopian Society of Animal Production
ESGPIP	Ethiopia Sheep and Goat Productivity Improvement Project
IBC	Institute of Biodiversity Conservation
ICARDA	International Centre for Agricultural Research in the Dry Areas
ILRI	International Livestock Research Institute
IPMS	Improving Productivity and Market Success of Ethiopian Smallholder Farmers
LIVES	Livestock and Irrigation Value Chain Development for Ethiopian smallholder Farmers
MoA	Ministry of Agriculture
NLIC	National Livestock Improvement Conference
NVI	National Veterinary Institute
SNV	Netherlands Development Organization

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Executive summary

This working paper reviews sheep research and development in Ethiopia. The objectives are to review and document sheep research projects/activities and provide an overview of major research outputs, dissemination of research results, impacts on the sheep industry, and the gaps in research. Thoughts on the future directions of sheep research are also presented. Sheep research and development in Ethiopia dates back to the early 1960s, and has focused on characterization of genetic resources, description of farming systems, genetic improvement, introduction and evaluation of forage species, development of feeding packages, identification of diseases and parasites, development of health interventions, and marketing studies.

Research on identification, classification and description of sheep resources of Ethiopia began in the 1970s with the classification of the sheep populations into broad categories of tail and fibre types; molecular characterization has been a relatively recent development. While Ethiopian sheep are now well characterized, further research may be required to fill gaps in previous projects. Sheep populations that need further characterization include Harerghe highland sheep, Begayit or Barca sheep and Nuer sheep. Documentation of breed information is currently handled by DAGRIS and DAD-IS projects. Characterization of performance identified small (Menz, Wollo, Tikur sheep), medium (Sekota and Simien sheep), large (BHS, Adilo, Farta and Arsi-Bale sheep) and very large (Gumz, Afar, Washera, Horro and Bonga sheep) sheep types in Ethiopia. The very large breeds are more prolific than the smaller breeds, with litter sizes varying from 1.0 to 1.09 in the small breeds and 1.28 to 1.55 in the very large breeds. Estimates of genetic parameters are now available for some breeds. The estimates indicate that there is substantial within-breed genetic variation in Ethiopian sheep populations and that appreciable improvement can be made through selective breeding, especially in growth traits. Numerous studies characterizing livestock production systems in Ethiopia have been reported by research institutes and agricultural universities.

Sheep genetic improvement in Ethiopia started in 1944 with the introduction of the Merino breed from Italy to improve the performance of the local Arsi-Bale breed. The strategy adopted included both within-breed selection and crossbreeding. So far, only a few sheep breeding programs have been implemented in Ethiopia. Research projects to-date include Afar, BHS, Horro, Menz and Washera sheep nucleus-selection projects/programs. Currently, two crossbreeding programs are using the exotic breeds of Awassi and Dorper. Despite decades of efforts, the research projects yielded unsatisfactory outputs and impacts. Genetic improvement is a long-term venture requiring enduring commitment, such that sustaining sheep breeding programs in Ethiopia has proved difficult. Past failures prompted research on the design of breeding programs. Village-based cooperative breeding programs have now been established for Menz, Horro and Bonga sheep breeds. Appreciable genetic improvement has been achieved in the Menz program.

A number of research projects to improve the production environment (feeding, health) have been conducted, resulting in generation of new technologies and information. The impact of these research projects on the sheep industry has been quite notable in some cases. These include adoption of improved forages in some areas, identification and mapping of geographical and agro-ecological prevalence of economically important diseases, vaccine development, and design of health interventions (e.g. strategic deworming regimens and vaccination for viral diseases).

The existing documentation system for research and development projects and their outputs is not systematic and the information is not readily accessible, making a comprehensive appraisal difficult. While the review reported here is not exhaustive, it can be seen that numerous research projects have been undertaken. A wealth of information and numerous technologies have been generated.

Some of the research outputs have been published in technical publications and journals, annual reports and progress reports. While technologies have been demonstrated to end users through farmers' field days and promoted through pamphlets and brochures, uptake by end users remains low. There are also gaps in the research and development endeavours (e.g. breeding programs are not coordinated).

This calls for a revisiting of the organization and functioning of the sheep research and development system. The links between research and development wings of the livestock sector need to be strengthened for effective dissemination of research outputs.

I Introduction

Sheep production is a major component of the livestock sector in Ethiopia owing to the large population of 25.5 million head (CSA 2011) and the diverse genetic resources (Gizaw 2008). At the smallholder level, sheep are the major source of food security serving a diverse function including cash income, savings, fertilizer, socio-cultural functions and fibre. Sheep are particularly important for the pastoralist/agropastoralist and for farmers in the subalpine highlands where crop production is unreliable. Sheep are also important foreign currency earners accounting for 34% of the live animal exports.

Sheep research and development have been practiced for decades in Ethiopia to improve the productivity of the local flocks, increase offtake rates, and increase their contribution to the livelihoods of farmers and pastoralists, and to the national economy. Several research and development projects have been undertaken by national and international agricultural research institutions and governmental and non-governmental development agencies.

Achievements, challenges, impacts on the sheep industry and research gaps need to be periodically evaluated to direct the research and development efforts to achieve the desired goals. To this end, a methodical and systematic appraisal of research projects may be required. This review is exploratory and indicative, rather than a comprehensive evaluation of the sheep research system. The main objective is to review and document sheep research projects/activities in Ethiopia, including an overview of major research outputs, dissemination of results, impacts on the sheep industry, and gaps in research. Thoughts on the future directions of sheep research are also presented.

2 Research projects, gaps and impacts

Sheep research and development in Ethiopia date back to the early 1960s. Several research and development projects have been initiated to address different aspects of the sheep industry. The focus areas include description of farming systems, identification of sheep production constraints, characterization of sheep genetic resources, genetic improvement, introduction and evaluation of forage species, development of feeding packages, identification of major diseases and parasites, development of health interventions, and marketing studies.

In Ethiopia, sheep research and livestock research in general have gone through various stages of transformation since their beginning in the 1960s. The transformations involve changes in the research strategy/agenda, approaches, methodologies and organizational structure. The research approach in the early years was largely station-based technology generation for problems identified through diagnostic surveys and researchers observations. More consideration was given to identification of real farming problems with the advent of farming systems research. Recently, on-farm studies involving the participation of farmers in the design and implementation of research projects have been adopted. For instance, sheep breeding programs have shifted from central nucleus schemes, where breeding objectives are set by researchers, to village-based breeding programs for some breeds. The research system is currently more engaged in development projects, including scaling-up of technologies and running full-fledged breeding programs (e.g. Dorper sheep breeding program).

The national agricultural research system is organized under one umbrella institute (EIAR) to coordinate all research in the country. The research entities engaged in sheep research include the federal research institute (EIAR), regional research institutes, agricultural universities, international research centres, and NGOs. The national research system is more involved in adaptive and applied research, whereas the international research centres are involved in both strategic and applied research. Collaborations between the international and national research institutions have become stronger in recent years. In the following sections, sheep research projects and their major outputs are presented. The review also attempts to analyse the dissemination of information and technologies generated to intermediate and end users, their impacts on the sheep industry, and the gaps in research.

2.1 Characterization of genetic resources

2.1.1 Phenotypic characterization

2.1.1.1 Origin, identification and physical descriptions

A few research projects have addressed the origins of Ethiopian sheep. African sheep are thought to be of Near-Eastern origin (Epstein 1954; Epstein 1971; Ryder 1984; Marshal 2000) and Ethiopia is believed to be one of the major gateways for domestic sheep migration from Asia to Africa (Devendra and McLeroy 1982). The history of introduction of sheep into Africa recognizes (Epstein 1971) three waves of migration from Asia of precursor populations (thin-tailed, fat-tailed and fat-rumped sheep, respectively). The earliest sheep in Africa were thin-tailed and hairy, and were introduced to East Africa via North Africa (Marshal 2000). The second wave of sheep introduction constitutes fat-

tailed sheep entering North Africa via the Isthmus of Suez and East Africa via straits of Bab-el-Mandeb (Ryder 1984). Fat-rumped sheep entered East Africa much later (Epstein 1954; Epstein 1971; Ryder 1984). Accordingly, African sheep have been described and classified based on their tail type (Epstein 1971; Ryder 1984).

Identification, classification and description of sheep genetic resources of Ethiopia began in the 1970s with the classification and of sheep populations into broad categories based on tail and fibre types (MoA 1975). Ethiopian sheep were initially categorized into fat-tailed (Arsi-Bale sheep), thin-tailed (Horro sheep) and coarse-woolled sheep (Menz and Tikur sheep), a classification that distinguished rather few of the populations. Later, Galal (1983) described the physical characteristics of four sheep types, and Sisay (2009) described the physical characteristics and ecoregional distribution of sheep resources in Amhara region. The above-mentioned classifications were not clear or comprehensive enough as they looked at sheep from a limited geographic area of Ethiopia. For instance, an earlier study described Horro as thin-tailed and Arsi-Bale as fat-tailed (MOA 1975), while Galal (1983) and Epstein (1971) described them as fat-tailed. BHS sheep have been classified as fat-tailed and fat-rumped sheep (Epstein 1971), while Galal (1983) described the tail as short and fat, with the rump being also fatty. Adal sheep are traditionally described as fat-tailed, but were categorized by Epstein (1971) as fat-rumped.

A more recent and comprehensive phenotypic classification and description at the national level (Gizaw 2008) classified sheep resources as short fat tailed, long fat tailed, fat-rumped, course-woolled and shorthaired sheep types. A detailed phenotypic description of the sheep types, estimates of breed population sizes, their breeding tracts, production systems and farmers preferences have been provided (Gizaw et al. 2008a). Furthermore, a guide for their field identification has also been produced (Gizaw 2010). These studies have found that the sheep types in Ethiopia are traditionally recognized and named after the communities maintaining them, their administrative locations, or their phenotypic characteristics, e.g. Afar sheep, Horro sheep and Black Head Somali sheep. A summary of the classification of Ethiopian sheep based on their morphological characteristics and their distinguishing characteristics is presented in Table 1.

Further research may be required to fill gaps in previous projects. Currently, research on morphological characterization continues at the district level mainly through Master's Degree research projects in various agricultural universities (See Table 2). Populations considered as distinct through district-level surveys/observations and those that need to be further characterized include Harerghe highland sheep, Begayit or Barca sheep, and Nuer sheep. A population spanning three districts (Metta, Gorogutu and Deder districts) across the Harerghe highlands has been described as Harerghe highland sheep (Wossen 2012). Further verification may be required to determine whether this population is of the Afar type, the Arsi type, a crossbred population between Afar and Arsi sheep, or a distinct pure breed. The following facts may need to be considered. The three districts are contiguous to the breeding tracts of Afar and Arsi sheep, the population shares the phenotypic characteristics of Afar and Arsi-Bale sheep, and other districts in the Harerghe highlands are inhabited by Afar, Arsi and/or BHS sheep types. Another population known as Begayit or Barca sheep found in northwestern tip of the Tigray region bordering Eritrea, which is the main breeding tract for Barca sheep, needs to be verified as a different breed from the Rutana breed of Sudan that has been introduced into northwestern Ethiopia. The Nuer sheep found in Gambella region and in Sudan have not yet been characterized.

