ICARDA

Science for resilient livelihoods in dry areas

Breeding Objectives of Sheep and Goat Keepers in Ethiopia

Solomon Gizaw, Ayele Abebe, Tesfaye Getachew, Barbara Rischkowsky, and Aynalem Haile

September 2020

WORKING PAPER

ISBN13: 978-92-9127-524-3

Keywords: Small ruminant breeds, production systems, agroecologies, production objectives, breeding objectives, breeding program design, multinomial logistic regression

Working Papers
Working Papers are one of ICARDA's global public goods; they capture and share knowledge and learning from projects and research partnerships. Each paper is internally reviewed as part of the Center's publishing process.

Suggested citation
Gizaw, S., A. Ayele, T. Getachew, B. Rischkowsky, and A. Haile. 2020. *Breeding Objectives of Sheep and Goat Keepers in Ethiopia*. Amman, Jordan: International Center for Agricultural Research in the Dry Areas (ICARDA).

About ICARDA
Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is a non-profit, CGIAR Research Center that focusses on delivering innovative solutions for sustainable agricultural development in the non-tropical dry areas of the developing world.

We provide innovative, science-based solutions to improve the livelihoods and resilience of resource-poor smallholder farmers. We do this through strategic partnerships, linking research to development, and capacity development, and by taking into account gender equality and the role of youth in transforming the non-tropical dry areas.

Address
Dalia Building, Second Floor, Bashir El Kasser St, Verdun, Beirut, Lebanon 1108-2010.
www.icarda.org

CGIAR
A CGIAR Research Center
cgiar.org

Table of contents

LIST OF FIGURES 5

Executive summary

Small ruminant production is the mainstay of livelihoods for the smallholder farmers and pastoralists in Ethiopia and the main foreign exchange earner for the country. The diverse production systems, agroecologies and small ruminant genetic resources in the country present a huge potential for small ruminant development. However, these genetic resources have not yet been fully exploited because of a lack of structured genetic improvement programs.

This study aims to synthesize, document and avail sheep and goat keepers' production and breeding objectives and also to look for patterns in sheep and goat keepers' objectives across breed groups, production systems, and agroecologies. The ultimate goal is availing the information for designing relevant breeding programs.

This study was based on publications on definition of sheep and goat breeding objectives. A total of 93 studies (61 on sheep and 32 on goat) were considered as observations/records for the study. These records were from 40 PhD dissertations, MSc theses, and journal articles (29 on sheep and 11 on goat); some of these being produced in more than one location and therefore resulting in more observations than the number of publications. All the studies used the same method to elicit the respondents' rankings of traits; namely deriving weighted index scores for each trait based on the number of respondents, ranking each trait from first to third most important. The studies were structured by production systems and agroecologies to conduct disaggregated analysis by system/agroecology. The index scores were used in descriptive analyses of production objectives and breeding objective traits across breeds and production systems/agroecologies and disaggregated analyses by production system/agroecology and breeds. Inferential statistical analyses were conducted to infer the statistical significance of the respondents' rankings of production and breeding objectives.

All 93 studies reviewed in this paper described the production systems in which the studies were conducted, which indicates the relevance of production system settings to the production and breeding objectives of sheep and goat keepers in Ethiopia. The production objectives mentioned by sheep and goat keepers include both tangible and intangible benefits. The tangible benefits of keeping small ruminants include: generating income from sale of live animals, producing meat, milk, fat tail (used to consume as a source of high energy food), and manure for household use, and producing skin for both sale and household use. Small ruminants also serve intangible functions as a form of capital store (mentioned in all 93 studies reviewed) and fulfilling social obligations (e.g. dowry and gifts). The objectives mentioned by the majority (at least 50%) of the studies reviewed were capital investment/saving, income generation, meat production, manure production, and social functions for keeping sheep, capital store, income generation, meat production, and milk production for keeping goats (although mentioned in only 37.5% of the studies). Skin, milk, fat tail and fleece production were mentioned in, respectively, 27.9%, 24.6%, 9.8% and 4.9% of the studies as sheep production objectives. For goat keeping, milk production, social function, skin and manure, skin production were mentioned in 37.5%, 34.4%, 25.0% and 21.9% of the studies, respectively.

© Credit to add

Inferential statistical analysis indicates cash income generation was the top production objective for sheep rearing, the difference between the ranks allocated by the sheep keepers for cash income being significantly higher than for all other objectives. Meat production and capital investment/saving were the joint second most important objectives for sheep keepers. For goat keepers, the most important production objective was cash generation, but its average rank was not significantly different ($P > 0.05$) from the other objectives except the social function ($P = 0.027$) and the ranks of the other objectives were statistically similar to the objective of social functions ($P > 0.05$). By system, important sheep functions are capital store (investment/saving), cash generation, manure, and meat production in the sub-moist highland mixed crop-livestock system; capital, cash, and meat in both the wet highland and sub-moist lowland mixed crop-livestock system; and capital, cash, meat, social functions, and milk production in the dry lowland pastoral/agropastoral system.

The most important goat rearing objective of smallholder farmers in the highland/midland and lowland mixed crop-livestock systems is to generate cash income. Cash income as a major objective was mentioned in all the reviewed studies conducted in the sub-moist highlands and in 85.7% of the studies in the sub-moist lowlands, but only in 28.6% of the studies in the wet highlands. In the pastoral/agropastoral system, milk production was the primary objective of keeping goats and was mentioned in all the studies reviewed, whereas cash generation and meat production for home consumption was mentioned in only 37.5% of the studies reviewed.