Table 1. Sheep types and their ecology, geographic distribution, distinguishing physical features and population sizes

Sheep types	Other names	Ecology	Geographic distribution	Important physical features*	Population (000)
SUBALPINE SHORT-FAT-TAILED GROUP					
Menz	Legegora, Shoa, Abyssinian, Ethiopian highland sheep	Submoist/dry, subalpine highlands (2500 and 3200 m);	North Shoa zone of Amhara state	Short fat tail turned-up at end; Small body size; short-legged; long fleece with coarse wool; commonly black with white patches, white, brown, white with brown patches; straight-faced; horned males; short semi-pendulous ears with 12% rudimentary ears in the population. Kept by Amhara community	971.4
Sekota	Tigray highland, Abergelle	Cool, dry/submoist highlands (2000 m); semi-arid river valley	Wag Himra zone of Amhara State and Tigray State	Short fat tail turned-up at end and fused with main part; medium-sized; Predominantly brown or white coat, few blacks with brown belly; white animals have finer hair or woolly udder-coat; semi-pendulous or rudimentary ears in Wag Himra and Tigray, predominantly rudimentary in Tekeze valley. Reared by Agew, Tigray and Amhara communities	732.3
Semien		Alpine mountains (3000–4000 m) including Semien Wildlife park	North Gondar zone of Amhara state (Debank, Dabat, Janamora, Wegera)	Short fat tail; well developed woolly undercoat; plain brown, plain white, brown/white with white/brown patches; plain black and black with brown belly; unique long laterally spiral horn in males and short horns in most females; largest of the highland woolled sheep. Reared by Amhara community	347.6
Tikur		Subalpine highlands (3000 m)	North Wollo zone of Amhara state	Short fat tail; woolly undercoat; Predominantly black (60%) coat; small body size; majority short semi-pendulous ears, 24% rudimentary ears. Reared by Amhara communities	525.3
Wollo		Cool highland (2000–3200 m)	South Wollo zone of Amhara state	Short-fat-tail with short twisted/coiled end, occasionally turned up at end; Small size; well developed woolly undercoat; Predominantly black, white or brown, either plain or with patches of white, black or brown; long hair with woolly undercoat; horned males. Reared by Amhara communities	1395.9
Farta		Submoist highland (2000–2500 m)	South Gondar zone; Gondar zuria, Belesa, Dembia districts	Short fat tail; medium size; woolly under coat; Commonly white (37.5%), brown (27.5%) and black with brown belly (15%), white/brown with brown/white patches; males are horned. Reared by Amhara communities	555.6
Washera	Agew, Dangilla	Wet, warmer mid-highlands (1600–2000 m)	West and East Gojam and Agew Awi zones of Amhara state; Dangur, Madura districts	Short fat tail; Large body size; short-haired; predominantly brown; both males and females are polled; reared by Amhara and Agew communities	1227.7

Sheep types	Other names	Ecology	Geographic distribution	Important physical features*	Population (000)
HIGHLAND LONG-FAT-TAILED GROUP					
Adilo		Wet, warmer mid-highland (1800–2000 m)	North Omo, Derashie, Gedio and Amaro zones of Southern state; some northern Borena districts (1300–2400 m)	Long fat tail; Large size; short-haired; males are short-horned and 18.4% of ewes are horned; predominantly brown (94.3%), brown with white patches (32%), black (16%), black (19%) and black with brown patch (9%). Reared by southern nationalities	407.7
Arsi-Bale		Mainly wet, cool and warmer highlands (2000–3300); submoist lowlands	Arsi, Bale, E. Shoa, W. Harerghe zones, some districts in Borena zones of Oromia; Hadya, Gurage, Kembata and Sidama zones	Long fat tail with twisted end in some animals; medium size; hairy fiber, especially in adult ewes, males have minor wool growth in some parts of body; Males and most females (52%) are horned; Large size; coat colors are brown (35.1%), brown with white patches (24.3%), black, white, and combinations of above colors. Reared by Oromo communities	6345.1
Horro		Cool, wet highlands (2991 m) to humid mid-highlands (1600 m).	East Welega, West Welega, Illubabor, Jimma and West Shoa zones of Oromia, and some bordering Gambella and Benishangul districts	Long fat tail extending below hock, either straight (51.4%) or coiled/twisted (48.6%) at the tapering end; prominent fat tail in males; Large, leggy and prolific; dominant colors are brown and fawn, belly is lighter especially in adult ewes, less frequent are black, white, brown with white patches; both sexes are polled. Reared by Oromo, Benishangul and Gambella communities	3409.3
Bonga	Gesha, Menit	Humid mid-highland zone (1200–2500)	Keffa, Sheka and Bench zones of Southern State	Long fat tail with straight tapering end (98.4%); hair sheep; Large size; predominantly plain brown (57.9%) or with black (9%) or white (5.3%) shade, plain white (10.5%) or with brown patches (10.5%), and black (2.6%); both sexes are polled. Reared by Keffa, Sheka and Bench communities	517.5
Harerghe Highland			Metta, Gorogutu and Dedere districts in east Harerghe zone, Oromia	Long fat tail with tapering end; strait or twisted/coiled at the tip.	
LOWLAND FAT-RUMPED/TAILED GROUP					
Afar	Adal, Danakil	Mainly arid lowland (< 1000 m); mid-highland (1200–1900 m)	Afar state; bordering Tigray, Amhara; E.&W. Harerghe and E. Shoa of Oromia	Wide fat tail, in some large fat tail reaching below the hock; hair fiber; medium size; characteristically uniform creamy white/ beige coat; rudimentary ear; polled; dewlap. Reared by Afar, Amhara, tigray communities	681.9
BHS	Wanke, Ogaden, Berbera black head	Mainly arid lowlands (215–900 m); highlands (up to 2000 m)	Somali state; lowlands of Bale, Borena and south Omo zones; part of east Harerghe	Short fat rump with a stumpy appendage; uniform white body and black head and neck; polled; convex face, especially in males; short, outward forward drooping ear; well developed dewlap. Reared by Somali and Oromo, Konso and south omo communities	906.2
LOWLAND THIN-TAILED GROUP					
Gumz		Moist lowlands (< 1000 m)	Benishangul-Gumz state; lowlands of North Gondar	Long thin tail; some what dwarf; convex face profile; long pendulous ear; commonly plain brown or with patch (39.4%), white with brown or black patch (2.1%), black (15.8%), white, black with white patch, brown with black patch; polled. Reared by Gumz and Amhara communities	50.9

Table 2. References to phenotypic¹ and genetic characterization activities on sheep resources of Ethiopia, including morphology, molecular genetics, production systems and breeding objectives

Sheep types	References to characterization projects
Adilo	Gizaw et al. (2007b); Gizaw et al. (2008a); Amelmal (2011)
Afar	Gizaw et al. (2007b); Gizaw et al. (2008a), Tesfaye (2008)
Arsi-Bale	Gizaw et al. (2007b); Gizaw et al. (2008a)
BHS	Gizaw et al. (2007b); Gizaw et al. (2008a); Fikerete (2008)
Bonga	Abegaz (2004); Gizaw et al. (2007b); Gizaw et al. (2008a), Zewdu (2008); Dejen (2010); Amelmal (2011);
Farta	Gizaw et al. (2007b); Gizaw et al. (2008a), Sisay (2009), Shigdaf (2012)
Gumz	Gizaw et al. (2007b); Solomon (2007); Gizaw et al. (2008a),
Harerghe highland ²	Wossenie (2012)
Horro	Abegaz (2004); Gizaw et al. (2007b); Gizaw et al. (2008a), Zewdu (2008), Kejela (2010); Bosenu (2012)
Menz	Gizaw et al. (2007b); Gizaw et al. (2008a), Tesfaye (2008), Sisay (2009); Tesfaye et al. (2012);
Sekota	Gizaw et al. (2007b); Gizaw et al. (2008a)
Simien	Gizaw et al. (2007b); Gizaw et al. (2008a), Sisay (2009), Surafel (2011)
Tikur	Gizaw et al. (2007b); Gizaw et al. (2008a), Sisay (2009), Mohamed (2012)
Washera	Gizaw et al. (2008a), Sisay (2009), Mengiste (2008); Shigdaf (2012); Tesfaye et al. (2012);
Wollo	Gizaw et al. (2007b); Gizaw et al. (2008a), Sisay (2009)

¹ All phenotypic characterization studies were based on questionnaire surveys and linear body measurements, except Mengistie (2004), Surafel (2011) and Shigdaf (2012), which were based on village flock monitoring studies.

² Characterization limited to morphology and production systems.

Documentation of breed information is currently handled by ILRI's DAGRIS and FAO's DAD-IS databases; both are actively involved in the documentation of livestock genetic resources. A reference review of characterization activities is provided in Table 2. The table shows that extensive efforts have been made to identify and describe sheep populations in Ethiopia. The information generated so far seems to suffice to describe the sheep types in Ethiopia. There is however continuing effort to characterize sheep populations at district level and a tendency to describe each population in a district as a separate breed without considering the already defined breeds nationwide or region-wide. The primary attempt should be to try to categorize populations at the district level into one of the recognized breeds by comparing and contrasting its characteristics with those described nationally and regionally. Characterization activities at district level will also contribute to provide location specific information on other components of characterization including description of the production system and environment, performance levels of the breeds, and farmers breeding practices and objectives.

2.1.1.2 Performance evaluation

On-station evaluation: Maintenance of nucleus flocks at research and development centres dates back to the introduction from Italy in 1944 of Merino sheep to be crossed with a nucleus flock of Arsi sheep by CADU (BOA 2000). Assessment of the performance of indigenous sheep types in nucleus flocks has been a priority research area since livestock research began in Ethiopia. The purpose of nucleus flocks was to provide controlled environments for a more accurate evaluation of performance, measuring several traits that would be difficult under village conditions, and comparative evaluation of more than one breed under similar conditions. The objectives were to establish the merits and demerits of the sheep breeds, utilize the breeds according to their merits, and improve on their drawbacks through selective breeding (recurrent selection) and crossbreeding with improved exotic breeds. Performance evaluation included growth, reproductive, fleece and carcass traits. The Institute of Agricultural Research (now EIAR) started the characterization work on Afar, BHS and Horro sheep in nucleus flocks maintained at its research centres. Currently, on-station performance evaluation is underway in nucleus flocks of Afar, BHS, Horro, Menz, Washera and Bonga sheep.

On-farm evaluation: Research on performance evaluation later shifted from on-station nucleus flocks to monitoring performance of village flocks under management by farmers and pastoralists. The objective was to obtain realistic information on the performance of breeds in the context of the specific farming system and production environment in which they are used. The information is thus more appropriate for the design of breeding and management interventions, and allows for assessment of breed risk status. In these studies, a wide range of data is collected on performance (growth and reproductive traits) and the production environment. Monitoring village flocks was a major research activity in Ethiopia, but such studies are expensive in terms of direct cost and duration; this could explain the limited number of such studies and their subsequent abandonment by the research system.

Questionnaire survey: Some breed survey projects (see reference list in Table 2) also collect information on performance in single-visit surveys. In such surveys, information on production and reproductive performance is collected using farmer recall by means of structured questionnaires and linear body sizes are measured on adult ewes at the time of survey.

Extensive data have been collected on the performance of sheep breeds from on-station, on-farm and questionnaire-based studies. The information has been collated and utilized to establish performance levels and estimate genetic parameters. The research outputs show that there is a large variation in performance among sheep resources. The breeds can be classified based on their body weight and linear body size as small (Menz, Wollo, Tikur sheep), medium (Sekota and Simian sheep), large (BHS, Adilo, Farta and Arsi-Bale sheep) and very large (Gumz, Afar, Washera, Horro and Bonga sheep). Body weights of full-mouth adult ewes of the small breeds range from 20.1 kg in Menz to 35.4 kg in Horro sheep (Gizaw et al. 2007b). The very large breeds are more prolific than the smaller breeds, with litter sizes varying from 1.0 to 1.09 in the small breeds, and 1.28 to 1.55 in the very large breeds (Abegaz et al. 2000ab; Abegaz 2002a; Gizaw et al. 2008a; Mengiste et al. 2011b). Performance indicators for some of the sheep breeds are presented in Table 3.

Table 3. Performance levels of some Ethiopian sheep breeds

Breed	Birth weight	Performance indicators					References
		Yearling weight	Adult ewe body			Litter size	
Weight	Height		Length				
Afar	2.5	25.8 ± 0.2; 26.0	31.0 ± 1	63.6 ± 0.8	58.3 ± 0.8		Galal and Kassahun (1982); Galal (1983); Gizaw et al. (2008a)
Arsi-Bale	2.8		28.6 ± 0.6	64.1 ± 0.6	62.3 ± 0.8	1.17	Brannang et al. (1987); Gizaw et al. (2008a)
BHS	2.7	24.8; 25.0	27.9 ± 0.8	63.3 ± 0.6	59.9 ± 0.9	1.04	Galal (1983); Wilson (1991); Gizaw et al. (2008a)
Horro	2.7 ± 0.02; 2.8	23.7 ± 0.04; 24.0 ± 0.3; 19.0	35.4 ± 0.8	70.0 ± 0.6	71.6 ± 0.6	1.34 ± 0.01	Abegaz and Gameda (2000b); Abegaz (2002a); Markos (2006); Gizaw et al. (2008a)
Menz	2.07 ± 0.01; 2.4 ± 0.01; 2.09 ± 0.03	15.4 ± 0.1; 16.9 ± 0.1; 19.1 ± 4.0	20.1 ± 0.3	57.5 ± 0.5	58.5 ± 0.4	1.03 ± 0.01; 1.07-1.12	Yiheyis (1990); Sisay et al. (1991); Mukasa-Mugerwa et al. (1995); Abebe (1999); Mukasa-Mugerwa et al. (2000); Gizaw (2002); Markos (2006); Gizaw et al. (2008a)
Washera	2.7 ± 0.02; 2.61 ± 0.0	23.6 ± 0.7; 24.7 ± 1.1	32.8 ± 0.9	69.4 ± 0.3	66.7 ± 0.5	1.11 ± 0.01; 1.11 ± 0.02	Gizaw et al. (2008a); Mengiste (2008); Shigdaf (2011)
Adilo			28.1 ± 0.5	65.5 ± 0.4	62.1 ± 0.5		Gizaw et al. (2008a)
Bonga			34.2 ± 0.8	66.7 ± 0.6	69.4 ± 0.5		DAGRIS; Gizaw et al. (2008a)
Farta	2.50 ± 0.02	20.08 ± 0.7	28.3 ± 0.7	67.9 ± 0.5	65.7 ± 0.7	1.01 ± 0.01	Gizaw et al. (2008a); Shigdaf (2011); Gizaw et al. (2008a)
Sekota			26.6 ± 0.7	62.3 ± 0.6	62.2 ± 0.6		Gizaw et al. (2008a)
Simien	3.04 ± 0.05	22.87 ± 0.63	26.9 ± 0.4	66.6 ± 0.6	64.7 ± 0.6		Gizaw et al. (2008a); Surafel (2010); Solomon (2007); Gizaw et al. (2008a)
Gumz	2.79 ± 0.028		31.0 ± 0.8	62.9 ± 0.7	65.8 ± 0.7	1.17	Gizaw et al. (2008a)
Tikur			25.4 ± 0.6	64.1 ± 0.6	63.6 ± 0.6		Gizaw et al. (2008a)
Wollo			21.7 ± 0.5	62.7 ± 0.6	61.2 ± 0.5		Gizaw et al. (2008a)

While information on performance of Ethiopian sheep has been published and presented in various scientific fora, such information does not appear to reach the intermediate and end users, including institutions involved in livestock development. Furthermore, utilization of the information is highly limited. The outputs accrued from performance evaluation do not seem to justify the effort, and its impact on the sheep industry is yet to be realized. Generated outputs need to be utilized in the design of breeding programs and management interventions if they are to provide a valuable impact. Further references on sheep performance evaluation are given in Table 4.

Table 4. Further references to on-station and village flock performance evaluation studies

Breed	Flock	References
Adilo	Village	Getahun (2008)
Adilo, Bonga	Village	Amelmal (2011)
Afar	On-station	Galal and Kassahun (1982)
Arsi-Bale	Village	Mukasa-Mugerwa et al. (1986); Tsedeke (2007)
Awassi-Menz	On-station	Zelalem (1987); Sisay et al. (1989); Sendros (1993) Gizaw (2002); Sisay et al. (2012a)
Awassi-Menz	Village	Gizaw et al. (2012b); Sisay et al. (2012b); Tesfaye et al. (2012)
Awassi-Wollo	Village	Hassen et al. (2002); Gizaw et al. (2012b); ; Sisay et al. (2012b); Tesfaye et al. (2012)
BHS	On-station	Bourzat et al. (1992)
Dorper and crosses	On-station	Debre Birhan, Sirinka, Werer Research Centres
Farta	Village	Shigdaf (2011)
Horro	On-station	Abegaz (1994, 1996a, 1996b, 1996c, 2002); Abegaz and Gameda (2000a); Abegaz et al. (1996, 2000b, 2002c); Gameda et al. (1997, 2003); Gizaw and Abegaz (1995); Gizaw and Thwaites (1997); Gizaw et al. (1995a, 1995b); Yohannes and Gizaw (1995); Yohannes et al. (1995a, 1995b)
Menz	On-station	Zelalem (1987); Sisay et al.(1989); Yiheyis (1990); Sendros (1993); Lahlou-Kassi (1995); Gizaw (2002); Mukasa-Mugerwa and Sisay et al. (2012a)
Menz	Village	Niftalem (1990); Tekleye and Kassali (1992); Mukasa-Mugerwa and Lahlou-Kassi (1995); Abebe (1999);
Menz, Horro	On-station	Awgichew (2000); Mukasa-Mugerwa et al. (2000); Mukasa-Mugerwa et al. (2002); Rege et al. (2002); Markos et al. (2004); Berhan and Arendonk (2006)
Sekota	Village	Aemiro (2011)
Simien	Village	Surafel et al. (2012)
Various breeds	Village	Wilson (1982, 1989)
Washera	On-station	Shigdaf (2011); Tesfaye and Gizaw (2011)
Washera	Village	Mengiste et al. (2009, 2011a, 2011b); Shigdaf (2011)
Washera-Farta cross	Village	Shigdaf (2011)
Wollo	Village	Hassen et al. (2002); Gizaw et al. (2012b); Sisay et al. (2012b); Tesfaye et al. (2012)

2.1.2 Genetic characterization

2.1.2.1 Molecular characterization

Molecular genetics of sheep in Ethiopia has not been on the National research agenda. Appropriate research facilities are limited to a few specialized genetics laboratories, although researchers and technicians trained in molecular genetics are lacking. To date, molecular genetics research has been limited to the study of genetic diversity of Ethiopian sheep using neutral microsatellite markers (Gizaw 2008). This study described the genetic diversity among and within the traditionally recognized sheep types in Ethiopia. The genetic information in combination with morphological diversity was utilized to classify Ethiopian sheep into six genetically distinct breed groups and nine breeds. Genetic distances between 14 Ethiopian sheep populations are presented in Table 5. These groups can form a reference unit to manage sheep genetic resources. The information can also be used to identify genetically unique populations, and to assess risk status of populations and formulate conservation priorities. Besides estimating genetic diversity, neutral molecular markers can be used in crossbreeding studies for parentage verification and estimating genetic composition of crossbred animals. A project is currently underway at Debre Birhan Research Centre to develop molecular tools to reconstruct pedigrees of crossbreds of Awassi and local sheep.

Research has not yet focused on direct application of molecular genetics to the design of breeding programs. This is a major gap in the national research agenda. Characterization using neutral genetic markers such as microsatellites may not help much in identifying Quantitative Trait Loci (QTLs) that can be used for designing improvement programs using Marker-Assisted Selection (MAS) tools. MAS is particularly useful for improving traits having low heritabilities, but may be less effective when applied to traits with high heritability, such as growth, which can be improved through conventional breeding (e.g. Gizaw et al. 2007a).

2.1.2.2 Estimation of genetic parameters

Estimates of genetic parameters (heritabilities and genetic correlations) are good indicators of the genetic characteristics of a population and are the basis for designing animal breeding programs. Genetic parameters have been estimated for Ethiopian sheep breeds using data collected over several decades in flocks maintained in research and development centres. Estimates are now available for growth, reproduction, fleece, survival, linear body sizes, and disease/parasite resistance traits (Table 6).

The estimates indicate large within-breed genetic variation and genetic improvement can be achieved through selective breeding, particularly for growth traits as demonstrated in the Menz sheep-breeding program (Gizaw et al. 2007a, 2011a). For reproductive traits and lamb pre-weaning survival, heritability estimates are often low and unreliable (Abegaz and Gemedo 2000b; Markos 2006). Heritability and genetic correlation estimates can sometimes identify indirect selection criteria to achieve gains in target traits. For example, heritability estimates for linear size traits (e.g. pelvic width, chest girth, body length, body height) that typically vary from 0.076 ± 0.004 to 0.361 ± 0.015 (Gizaw et al. 2008c) indicate that overall growth can be improved through indirect selection on linear body measurements, which are easier to measure particularly under village conditions. Furthermore, heritability estimates in Menz/Horro sheep for semen/spermatozoa characteristics vary from 0.16 ± 0.12 to 0.35 ± 0.13 and the genetic correlation of scrotal circumference with semen volume has been estimated as 0.55 ± 0.11 (Rege et al. 2000), indicating that testis size could be used as an indirect selection criterion to improve male reproductive capacity. Heritability estimates for resistance to gastrointestinal parasites (EPG and PCV counts) are also available for Menz and Horro sheep (Rege et al. 2002).

Table 5. Pairwise FST (above diagonal) and Nei's genetic distances DA (below diagonal) between 14 Ethiopian populations of sheep

Population	Simien	Sekota	Farta	Tikur	Wollo	Menz	Gumuz	Washera	Horro	Adilo	Arsi	Bonga	Afar	BHS
Simien		0.0312	0.0195	0.0294	0.0271	0.0275	0.0703	0.0449	0.0847	0.0713	0.0916	0.1074	0.0558	0.0848
Sekota	0.0791		0.0072 NS	0.0158	0.0136	0.0078	0.0541	0.0223	0.0587	0.0481	0.0656	0.0740	0.0277	0.0476
Farta	0.0654	0.0394		0.0001 NS	0.0048 NS	0.0035 NS	0.039	0.0183	0.0422	0.0322	0.0503	0.0607	0.0279	0.0481
Tikur	0.0838	0.0556	0.0368		0.0112	0.0005 NS	0.0378	0.0251	0.0456	0.0302	0.0505	0.0654	0.0292	0.0540
Wollo	0.0694	0.0538	0.0425	0.0595		0.0089	0.0393	0.0231	0.0480	0.0351	0.0520	0.0590	0.0381	0.0522
Menz	0.0807	0.0511	0.0377	0.0486	0.0507		0.0503	0.0229	0.0467	0.0351	0.0592	0.0680	0.0265	0.0537
Gumuz	0.1647	0.1346	0.1170	0.1279	0.1109	0.1292		0.0357	0.0482	0.0496	0.0587	0.0585	0.0494	0.0741
Washera	0.1082	0.0843	0.0736	0.0931	0.0689	0.0692	0.1115		0.0317	0.0287	0.0457	0.0623	0.0436	0.0626
Horro	0.1645	0.1183	0.0994	0.1220	0.1101	0.0958	0.1235	0.0828		0.0287	0.0573	0.0660	0.0561	0.0874
Adilo	0.1551	0.1124	0.0949	0.1133	0.0915	0.0983	0.1241	0.0859	0.0711		0.0246	0.0597	0.0414	0.0706
Arsi	0.1593	0.1161	0.1078	0.1336	0.1065	0.1147	0.1317	0.1075	0.1044	0.0681		0.0979	0.0430	0.0542
Bonga	0.2235	0.1716	0.1531	0.1614	0.1489	0.1506	0.1509	0.1449	0.1220	0.1239	0.1729		0.0748	0.1069
Afar	0.1375	0.0830	0.0884	0.1086	0.0988	0.0749	0.1389	0.1062	0.1151	0.1145	0.1133	0.1623		0.0222
BHS	0.1628	0.1064	0.1117	0.1344	0.1155	0.1011	0.1619	0.1232	0.1447	0.1290	0.1163	0.1864	0.0747	

Except those marked NS, all FST values were significantly different from zero at 0.1% level of significance based on 91 000 permutations

Table 6. Available estimates of genetic parameters for sheep breeds in Ethiopia

Breed	Trait										References [†]
	Birth weight	Weaning weight	6-month weight	Yearling weight	Fleece weight	Staple length	Litter size	Survival			
Menz ^f	0.276 ± 0.052	0.238 ± 0.054	0.338 ± 0.113	0.334 ± 0.166				^a 0.024 ± 0.018; ^b 0.051 ± 0.018; ^c 0.179		Gizaw and Joshi (2004a, 2004b)	
Menz	0.22	0.15		0.21				0.017 ± 0.02 ^h 0.00 ⁱ		Markos (2006)	
Menz ^g	0.464 ± 0.014	0.477 ± 0.016	0.514 ± 0.017	0.559 ± 0.019	0.393 ± 0.016	0.339 ± 0.014				Gizaw et al. (2007a)	
Awassi-Menz	0.324 ± 0.082	0.425 ± 0.107	0.455 ± 0.182	0.377 ± 0.232				0.055 ± 0.024; 0.109 ± 0.024; 0.056		Gizaw and Joshi (2004a, 2004b)	
Horro	0.26	0.12		0.04				0.022 ± 0.024 h 0.003 ⁱ		Markos (2006)	
Horro	0.18–0.32 ^c 0.12–0.23	0.1–0.26 0.19–0.24	0.16–0.26 0.09	0.23–0.31 0.08–0.14				0.15 ± 0.03 ^d 0.07 ± 0.04		Abegaz (2002a), Abegaz et al. (2002b)	
Afar	0.38 ± 0.038	0.12 ± 0.034 0.21 ± 0.026	0.15 ± 0.040 0.07 ± 0.025	0.28 ± 0.041						Yibraha and Abegaz (2012)	
BHS	0.35 ± 0.111 0.15 ± 0.056	0.00 ± 0.000 0.20 ± 0.048	0.03 ± 0.077 0.20 ± 0.057	0.25 ± 0.111						Yibraha and Abegaz (2012)	

a. Estimates from linear model unadjusted and adjusted for normality

b. Estimate from threshold model

c. First row: direct heritability; second row: maternal heritability

d. First row: direct additive model; second row: repeatability model

e. Perinatal and pre-weaning survival using logit and probit models

f, g. Estimates from sire model and animal model, respectively

h, i. Estimates from linear model and survival analysis, respectively

[†] Further references:

Menz sheep: Linear body size traits (Gizaw et al. 2008c); growth traits (Hassen et al. 2003); growth and reproduction (Zelalem 1987; Ewnetu 1999;)

Horro sheep: Total weight born, total weaning weight and fertility estimates (Abegaz 2002; Abegaz et al. 2002c); growth (Temesgen 2010).

Horro and Menz: Semen, testicular characteristics and EPF/PCV counts (Rege et al. 2000; 2002).

Very few of the genetic parameter estimates of have been utilized to improve efficiency of breeding. This information for breeding-objective traits needs to be combined in the construction of selection indices for use in breeding programs, but this has yet to be done. Estimation of genetic parameters requires years of painstaking effort and large on-station flocks maintained under controlled-breeding practices. Thus, the available genetic parameter estimates (see Table 6) may have to be applied to design breeding programs for other sheep breeds for which estimates are not yet available. Estimation of genetic parameters so far relied on performance and pedigree data collected on on-station flocks. However, recent studies indicate that indicative parameters can be estimated based on recording in village flocks maintained under smallholder sheep production systems (Gizaw et al., paper submitted).

2.2 Research on conservation of genetic resources

Research and development on conservation of sheep genetic resources in Ethiopia are limited. Major accomplishments include the extensive characterization and documentation of breed information by IBC (FAO 2007) and DAGRIS. The relative contributions of breeds to the total sheep genetic diversity in Ethiopia, their risk status and economic merits were assessed and conservation priorities set by Gizaw et al. (2008d), although the information has been little used to develop conservation programs for indigenous sheep. As a result, the Gumz breed, while contributing most to sheep genetic diversity and being the only thin-tailed breed in Ethiopia (Gizaw et al. 2007b), is being eroded through uncontrolled crossbreeding with Rutar sheep. The current drive for rapid livestock development through crossbreeding and the threat status of indigenous sheep (Gizaw et al 2008d) requires that research and development on genetic conservation be made a priority.

Recent research approaches to conserve sheep genetic resources have developed breeding strategies for sustainable and rational utilization of indigenous breeds. Developing rational crossbreeding programs is necessary to strike a balance between increasing livestock productivity and conserving indigenous resources. Limited research has been done on conservation-based crossbreeding programs. This includes crossbreeding programs for the national and Amhara Region's Dorper sheep breeding programs. Experiences with the Awassi sheep-crossbreeding program in Ethiopia showed the negative effects that result in the absence of rational crossbreeding strategies, as the program did not bring about positive impacts for the sheep industry, but rather diluted the sheep genetic diversity.

Research on indigenous breeds could serve to both conserve and improve genetic resources. Nucleus flocks maintained in research and development centres are serving conservation efforts, albeit not deliberately. Research on the management of on-station flocks shows that they can be genetically improved while conserving their genetic diversity if inbreeding is avoided (Gizaw et al. 2013). *In situ* conservation of sheep resources is being integrated with genetic improvement in community-based sheep-breeding programs by national (e.g. Debre Birhan Research Center) and international research institutions (e.g. ICARDA, ILRI) for Menz, Horro and Bonga breeds, although these efforts are limited to pilot villages and need to be scaled up to breed-level regional programs.

2.3 Characterization of sheep production systems

2.3.1 Classification and description of production systems

Numerous studies have described livestock production systems in Ethiopia since the mid-1980s when a farming-system research approach was adopted by EIAR (see Table 7). Many more are likely to remain unreported and inaccessible. Results of farming-systems studies by ILRI–IPMS covering a wide range of production systems and agro-ecological zones have been compiled and analysed (Gizaw et al. 2010b, 2011e).

Table 7. Livestock production systems characterization activities in Ethiopia

Geographic area	Production system	References
Ada'a Liben district; Oromia regional state	Mixed crop–livestock	Samuel (2005)
Goma; Oromia regional state	Mixed crop–livestock	Belete (2009)
Metema; Amhara regional state	Agropastoral	Tesfaye (2009)
Alaba; SNNP regional state	Mixed crop–livestock	Tsedeke (2007)
Burie; Amhara regional state	Mixed crop–livestock	Yenesew (2009)
Ziquala; Amhara regional state	Mixed crop–livestock	Dereje Anduwalem (2004)
North Gondar zone; Amhara regional state	Mixed crop–livestock	Sisay Amare Zeleke (2006)
Debre Birhan, Jimma, Sebeta, Ziway	Mixed crop–livestock	Zewdie Wondatir (2010)
East Wellega, and West Shewa; Oromia regional state	Mixed crop–livestock	Abegaz et al. (2005)
Lalo Mama; Amhara regional state	Mixed crop–livestock	Abebe (1999)
Kocher; SNNP regional state	Mixed crop–livestock	Adugna (1988)
Debre Birhan area; Amhara regional state	Mixed crop–livestock	Agyemang et al. (1985)
West Ethiopia; SNNP regional state	Mixed crop–livestock	Berhanu (1997)
Baso and worena; Amhara regional state	Mixed crop–livestock	Gryseels (1988)
Southeastern Ethiopia; BHS sheep breeding tract	Pastoral; Agropastoral	Girma (1992)
Darolebu, Habro and Boke; Oromia regional state	Mixed crop–livestock	Dereje and Tesfaye (2008)
Amhara region; Amhara regional state	Mixed crop–livestock	Amha and Fletcher (1991)
Different regions		Desalegne (2009)

Note: The studies cited in Table 2 also included chapters in characterization of livestock production systems.

The extensive research on farming systems led to the classification and description of a range of livestock production systems (documented by Alemayehu 2003). Classification of production systems was based on the level of livestock production and its contribution to the community as well as the type of crop–production enterprises. The livestock production systems have also been described in relation to the sheep breeds (Gizaw et al. 2008a). The systems have been well described in terms of the production environment such as feed resources and important diseases, major constraints to sheep production, flock characteristics, farmers' sheep breeding and management practices, farmers breeding objectives, agricultural service delivery and sheep marketing. These research outputs are published in technical papers and MSc theses and are thus not readily accessible to end users. Failure to convert these materials to a usable format will limit the impact of this research effort on the sheep industry. A summary of production systems in relation to sheep breeds in Ethiopia is presented in Table 8.

Table 8. Major sheep production systems in Ethiopia

Production systems	Environment	Geographic regions	Characteristic features of production systems	
			Main products	Scale of production and management [†]
Subalpine sheep–cereal system	Subalpine (> 3000 m)	Menz area, Wag Himra, parts of North Gondar (Debank, Dabat, Janamora, Wegera), South Gondar, North and south Wollo zones of Amhara state, and Tigray State	Meat, fiber, manure, skin; unreliable, long-season barley	Medium scale sheep production; Semi-intensive/extensive, low-input
Highland cereal–livestock system	Highlands (2000–3000 m)	Most of Oromia; West and East Gojam and Agew Awi zones of Amhara state; Central Tigray	Mainly cereal cropping; meat, manure, skin	Small-scale sheep production; semi-intensive, low-input
Highland perennial crop system	Highlands (1500–2000 m)	Coffee, Inset and fruit growing areas of Southern and Oromia	Mainly perennial cash crops (coffee, inset, khat); meat, skin	Minor sheep production; semi-intensive, low-input; some practice tethering
Lowland crop–livestock system (agropastoral)	Submoist/moist lowland (≤1000 m)	Benishangul-Gumuz, lowlands of Amhara, Tigray, Oromia	Cereals, sesame, cotton; meat, skin	High level of livestock keeping; extensive/semi-intensive, low-input
Pastoral system	Semi-arid/arid (≤1000 m)	Pastoral regions in Somali, Afar, Oromia and southern states	Meat, milk, skin; minimal or no cropping	Rangeland-based large-scale sheep production; extensive, low-input

[†] Based on feeding, veterinary care, housing practices

Adapted from Gizaw et al. (2008).

2.3.2 Breeding objectives and breeding practices

Definition of breeding objectives and description of the production system and environment is the basis for designing tailor-made management and breeding interventions. Methodological approaches for defining breeding objectives have been reviewed by Gameda et al. (2008). A participatory approach has recently been adopted and used to define breeding objectives for various sheep breeds (Tesfaye 2008; Zewdu 2008; Kahsa 2009; Tesfaye 2010; Gizaw et al. 2010c; and most of the studies cited in Table 2). These studies invariably identified that farmers' primary breeding objective is to increase meat production. The breeding objectives defined for some of the breeds (Menz, Horro, Bonga, and Washera) have been well utilized to design breeding programs.

Research to understand farmers' traditional breeding practices have recently gained momentum. Some of the information has been used to design village-based selection and breeding programs. Results show that farmers do select their breeding stock (e.g. 93% select rams in Menz region), using subjective selection criteria (Gizaw et al. 2010). Research conducted to validate farmers' subjective selection criteria showed that there is a high congruence between selection based on subjective criteria and that on estimated breeding values. There is also a limited research effort to evaluate the effectiveness of farmers' traditional breeding practices. An investigation on Menz sheep farmers breeding practice (Gizaw et al. 2011a) showed that the failure to achieve controlled mating hinders genetic improvement in village flocks.

2.3.3 Identification of production constraints

Studies indicate that constraints to increased productivity and market success of smallholder farmers are primarily diseases and parasites, feed shortage, and inadequate extension service delivery or lack of improved technologies (Table 7). There are also other constraints whose severity varies across production systems and agro-ecozones. The importance of diseases and parasites also vary across agro-ecozones, with the most important being pasteurellosis,

fasciolosis, sheep pox, orf, anthrax, coenerosis, and ectoparasites. The major feed source across production systems and agro-ecozones are natural pastures. Sheep production is subsistence oriented and characterized by low inputs and outputs. This has led to low adoption of improved technologies and production strategies.

2.4 Genetic improvement—Research and development programs

Sheep genetic improvement in Ethiopia started in 1944 with the introduction of the Merino breed from Italy to improve the performance of the local Arsi-Bale breed at CADU (MoA 2000). Sheep genetic improvement has since been the major component of livestock research and development efforts in Ethiopia. The strategy adopted was selective breeding (recurrent selection) to exploit the within-breed genetic variation and crossbreeding of local ewes with sires from exotic breeds. Research projects addressed both crossbreeding and within-breed recurrent selection, whereas development programs focused exclusively on crossbreeding. The breeding programs addressed only a limited number of breeds of sheep in the country.

2.4.1 Selection programs

2.4.1.1 Central nucleus-based breeding programs

Breeding programs in Ethiopia started in the 1970s by the EIAR. The programs utilized closed-nucleus breeding flocks maintained exclusively in research centres. The objectives of the research projects have been to evaluate the genetic response and potential of local breeds to selection and to establish elite nucleus flocks as sources of improved rams. The research projects include Afar, BHS, Horro, Menz, and Washera sheep selection projects/programs (Table 9). The breeding programs have mostly targeted growth performance of local breeds. Local breeds are reputed to be slow growers with low meat yields, the average carcass yield being about 6–7 kg at yearling age. The selection criteria were post-weaning growth rates, six-month weights and yearling weights. Ewe reproductive traits have now been included in the Washera sheep-breeding program.

Table 9. Central nucleus based sheep breeding programs in Ethiopia

Breed	Selection criteria	Institution	Current status
Afar	Post-weaning weight gain	Werer Agricultural Research Centre	Initial program discontinued; re-initiated in 2011
BHS	Post-weaning weight gain	Werer Agricultural Research Centre	Discontinued; flock established by SoRPARI but no selection activity
Horro	Yearling weight	Bako Agricultural Research Centre;	Continuing
Washera	Pre-weaning weight gain and litter size	Andasa Agricultural Research Centre	Discontinued
Menz	Yearling weight	Debre Birhan Agricultural Research Center	Continuing

Despite decades of research, projects generally yielded unsatisfactory results. Since genetic improvement is a long-term venture, sustaining sheep breeding programs in Ethiopia has proved to be difficult. Results of selection in the nucleus flocks of Afar and BHS sheep remain unreported and the initial breeding programs were discontinued, with whatever genetic improvement achieved being lost with the disposal of the flocks. The Afar breeding program was re-initiated recently with a new flock. Although the Washera breeding program was initiated in 2004 with a flock of 200 ewes, it is yet to be evaluated. Selection in the Horro sheep nucleus flock did not result in appreciable genetic improvement (Abegaz and Gemedo 2000b; Temesgen 2010) and the breeding program shows no progress. The reasons for the failure could be lack of documented selection procedures, high turnover of breeders managing the nucleus flocks, lack of skills in quantitative genetics particularly the accurate estimation of breeding values, budgetary

constraints, lack of vision and commitment from researchers, and bias in the livestock development strategy towards crossbreeding with less emphasis on the recurrent selection program. Despite these negative outcomes, recurrent selection has led to appreciable genetic improvement in local breeds. For instance, an elite nucleus flock of Menz sheep has been established with genetic superiority in yearling weight of about 7 kg above average, and improved rams are being disseminated to village flocks (Gizaw et al. 2011a).

2.4.1.2 Village-based breeding programs

Village-based breeding programs that do not involve central nucleus flocks are a more recent development. Attempts to develop village-based breeding programs in Ethiopia began as early as 2003 with Washera and later with Gumz sheep (ARARI research directory), but failed because of lack of proper knowledge among researchers on the new approach to breeding improvement. Currently, international research institutions (ILRI, ICARDA and BOKU) in collaboration with national research institutions are involved in developing village-based breeding programs. These have been established for Menz, Horro and Bonga sheep breeds (Gemedo 2011; Gizaw et al. 2011a; Tadello 2011). Appreciable genetic improvement has been achieved in the Menz program. Body weights at birth, 3 and 6 months of age increased by 0.42, 2.29 and 2.46 kg, respectively, in the third generation over those in the base generation.

There has been negligible impact of genetic improvement research on the sheep industry, despite there being large amounts of data and estimated genetic parameters that can inform the design of effective breeding programs, as well as well-characterized farmer breeding objectives. The pitfalls of genetic improvement studies have been the failure: to establish and maintain nucleus-breeding flocks as sustainable sources of improved rams; to develop clear selection methodologies; and to design breeding programs/schemes for most of the breeds studied. Consequently, there are hardly any effective livestock development programs in Ethiopia for improvement of sheep flocks through breeding. In addition, the sheep flocks maintained in the MoA sheep breeding and multiplication ranches at Debre Birhan and Amed Guya for Menz sheep and Horro ranch for Horro sheep are not bred due to technical limitations among the breeders in the development ranches. Lack of skills in quantitative genetics theory has been a major problem until recently.

Optimism seems to prevail for livestock breeding research in Ethiopia. While the on-station Menz sheep-breeding program and the village-based Menz, Horro and Bonga sheep-breeding programs are a promising start, a long-term commitment to these initiatives needs to be built into the livestock development programs of the Ministry of Agriculture and the regional livestock development agencies. The effort put on these initiatives can also serve as a model for breeding programs for other breeds.

2.4.2 Crossbreeding programs

The dominant genetic improvement strategy for cattle, chicken and sheep in Ethiopia has been crossbreeding of the indigenous breeds with sires from imported exotic breeds. Sheep crossbreeding has been condemned from two perspectives. First, crossbreeding is considered a threat to the survival of the adapted indigenous breeds. Second, crossbreeding as a strategy failed to sustain genetic improvement in village flocks owing to exotic genotypes being maladapted to the local environment. Crossbreeding can be considered "a necessary evil in livestock improvement", but its negative impacts on indigenous breeds can be ameliorated through rational crossbreeding strategies (see Section 2.4.3). The failure of crossbreeding programs cannot be attributed solely to poor adaptation of exotic genotypes, but also to the failure to design village crossbreeding programs that are in line with farmers' aspirations and village breeding practices.

Early crossbreeding programs: Research and development on sheep crossbreeding started at CADU with the introduction of several exotic wool sheep breeds (Blue De Maine, Merino, Corriedale and Hampshire) in the late 1960s (Beyene 1989; Brännäng et al. 1987). The Menz crossbreeding program started in 1967 using Corriedale, Hampshire and Romney Marsh as sire breeds. The primary objective of the programs was to improve wool and meat production in local breeds. The program was terminated and none of the exotic breeds can be traced except for a few

Corriedales in a South Wollo village with a high contribution from local breeds. Such has been the history of sheep crossbreeding in Ethiopia and the lack of critical evaluation of failures has resulted in perpetuation of the same in subsequent projects and reluctance to fund crossbreeding projects. As a result, the potential impact of sheep genetic improvement on the sheep industry is yet to be realized.

Awassi crossbreeding program: The follow up to the wool improvement project was the introduction of the Awassi sheep breed from the Middle East. The Awassi crossbreeding program was initiated in 1980 using Menz sheep as dams. The research component of the program is mandated to Debre Birhan and Sirinka research centres, and the development wing is run by Debre Birhan and Amed Guya sheep breeding and multiplication centres under Amhara Bureau of Agriculture. While the program has a clear crossbreeding scheme for the multiplication of crossbred rams in the multiplication ranches, the strategy for dissemination of genetic improvement to villages and sustaining crossbreeding at the village level is not well defined. Extensive and indiscriminate distribution of crossbred rams across the country for the last three decades yielded virtually no impact on the sheep industry (Gizaw and Tesfaye 2008). There have also been problems in the production of crossbred rams. The number of crossbred rams produced over the years have been far below the demand. This is mainly because of the lengthy crossing and backcrossing in order to produce rams with 75% Awassi blood. The crossbred ram dissemination strategy may have to shift to distribution of 50% Awassi crossbred rams, rather than 75% crosses. There have also been repeated outbreaks of viral diseases (Maedi-Visna) that forced the elimination of purebred Awassi and crossbreds, followed by restocking. Furthermore, the failure to maintain purebred Awassi flock has necessitated repeated importation of pure stock. The recently imported large pure Awassi flock needs to be maintained properly to avoid further importations. This requires, among other things, planned breeding of the nucleus flock to avoid inbreeding and improved health management.

Research on Awassi crossbreeding started well after the implementation of the development program. The research focused initially on comparative evaluation of crossbreds with varying Awassi blood levels to determine the optimal crossbreeding level for the local conditions, developing feeding packages, and evaluation of the combining ability of local Bonga and Washera dam breeds with Awassi (Sisay et al. 1989; Sendros 1993; Sendros et al. 1995; Gizaw 2002). Unfortunately, the recommendations and feeding packages developed were not utilized in designing Awassi sheep development programs because the crossbreeding program could not be established in villages. The observed absence of effective and sustainable crossbreeding at the village level has prompted a shift in the Awassi sheep research agenda to design of village crossbreeding programs (Gizaw et al. 2011c, 2012a). Subsequent pilot implementation of Awassi crossbreeding activities in model villages has shown that crossbreeding can be effective if appropriate designs are adopted and strong monitoring and evaluation are in place (Gizaw et al. 2012b; Sisay et al. 2012b; Tesfaye et al. 2012).

Dorper crossbreeding program: The main breeding objective for the majority of Ethiopian sheep farmers is meat, rather than wool production, and is driven by market demands and agro-ecology. A national sheep-breeding program was therefore initiated to address farmers' objectives with the introduction of a specialized meat breed, the Dorper sheep, by the ESGPIP project in 2006. The program was well-designed with strategically located nucleus and breeding/extension/dissemination centres across the country and coordinated nationally. The promising start now faces the common tragedy of sheep-breeding programs in Ethiopia with the phasing-out of the ESGPIP. Currently, the various Dorper centres in the country are being run with little national coordination. The vision and strategy for a nationally coordinated breeding program and consortium of Dorper breeders formulated upon the exit of the ESGPIP have not materialized. Nonetheless, there are promising regional Dorper sheep research and development projects across the country with rational crossbreeding strategies and schemes.

Sheep research has been witnessed a paradigm shift with the Dorper breeding program. Research orientation has changed from the usual crossbreeding activities and performance evaluations, to developing crossbred genotypes and the design and testing of village crossbreeding programs. The Dorper research can be considered a research-cum-development project, where research centres assumed the role of breeding, multiplication and dissemination. Research on Dorper crossbreeding currently focuses on village monitoring studies, design of village crossbreeding schemes, formulating feeding packages, and studies on carcass characteristics of crossbreds (Mekonen 2012), with evaluation of the comparative performance of purebred and different grades of crossbreds as a sideline activity. It is

too early to assess the outputs of the research projects and the impacts of Dorper research and development on the sheep industry.

Crossbreeding among local breeds: Research on crossbreeding has recently added a new dimension to include crossbreeding among indigenous sheep breeds. The performance of Bonga and Washera sheep as sire breeds to improve Menz sheep is promising (Debre Birhan Research Center, unpublished data). Washera rams are being used widely to improve the highland sheep breeds in the Amhara region (Shigdaf 2012). While this research and development project is having a positive impact on the sheep industry, the widespread and indiscriminate use of Washera sires could threaten the genetic diversity of populations in the area.

2.4.3 Designing breeding programs

Past failures in sheep genetic improvement have led to research on design of breeding programs. Small flock sizes, communal grazing/herding and uncontrolled mating did not favour the implementation of selective breeding/recurrent selection programs within village flocks. The approach adopted initially and implemented for Afar, BHS, Horro and Menz sheep was to generate improved rams in closed, nucleus flocks and to disseminate them to village flocks. The projects generally ended in failure, as most lacked long-term vision and did not involve farmers in the planning. These failures led to the argument that such breeding schemes may not be appropriate for smallholder systems in developing sheep industries. A new village- or community-based breeding scheme, which does not involve central nucleus flocks, has thus been adopted recently to improve village flocks through recurrent selection (Gizaw et al. 2009; Gemeda 2011; Haile et al. 2011; Tadelle 2011). Gizaw et al. (2011a) also suggested a breeding scheme that integrates the merits of central nucleus-based and village-based breeding schemes.

Lack of appropriate guidelines to produce crossbreds sustainably with a desired blood level in village flocks, inherent complexity of crossbreeding programs and lack of follow-up by implementers are some of the reasons for the lack of impact on the sheep industry. Research has now focused on developing rational crossbreeding strategies, alternative crossbreeding systems, and design of village crossbreeding schemes. A rational crossbreeding strategy that considers the conservation of locally adapted breeds with clear delineation of crossbreeding zones is being implemented for Dorper sheep in the Amhara region. Regulation to enforce the rational crossbreeding strategy suggested for the national Dorper crossbreeding program is also suggested. A lot of effort has gone into designing recurrent-selection and crossbreeding programs suited to smallholder farmers. Various designs of breeding schemes have been developed and tested, guidelines produced (Aynalem et al. 2011; Gizaw et al. 2011b), and model villages established with simultaneous impact on improved livelihoods in the project areas (Table 10).

Table 10. Research efforts on strategy and design of breeding programs

Breeding designs/strategies	Breeding program	References
Village-based cooperative breeding scheme	Menz, Horro, and Bonga sheep breeding programs	Gizaw et al. (2009, 2011a); Haile et al. (2011); Gizaw et al. (2012e); Tadelle et al. (2012)
Nucleus breeding scheme	Washera sheep breeding; Menz sheep breeding	Gizaw et al. (2010a); Gizaw et al. (2011a)
Linked Nucleus-village breeding scheme	Menz sheep breeding program	Gizaw et al. (2011a)
Cooperative village crossbreeding scheme	Awassi sheep crossbreeding program	Gizaw et al. (2011c, 2012a)
Coordinated national breeding program	ESGPIP Dorper sheep breeding program	ESGPIP unpublished document
Dorper sheep crossbreeding strategy	ESGPIP Dorper sheep breeding program	ESGPIP unpublished document
Dorper sheep crossbreeding strategy	ARARI Dorper sheep crossbreeding program	ARARI research directory
Development of synthetic breeds	Awassi sheep crossbreeding program	Gizaw et al. (2012c)

2.5 Improvement of the production environment

Research projects aimed at improving the production environment can be categorized into three areas: 1) feed development and feeding; 2) disease diagnostics and health interventions; and, 3) research on husbandry practices. Some of these projects such as forage development may not be specifically targeted to sheep. A number of research projects have been conducted, with concomitant generation of technologies and information. While some of the findings have been published and are available in proceedings of the NLIC and ESAP and in some journals, the majority are published as internal documents (e.g. institutional progress reports) that are not readily accessible.

Research on feed development has focused on introduction and evaluation of forages, with several varieties recommended and introduced in various agro-ecological zones of Ethiopia. The most widely adopted species include alfalfa, sesbania, Napier grass, and tree lucerne. These feeds are used mostly for fattening sheep. Despite sustained efforts by the MoA and the research system to disseminate improved forage varieties, the impact on the livestock industry has been very limited, although with some notable exceptions. This could be due mainly to low adoption rates by farmers where land for forage production is limited. Forages adopted were planted on marginal entry points such as farm and homestead fences, soil conservation terraces, and along irrigation channels. The focus of forage research may have to shift to identify suitable entry points for forage production. There is also a gap in research on improving the traditional grazing management and grazing lands.

Development of feeding/fattening packages is the major component of sheep production research in Ethiopia. Fattening packages are now available for Menz, Awassi-Menz crosses, Horro, Washera, Tikur, Afar, and BHS sheep. Most of these activities are reported in proceedings of livestock conferences. These results are yet to be adopted by the farming community, although sheep fattening is common among highland farmers. Feeding packages to improve reproductive performance and lamb survival are limited (Table 11).

Research has led to the identification and mapping of geographical and agro-ecological prevalence of economically important diseases. Disease diagnostics research is mainly mandated to regional disease laboratories and the national animal health laboratory at Sebeta. Farming systems research by regional research centres and Master's Degree research programs include identification of diseases through farmer participatory research. Disease and parasite identification studies have been the basis for designing health interventions tailored to specific agro-ecologies such as strategic deworming regimens and vaccination for viral diseases. Vaccine development by NVI is an important contribution of research and this is attributed to research results from serotype identification studies.

Research gaps are observed in management interventions such as improved housing and improved-flock management. Analyses of flock productivity utilizing data collected from village monitoring studies merely report on the existing level of productivity. Recommendations on interventions to introduce modern flock management practices are rarely suggested. Research to improve traditional sheep production practices need to be strengthened.

Table II. Documented research projects on sheep diseases/parasites, feeding and other management interventions

Research topic	Breed/district	References
Improved feeding for growth, fattening, and carcass quality	Menz	Sisay (1995); Abebe (2008c); Abebe et al. (2008a, 2008b); Anteneh et al. (2008); Gizaw et al. (2008b); Tefera (2012); Tesfaye et al. (2012); Tewodros et al. (2012)
	Washera	Gizaw et al. (2012d); Simegnew et al. (2012)
	Horro	Abegaz et al. (2005); Amensissa Eresso (2010); Gemedo et al. (2004, 2007); Gizaw and Abegaz (1995); Gizaw et al. (1991); Lemma et al. (1991); Takele (2010); Takele et al. (2005); Temesgen et al. (2007); Ulfina et al. (1999, 2003)
	Tikur	Fitsum Berhe (2009)
	BHS	Yibrah et al. (1991); Emebet Legesse (2008); Getahun (2012)
	Afar	Yibrah et al. (1991); Tesfay Hagos (2007); Getahun (2012)
	Farta	Getachew Asefa (2005); Fentie Bishaw (2007); Jemberu Dessie (2008)
	Wollo	Mesfin et al. (2008)
	Tigray Highland/Sekota	Tikabo Gebremariam (2005)
	Arsi-Bale	Abebe Taffa (2007); Ermias Tekletsadik (2008);
	-----	Getahun Kebede (2006); Mulat Alem (2006); Zemichael G/sillasi (2006); Almaz Ayenew (2008)
Feeding for improving wool production	Menz	Sisay et al. (1991)
Feeding to meet export demands	Afar and BHS	EIAR summaries of completed research 2010/2011.
Feeding for improving reproduction	Horro	Mukasa-Mugerwa et al. (1994); Abegaz et al. (1998); Gemedo et al. (1999, 2000, 2007); Yohannes et al. (1997); Ulfina et al. (2000a, 2000b, 2003a, 2003b)
	Menz	Sendros et al. (1995)
Disease and parasite identification	Burie, Atsbi-womberta, Mieso, Metema, Fogera, Alaba, and Alamata districts	GebreMedhin (2007); Getahun (2007); Gizachew (2007); Kassaw (2007); Kuastros (2007); Yohannes (2007); Aklilu (2008)
Strategic parasite control		Markos (2006); Argaw et al. (2010); Markos et al. (2010); Kassa et al. (2012);

2.6 Value-chain development—Marketing and policy issues

2.6.1 Value-chain analyses

There has been a paradigm shift in livestock research toward addressing value chains through a holistic approach. The national research system has recently embarked on livestock value-chain projects (Table 12), though most are yet to be implemented. The CGIAR centres and NGOs in collaboration with the national research system are particularly active in livestock value-chain research and development. A research and development program (LIVES) dedicated to livestock and irrigated-crops value-chain development in Ethiopia has recently been launched by ILRI, while ICARDA has also launched the Ethiopian small ruminant value-chain development program. SNV is also one of the leading institutes in livestock value-chain research and development in Ethiopia.

Table 12. Rank-order of importance for marketing constraints in live sheep, goats and skins

Constraints	District		
	Alaba	Gomma	Bure
Live sheep and goats			
Excessive tax	4	4	–
Brokers/dealers	1	2	–
Seasonality of markets	5	1	–
Lack of access to incentive markets	3	5	3
Lack of market and price information	2	3	–
Low market prices	–	–	1
Counterfeit Birr	–	–	4
Skins			
Lack of price and market information	2	–	–
Lack of extension support on skin handling and marketing	1	–	–
Poor skin quality of local animals	3	–	–

Sources: Bekele (2007), Tsedeke (2007), Yenesew (2009).

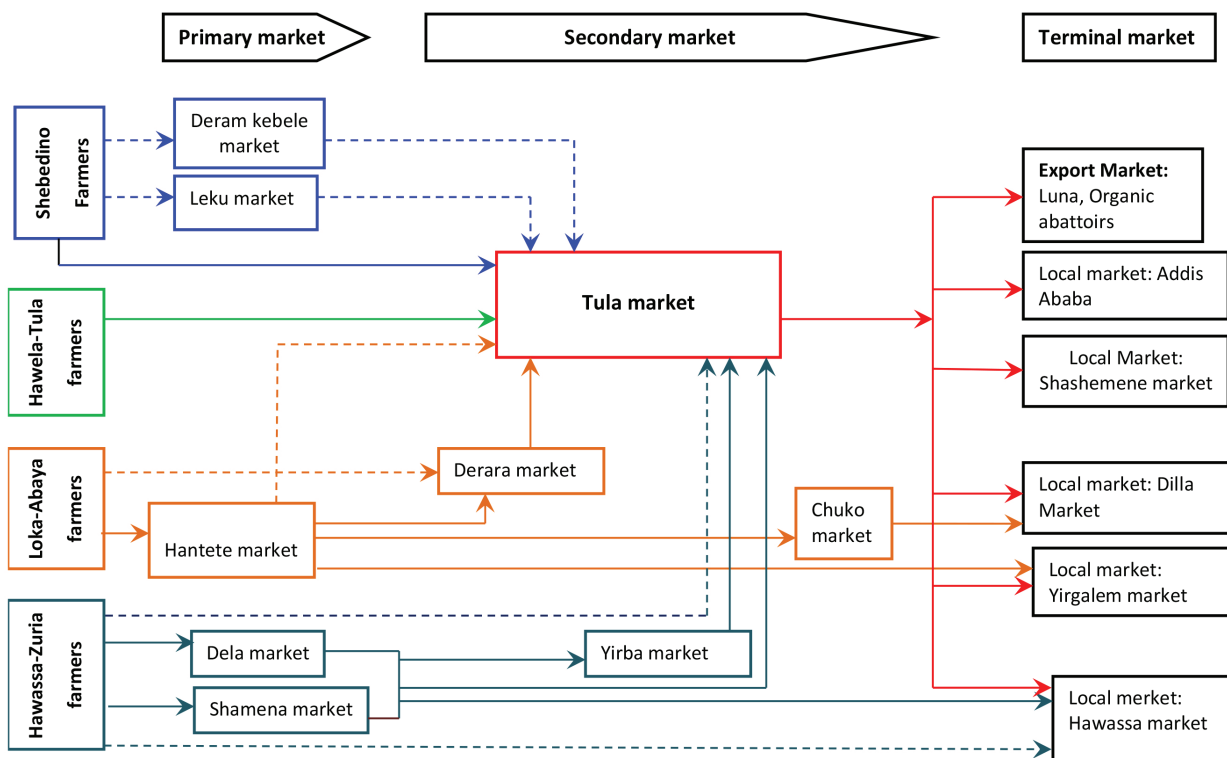
While few studies on sheep value chains have been published to-date (e.g. Hailemariam 2008; Dugassa and Belachew 2008), internal reporting by ICARDA/ILRI and SNV for current value-chain studies has identified the core functions, actors, market routes, market channels, constraints, existing opportunities and recommendations on interventions at each node of the value chain. These studies cover a number of geographic locations and agro-ecological zones. The results are for the most part very similar, although there are some peculiarities for each location. The major core functions identified include input supply, production, marketing, transporting, processing, and consumption of sheep and sheep products. Among the actors are sheep producers (farmers), who are the primary actors, rural collectors, brokers, small traders, big traders, hotels/restaurants/butchers, individual consumers and export abattoirs.

The studies have identified the major constraints to improving the sheep value chain:

- shortage of adequate veterinary services, drugs and equipment,
- lack of adequate and flexible credit service,
- lack of supply of forage seeds and cuttings for forage development,
- supply of ineffective drugs and vaccines, low breed productivity,
- high morbidity and mortality rate,
- poor feeding management,
- feed shortage during dry seasons,
- high incidence of diseases and parasites,
- lack of training on improved sheep husbandry,

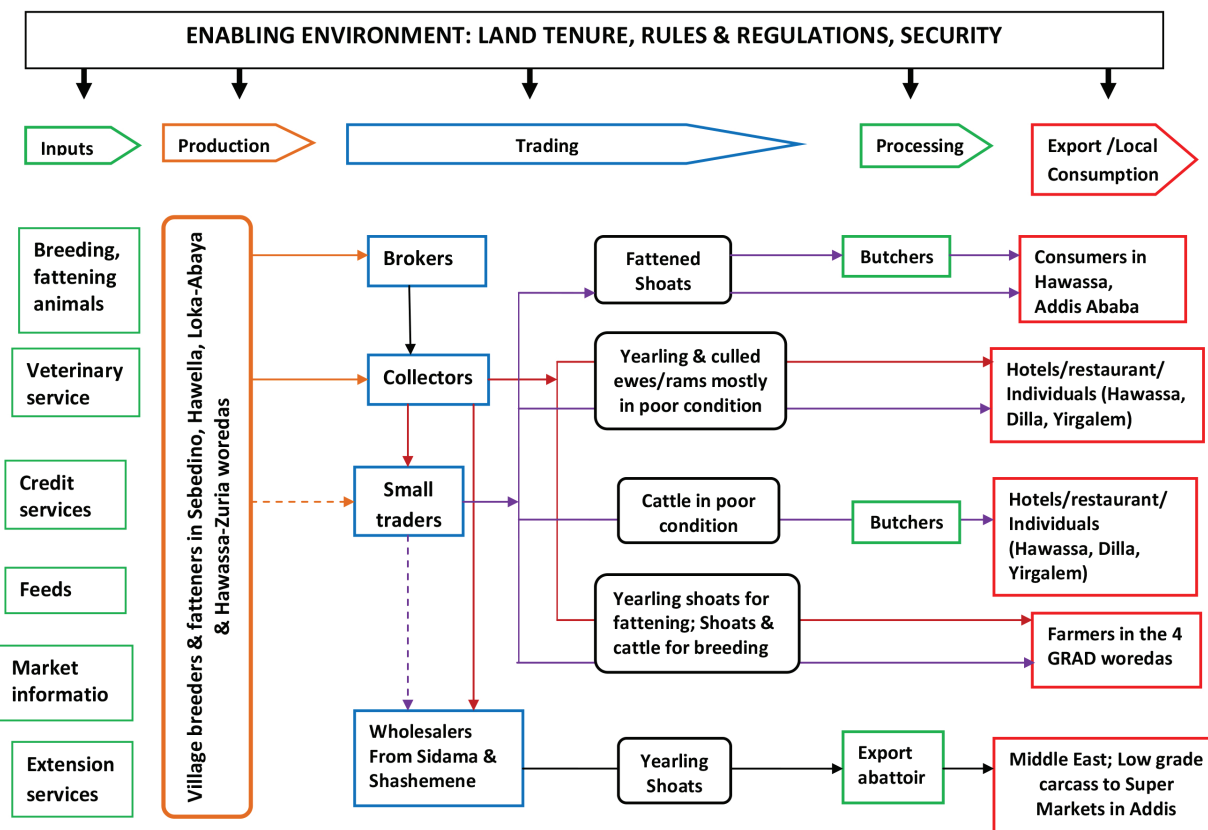
- high incidence of abortion and lamb mortality,
- weak vertical and horizontal linkage among actors,
- multiple taxation for traders,
- lack of adequate working capital,
- lack of formal and adequate market information,
- low bargaining power of producers,
- seasonality of demand and supply for sheep,
- transportation constraints, and
- processing constraints.

These studies uncovered constraints that could affect producers' adoption of improved sheep-production technologies. Analysis of the value of sheep across the value chain in southern Ethiopia (SNV, Gizaw 2012) showed that the values vary as they move from the producers to the final consumers. The variations are usually incremental and are the result of value adding and costs incurred by the actors across the value chain. A simplified gross-margin analysis (SGM) indicates that both type of product (value adding) and market channels affect profit of producers. The highest SGM was found for producers indicating that shoat production is a feasible enterprise for farmers in Sidama zone in southern Ethiopia. The results also indicate that fattening yearlings is more profitable than fattening bigger rams. The gross margin for farmers who have access to the big zonal markets is greater than for farmers who are far from these markets. The results show that farmers' operational profit and their gross margins will be higher if they add values and market their sheep in domestic zonal markets (SGM from 72.4 to 87.5%) rather than selling unfinished yearlings to exporters (SGM from 44.4 to 47.9%). The issue of competition between the domestic and export markets needs to be addressed. Typical market routes and value-chain mapping for southern Ethiopia are shown in Figures 1 and 2, respectively.



Source: Gizaw (2012).

Figure 1. Market routes linking sheep, goat and cattle supply from the Sidama zone to local and export markets. Dotted lines represent infrequent routes



Source: Gizaw (2012).

Figure 2. Small ruminant meat and beef value-chain map for four GRAD project woredas in the Sidama zone

The sheep research section of the national research institutes is organized to address problems across the various stages of the sheep value chain. The section has teams addressing research issues related to provision of inputs, production, value addition, and marketing. Nevertheless, the research is strongly biased toward inputs and production (see Table 13). Research on product quality and marketing is negligible; the only project dealing with value addition is on sheep fattening, and that on product quality is limited to carcass qualities of Ethiopian sheep (see Table 10) and darkening of frozen meat from highland sheep (Unpublished data on BHS, Afar, Menz and an unpublished MSc thesis). Research on wool quality and marketing is also lacking. Socioeconomic research includes characterization of farming systems, market structures and credit services (Andargachew and Borokken 1992; Ayele et al. 2003; Berhanu et al. 2007; Feven 2009). There is very limited research on strategic issues that could guide policy development such as analysis of sheep production and offtake trends (Senait 1992; Asfaw et al. 2010).

2.6.2 Research on sheep marketing

Characterization of market structures has been a major component of sheep marketing research in Ethiopia (Ayele et al. 2003; Berhanu et al. 2007; Tsdeke 2007; Belete 2009; internal reports of ICARDA, ILRI, SNV; MSc research projects cited in Gizaw et al. 2010b). Livestock marketing structure in Ethiopia follows a four-tier system (Ayele et al. 2003). The main actors of the 1st tier are local farmers and rural traders/rural assemblers who transact at the farm level. The 2nd tier consists of small traders from different corners who bring their animals to the local market, where traders/wholesalers purchase a few large animals or a large number of small animals for selling to the secondary markets. In the secondary market (3rd tier), both smaller and larger traders operate and traders (wholesalers or retailers) and butchers from terminal markets come to buy animals. In the terminal markets (4th tier), large traders, butchers and export abattoirs (wholesalers or retailers) transact larger number of mainly slaughter type animals. Consumers get meat through purchase of live animals or from butchers.

Another dimension of market research is the characterization of market prices (Andargachew and Borokken 1992; Beneberu 2003; Even 2009). Such studies attempted to identify factors determining market prices including size, colour, and age of animals. Most of the value-chain and production-system characterization studies cited here also identified marketing problems faced by producers and marketers along the value chain. The major constraints and their rankings for some regions of Ethiopia are shown in Table 12.

The focus in market research has largely been on characterization of the marketing system. There has been limited effort to develop intervention strategies for identified marketing problems such as farmers' access to profitable markets, although some studies have addressed macro-level issues such as the economic significance of sheep production and factors affecting sheep offtake rates (Adane and Girma 2008; Asfaw and Mohammed 2008). These studies found that offtake rates due to sale are low, being exceeded in some cases by mortality rates, indicating low flock productivity and that flock inventory changes over a period of one year were negative for sheep and goats in the study area.

The livestock marketing structure in Ethiopia is based on traditional organization of the market channels. Meat exporting abattoirs complain of the lack of defined market routes, which is considered a hindrance to the smooth flow of livestock supply required to operate at full capacity. Value-chain analyses revealed that livestock marketing downstream and at the collectors' level is based on mutual trust between individuals and there are currently no strong market support structures in place, particularly at the *woreda* level. Although some Marketing Offices (e.g. Sidama Zone) are trying to organize market structures such as registration and certification of traders to control illegal trading, the Offices are limited by lack of facilities such as holding yards to accommodate animals confiscated from illegal trades. Most of the Offices are thus limited largely to collecting weekly livestock market prices.

The SNNP Regional Marketing and Cooperative Office has issued guidelines for live animal marketing (SNNP 2011). While the guidelines stipulate a stringent requirement for issuance of certificates to collectors, wholesalers and exporters of live animals, field observations show that most of the traders may not meet the requirements. The guidelines also outline regulations on handling and marketing of animals, and control of illegal trading, although Marketing Offices at the *woreda* level are ill equipped to execute the guidelines.

Institutional support of livestock inputs and product marketing in Ethiopia is largely limited to health services, even if there are still farmers who obtain alternative veterinary services from illegal sources. There are no private or governmental enterprises or cooperative associations (except very few and poorly organized cooperatives) working on livestock marketing or input supply. The informal livestock input provision, such as through retail traders, is not accessible in most parts of the country. This is in contrast to the emerging crop-marketing cooperatives that help to overcome the production and marketing problems. So far, institutions involved in generation and dissemination of improved livestock technologies (e.g. improved breeds) have had limited impact on livestock development.

Absence or weakness of trade regulations and value-chain governance has resulted in a lengthy supply chain, lower profits for producers and high prices for consumers. For processors and exporters, however, the government has favourable regulations and policies, such as absence of export tax, availing access to loans, providing inspection services, and facilitation of transit. The government has restructured the former MoARD and has created Livestock Production, Health and Marketing Agency, in order to give greater emphasis to livestock, which may improve the situation at the *woreda* level.

2.6.3 Business-development environments—Institutional and policy issues

Assessment of the institutional framework for livestock development in Ethiopia shows that the groundwork for enhancing the livestock value chain has been laid. The existence of research and development institutions (e.g. Livestock State Ministry, Regional Livestock Development and Health Agencies, EIAR, RARIs, EMDTI, CGIAR centres and other NGOs in the country, livestock exporters associations, and upcoming initiatives such as the Livestock Growth Project) are the basis for improving the livestock value chain. There is growing evidence that the major factor

explaining low adoption of technology in Africa is lack of appropriate institutional and policy support (Kedir 1998). Adoption of improved technologies is strongly affected by the policy environment affecting input supply, market, credit, and price policies. Land-tenure regulations to producers and security to marketers should also facilitate the effective functioning of the value chains.

Analyses of sheep value chains cited above indicate that enabling environments at the macro-level that includes policy, institutional and regulatory support needs to be facilitated to enhance the operation and performance of livestock value chains. Such support is the basis for all other strategic interventions to improve livestock production and farmer income. Lack of regulations, such as absence of licensing requirements for involvement in livestock trading in some regions (Berhanu et al. 2007; Marketing and Cooperative Office reports), is also a hindrance to market success of producers and consumers. In most of the studies, it has been suggested that organizing marketing groups or cooperatives and regulation of traders' activities could entitle farmers to their fair share of the market profit margins.

A commonly cited gap in the livestock development effort has been the absence of breeding policy and strategy, and the lack of due consideration in the institutionalization of livestock development. The livestock resource base and the prospects and contribution of livestock development to the national economy and livelihoods of millions of farmers and pastoralists could rightly justify moving away from past failed attempts and setting up a new, dynamic and innovative institutional arrangement in Ethiopia. In this regard, a greater public investment in livestock research and development commensurate with the potential contribution of the livestock sector to the national and household economy needs to be considered.

2.7 Strategic research

Strategic research projects are highly limited in the research agenda of the national research system (Table 13). While a few field experiments on ewe and ram reproduction were conducted (Table 12), the national research system is engaged largely in developing livestock development packages, dissemination, and up scaling of livestock technologies. Strategic and basic research on sheep biology including reproductive biology has been done largely by ILRI, which conducted extensive laboratory and field research on reproduction in Menz sheep (Mukasa-Mugerwa and Lahlou-Kassi 1995).

Research in molecular genetics (particularly QTL mapping) and animal biotechnology (e.g. reproductive technologies including AI in sheep) suffers from the lack of a national program. The human resource and equipment capacity needs to be developed before molecular genetics can be incorporated into the national research agenda. The national molecular genetics/biotechnology unit established at the Holetta Research Center has yet to engage in sheep research. Still other aspects of the research need to be strengthened and organized before embarking on such strategic research; for instance, without a well-documented and organized database on phenotypic performance and pedigree records, molecular data are of little or no significance. Neither of the CGIAR centres in the country are involved in such strategic research, while research on AI for small ruminants is badly needed.

Table 13. Current sheep research projects and activities of the national research system (EIAR)

Project	Component	Activities	Institutes
Project 1: Improving productivity of indigenous sheep through selective breeding and improved management			
	Breeding	Establishing and upgrading elite nucleus flocks of Menz sheep	ARARI
	Breeding	Development of 50% Awassi × Menz synthetic sheep breed	ARARI
	Breeding	Developing community-based pure-breeding scheme and model breeding villages for Menz sheep	ARARI
	Breeding	Establishing and upgrading elite nucleus flocks of Afar sheep	EIAR (Werer)
	Breeding	Developing community-based pure-breeding scheme and model breeding villages for Afar sheep	EIAR (Werer)
	Breeding	Analysis of community breeding objectives and practices for sheep production in Fentale district (Phase I)	ORARI
	Breeding	On-farm productive and reproductive performance evaluation of sheep in Fentale area (Phase II)	ORARI
	Health	Study on major health problems causing sheep carcass condemnation at export abattoirs	EIAR (Debre Zeit)
	Health	Evaluation of anthelmintic activity of <i>Vernonia amygdalina</i> against <i>Haemonchus contortus</i> infections of sheep and goats of pastoralists and smallholder farmers in eastern Ethiopia	Haramaya University
	Health	Assessment of major diseases and associated risk factors of sheep in Fentale district (Phase I)	ORARI
	Health	Identification of economically most important sheep diseases and designing disease prevention and control schemes (Phase II)	ORARI
	Marketing	Study on meat sheep handling and transport by export abattoirs	EIAR (Debre Zeit)
	Marketing	Factors influencing the supply response of sheep export markets to price incentives	EIAR (Debre Zeit)
	Marketing	Assessment of sheep marketing systems in Fentale district (Phase I)	ORARI
	Nutrition	Fattening Arsi-Bale sheep with sugar cane top based diets: effect of supplementation and silage making	EIAR (Debre Zeit)
	Nutrition	Determining optimum dietary crude protein level for fattening local lambs	EIAR (Debre Zeit)
	Nutrition	Evaluation of biological performance and economic benefits of cost-effective diets fed to fattening lambs	EIAR (Debre Zeit)
Project 2: Development of cross-breeding schemes and production packages for Dorper sheep			
	Breeding	Maintenance, multiplication and distribution of purebred Dorper and 50% Dorper × local sheep	ARARI
	Breeding	Maintenance, multiplication and distribution of purebred Dorper and 50% Dorper × Afar	EIAR (Werer)
	Breeding	Evaluation of village Dorper crossbreeding schemes	EIAR (Werer)
	Breeding	Evaluation of the performance of 25% and 37.5% Dorper × Afar/BHS crossbred sheep	EIAR (Werer)
	Breeding	Maintenance, multiplication and distribution of purebred Dorper and 50% Dorper × BHS sheep	SoRPARI
	Breeding	Evaluation of the performance of 25% and 37.5% Dorper × Afar/BHS crossbred sheep	SoRPARI
	Nutrition	Performance of Dorper × Afar and Afar sheep grazing on <i>Panicum antidotale</i> , <i>Chloris gayana</i> and <i>Cenchrus ciliaris</i> grown with alfalfa	EIAR (Werer)
	Nutrition	Development of finishing packages for 25% and 37.5% Dorper × Afar lambs under market-oriented semi-intensive feeding systems	EIAR (Werer)
	Nutrition	Development of finishing packages for 25% and 37.5% Dorper × Afar lambs under market-oriented semi-intensive feeding systems	SoRPARI

2.8 Organization of the research system and current projects

The national research system in Ethiopia is organized into a federal (EIAR) and regional research institutes in each state. EIAR is mandated to coordinate research in Universities and the other institutes. There are two CGIAR centres (ILRI and ICARDA) and other NGOs such as SNV involved in research, particularly on value-chain development. Such organization could enhance wider research coverage in different ecological zones, but activities in the national research systems lack synergy because each regional institute is autonomous in its research agenda, although some regional projects are coordinated by EIAR. This can lead to duplication of effort and inefficient utilization of limited expertise. Ongoing research projects are summarized in Table 13.

2.9 General impact assessment

Evaluating the impact of research on the sheep industry calls for a thorough assessment of technology adoption by farmers and pastoralists, and its effect on sheep productivity and livelihoods, following standard impact assessment methods. Unfortunately, such information is not readily available and impact is assessed in this review from the few available reports and field observations.

While a wealth of information has been generated by research institutions and disseminated to end-users through various media, including conferences and publications, much information remains inaccessible as unpublished reports or 'grey literature'. The published knowledge and information is certainly useful to guide research and development projects, but it remains to be evaluated whether the quality and volume of information being generated is in accordance with the real demand by the development sector.

Despite the large number of technologies generated, their impact on the sheep industry and farmer livelihoods is minimal. The feeding and fattening packages, improved genotypes and forage species are not well disseminated to sheep farmers. Breeding programs set up in the country are not functioning effectively, although there are some encouraging results at model village level. The time is now appropriate to investigate the bottlenecks hindering effective dissemination and adoption of technologies; is it due to poor linkage between research and development, inappropriate dissemination, inappropriate technologies, or farmers' socioeconomic and cultural preferences and aspirations?

3 Thoughts on research strategies

3.1 Appraisal of the research system

Several research strategies have been formulated since the beginning of livestock research in Ethiopia. It is important to review the research projects and outputs generated to-date and to evaluate if the livestock research is directed according to the current strategy and the country's livestock development needs. The projects being undertaken by the various regional and national research institutes, centres, substations, universities etc. need to be evaluated in terms of organization, budgetary support and work force expertise. The evaluation should also include whether projects are in-line with the role of research in development, which involves solving current problems with a view to the future. It is imperative, therefore, that the research systems be appraised by professional strategists and policy analysts.

3.2 Focusing research along the value chain

The agenda of the national research system focuses on improving productivity and, to a lesser extent, on input provision such as improved forage materials and health services. A research gap exists at the other stages of the value chain, such as product quality, value addition and marketing. The value-chain analyses cited here have also shown that there are major problems in marketing of sheep. In general, from the current review, two areas of research and development gaps can be identified: the challenge to introduce technologies generated into the farming communities; and fair markets for inputs and products.

One of the major bottlenecks in the research effort could be the challenges facing the introduction of technologies to farming communities. Research may have to focus on designing approaches and mechanisms for efficient delivery of improved genetics, forage germplasm, health services and other production technologies. This requires research on strategies; for instance, delivering improved genetics requires designing appropriate breeding schemes that suit the smallholder sheep farming systems.

Two aspects of the sheep-marketing problem can be identified from the value chain analyses: farmers' access to fair markets for inputs and products, and the supply of sheep to markets, particularly to the export market. Access to markets influences farmers' incomes. Unfair profit margins due to weak product prices can discourage farmers from adopting improved technologies. Research should thus focus on addressing issues that diminish producers' profits across the value chain by developing marketing approaches to overcome the problem. Research on problems associated with the supply of small ruminants to the export market may have to focus on: quality standards to meet market demands; causes of inconsistent supply and demand; mechanisms for efficient supply chains; increasing offtake rates and factors determining offtake rates; and macro-level studies on the sheep industry to determine trends in production and marketing.

There are targeted projects on small ruminant value chains including LIVES by ILRI, the Ethiopian Small Ruminant Value Chain Development Project by ICARDA/ILRI, and the GRAD project by SNV/CARE-Ethiopia in Southern Ethiopia. Duplication of effort among these projects and the national research system needs to be avoided.

3.3 Research on sheep development strategies

From Table 13 it is clear that the focus of sheep research is to generate information and technologies to improve productivity and marketing. Research on development strategies and schemes is minimal. The effort should go beyond biological research at the animal level. Research on strategies provides baseline information to guide sheep development. The diverse production and agro-ecological systems pose different potentials and challenges for sheep production. Mapping and stratification of production zones should guide sheep development strategies and programs. Sustainable utilization and conservation of indigenous sheep genetic resources requires delineation of crossbreeding, pure breeding, conservation, multiplication and finishing zones.

The low levels of improvement in livestock production in smallholder systems may not be limited to lack of improved technologies, but can also be due to challenges in introducing appropriate technologies into the system. Village livestock husbandry, such as communal ownership of village resources (e.g. grazing lands), communal flock management, uncontrolled livestock herding and breeding, and dominant crop culture in the highlands, are the major challenges to improving breeds, forage development and health interventions. The smallholder sheep-production system requires designing appropriate dissemination pathways to introduce technologies. Few projects aimed at designing improved breeding strategies for communal sheep breeding systems are underway. To this end, researchers need to be trained and favourable environments established to cultivate thinkers, methodologists and strategists.

3.4 Sheep breeding research

Breeding strategy: Although there have been consistent efforts by the livestock department of the MoA to develop breeding strategies and programs for some sheep breeds, there is yet no countrywide strategy to guide livestock genetic improvement. Both government and non-governmental research and development institutes are developing genetic improvement projects at will without any regulation of their activities. This is rather dangerous and concerned institutes, including the Livestock State Ministry and Institute of Biodiversity Conservations, need to take immediate action. In the meantime, strategies by research institutes for their mandate breeds and zones can be developed. While this was the approach adopted for Menz and Dorper sheep breeding in Amhara region and the national Dorper/Boer breeding strategy, it is now desirable to have a national breeding strategy so that the breeding efforts will not be *ad hoc* and to harmonize the mandates of the different regional institutes.

Breeding programs: Research centres are actively involved in sheep research projects, but the activities are not leading to effective breeding programs. Most projects are limited to maintaining nucleus-breeding flocks and the relatively effective projects are limited to pilot villages. The research system may need to embark on full-fledged breeding programs. Livestock breeding by its nature can not be delineated into research and development projects; it needs to be integrated into research-cum-development projects, carried out jointly by both research and development institutes. This is because breeding activities are long-term projects, costly, and the improved genetics developed through research have to be the basis for the breeding program. A promising example is the Dorper sheep-breeding program undertaken by ARARI. There is a pressing need to integrate efforts by research and development institutes, where resources must be pooled and utilized efficiently. To this end, ways and means must be found to utilize effectively the expertise in various research centres and the nucleus flocks in multiplication and research centres (e.g. the Awassi and Bonga flocks). A further point is that breeding programs are costly and hence should not be initiated if they cannot be sustained in terms of budget and staff commitments.

The research focus has to be on designing of breeding programs. This is because absence of a plan or faulty designs without clear vision might be the major reasons for failure of some programs. The design of breeding programs should consider alternative approaches such as marrying nucleus and village-based breeding schemes, as well as the conservation of indigenous genetic resources. A lot of work is required to make crossbreeding programs effective—such as schemes for efficient multiplication of crossbred rams, dissemination strategies, and maintaining desired blood levels at village levels. The design of breeding programs should be coordinated at the national level, as this requires strong expertise in quantitative genetics. In this regard, establishment of the national livestock genetic improvement centre by the MoA is a step in the right direction.

3.5 Management interventions

Genetic improvement activities have traditionally formed the centre piece of sheep research. Complementary research on improved feeding, health and socioeconomics including marketing is associated with some sheep-breeding programs, but lacking in others. The recent integrated value-chain approach with a wholesome package for sheep improvement should be promoted further. In addition, research on sheep production management needs to be revisited.

While research on feeding management currently focuses on testing improved forage varieties, most of the forage species and varieties are not well-accepted by the farming community. Research may be required on approaches for effective dissemination of improved forages, adopting species with high biomass (which are lacking for the highlands and subalpine highlands), and improving the conservation and utilization of agricultural by-products that can provide high biomass. Development of feeding and fattening packages seem to be fragmented. Projects targeting development of fattening packages for the major agro-ecological zones and sheep breeds could be considered, with a component of scaling-up for further dissemination by development institutions.

Research on disease prevalence may have to be scaled back, as extensive work has already been done and the major diseases and parasites have been identified in most of the agro-ecological zones. Animal-health research may have to focus on the delivery of health services such as strategic disease and parasite controls, improving efficiency of health clinics, improving existing and developing alternative systems for provision of community-based animal health services. Most survey reports indicate that farmers doubt the efficiency of vaccines and drugs.

Another area of research should be improvement of net offtake rates, which have been reported as low. High lamb mortality and low reproduction rates account for the major losses in sheep and reduced offtakes.

3.6 Village research sites

Livestock research in its early stages was limited to on-station research activities, but recently the focus has shifted to on-farm. A model village-based approach through organizing farmers into cooperatives has been adopted by some research institutes, such as Debre Birhan Research Centre, ILRI and ICARDA. Such models integrate research and development on breeding, feeding, health service, input provision and marketing in a cooperative context. A cooperative approach is essential to introduce technologies such improved breeding and disease control into villages. Model villages can serve as research sites for developing and testing technologies as well as demonstrating 'good practice'.

3.7 Strategic research

There is a general agreement that applied research should be the primary focus in developing countries where attaining food security is a priority. The livestock research agenda in Ethiopia targets the adoption and generation of improved technologies such as improved breeds, forages, feeding, and health packages. Lately the focus of research has shifted to scaling-up of best-bet technologies rather than generating technologies. This is an appropriate strategy given the wealth of information and technologies lying idle in research and development institutions. Research for tomorrow needs to be considered today as a small fraction of the current research agenda, while the comparative advantage of involving strategic research projects in the national program versus utilization of information generated from the international research system could also be considered.

3.8 Dissemination of information and technologies

The directories of projects and outputs of the various research institutes are readily accessed. These need to be accessible to planning departments and researchers to avoid duplication of effort. Collating and documenting such information in a national online repository would facilitate access. Professional societies such as ESAP or EIAR could be mandated to undertake the task.

Documentation should also include the various strategies, master plans and project documents published in 'grey literature'. Review and evaluation of the research system is rather difficult with current documentation.

Dissemination of research results generally targets professionals and experts through conferences and journal articles. Very little has been done to present information and technologies to end-users. The approach taken by ESGPIP and MoA to disseminate information and technologies through manuals and technical bulletins in local languages is a step in the right direction.

3.9 Effective organization of sheep research

The national research system needs to be re-organized to improve efficiency in the utilization of scarce resources and skilled personnel, within and across research centres and regional institutes. For instance, there are three main centres dealing with sheep within ARARI. Sheep research within regional institutes can be coordinated under the umbrella of one main research centre with a critical pool of staff and satellite centres (staffed with a few technical assistants) to address the different agro-ecologies and breeds. Organization of the national sheep research needs to be revised (e.g. Afar sheep/goat research by EIAR and Afar Regional Research Institute), but this cannot be done in isolation from the overall livestock research system. It is time for a more efficient research and development system and concentrating efforts on selected commodities—for instance, setting up institutes for selected species (such as an Institute for Sheep Research) and integration of research and development to facilitate the dissemination of technologies (such as Ministry of Livestock Research and Development).

4 Concluding remarks

The way information on activities on sheep research, results/outputs and development projects is currently documented does not enable a comprehensive appraisal of the sheep research system in Ethiopia. The purpose of this review was therefore to provide an overview of sheep research in Ethiopia and suggest a way forward based on the collated information. Given the challenges encountered in obtaining all the information necessary, the review is in no way exhaustive; a comprehensive bibliographic review of individual research projects and outputs and a systematic appraisal of the entire research system are still necessary.

From this review, it is clear that numerous research projects have been undertaken. A wealth of information and a number of technologies have been generated. Some of the research outputs have been published in technical journals, MSc and PhD theses, annual and progress reports. While technologies have been demonstrated through field days and promoted through pamphlets and brochures, adoption of the technologies by end-users remains low. There are also gaps in research and development efforts (e.g. breeding programs by the research and development institutes are not coordinated) that need to be addressed. This calls for a restructuring of the entire sheep research and development platform. The link between research and development wings of the livestock sector need to be strengthened for effective dissemination of research outputs.

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