Using nominal regression analysis of the ranking of ram breeding objective traits showed that body size was significantly ($P = 0.00 – 0.04$) more likely to be ranked in the top three most preferred traits, compared to all the other traits; the odds ratio ranging from 0.001 to 0.108. Similarly, the likelihood of sheep keepers including other traits in their three top preferred traits was significantly lower than the odds for coat color, but not body size and growth rate. Body size was found to be 9.3 times more likely ($P = 0.039$) than coat color to be ranked among the top three traits. Similar preferences of traits were observed for ewe traits. Twinning rate was also more likely to be among the top three most preferred traits compared to the other ewe traits. In general, meat production/size/growth traits (body size, ram growth rate, ewe growth rate, lamb/kid growth rate) were about 99, 79, and 98 times more popular as top traits than adaptation traits (tolerance to diseases, tolerance to drought, survival, mothering ability), reproduction traits (libido/mating ability, testicle size, age at first mating/parturition, prolificacy, lambing interval, twinning rate, longevity), and aesthetic/appearance traits (horn size/shape, coat color, tail size/shape). Similar preferences were expressed by buck breeders, except aesthetic traits were equally as popular as size/growth traits. For ewes and does, size traits are 84, 54, 71, and 58 times more popular for ewes and 96, 14, 84, and 21 times more popular for does than adaptation, aesthetic/appearance, reproduction and milk traits, respectively.

Very few studies used bio-economic modelling to derive economic values of traits, which helps to rank the relative importance of traits, their relative weights for constructing multi-trait selection indexes as well as returns to investment in selection programs. Based on their economic values, the top four traits identified were lamb survival, lambing interval, litter size, and body size.

It can be concluded that the primary small ruminant production objective of sheep and goat keepers in Ethiopia is to generate cash income from the sale of live animals. Use of animals as capital store, savings, and investment is also a high priority objective. There are slight variations across production systems and species. While the above definition of breeding objectives applies mainly for smallholder sheep keepers in the highlands, the pastoralists/agropastoralists aim to produce sheep that are well adapted to their production environment and, at the same time, fetch higher market prices. Goat breeding objectives are similar to sheep breeding objectives, except that goat keepers in the lowland mixed crop-livestock system prefer to breed dual purpose meat-milk animals. Contrary to current trends of defining objectives at district level, it is recommended that breeding objectives may be defined at breed level with sound sampling strategy considering production systems, agroecologies, and farmers' cultural values. Multi-trait selection programs are recommended considering the high-ranking traits. This requires revising the existing breeding programs. Simulated alternative breeding program designs need to be evaluated to design breeding programs including the top-ranking traits. Further studies to refine the importance of adaptation traits, particularly in marginal areas, must be carried out.

1. Introduction

Small ruminant production is the mainstay of livelihoods for the smallholder farmers and pastoralists and the main foreign exchange earner for Ethiopia. In Ethiopia, sheep and goat populations are estimated at 30.7 and 30.2 million, respectively (Central Statistical Agency 2017). The diverse production systems, agroecologies, and small ruminant genetic resources in the country means the potential for small ruminant development is huge. However, these genetic resources have not yet been fully exploited because of a lack of structured genetic improvement programs.

Currently, there is a great drive towards the utilization of these small ruminant genetic resources. Several genetic improvement programs and projects by the national agricultural system and international research organizations are underway. Genetic improvement of the small ruminant resources has been identified as a major component of the Livestock Master Plan (Shapiro et al. 2015) and a major component of the sectoral project of the Ministry of Agriculture and Livestock resources. Commensurate to this campaign, and now a major topic of research encompassing MSc and PhD projects, is the design of breeding programs, which necessitates the definition of breeding objectives.

The diverse production systems, agroecologies, and small ruminant genetic resources also entail diverse production and breeding objectives of sheep and goat keepers. Since describing production systems and defining production and breeding objectives of sheep and goat keepers are the first and critical steps towards designing breeding programs, due attention needs to be given to the accuracy of the methods used and approaches taken by research projects. The cost-effectiveness of such research endeavors also needs to be evaluated. Furthermore, it is important to explore agroecological, production system, and breed group patterns in the breeding objectives of sheep and goat keepers.

This study aims to synthesize, document, and avail sheep and goat keepers' production and breeding objectives, and also to look for patterns in sheep and goat keepers' objectives across breed groups, production systems, and agroecologies. The ultimate goal is availing the information for designing relevant breeding programs. The numerous published and unpublished research outputs available in the form of published journal articles and PhD and MSc theses were used for the study.

2. Materials and methods

2.1. Data source

This study was based on publications on the definition of sheep and goat breeding objectives. A total of 93 studies (61 on sheep and 32 on goat) were considered as observations/records for the study. These records were from 40 PhD dissertations, MSc theses, and journal articles (29 on sheep and 11 on goat); some of these being produced in more than one location and therefore resulting in more observations than the number of publications.

Data were generated from the publications on ranking of breeding objective traits. All the studies used the same method to elicit the respondents' rankings of traits, namely the method laid out by Bett et al. (2009); deriving weighted index scores for each trait based on the number of respondents ranking each trait from first to third most important.

2.2. Description of study locations

The studies were structured by production systems and agroecologies to conduct disaggregated analysis by system/agroecology. The studies classified the systems very broadly into mixed crop-livestock and pastoral-agropastoral systems, although some did classify the mixed system by agroecology. We followed an earlier

Table 1. Small ruminant production subsystems in the mixed crop-livestock system in Ethiopia.

Subsystems	Agroecology		Cropping pattern (ha/head)			Flock characteristics*				
	Alt. (m)	Rainfall (mm)	Cereal	Coffee	Enset*	Sheep1	Sheep2	Goat1	Sheep flock	Goat flock
I. Sheep extensive subsystem	2,524	660	1.9	0.000	0.00	0.29	70.7	0.13	6.7	6.7
II. Sheep semi-extensive subsystem	2,352	1,279	4.7	0.007	0.00	0.23	75.4	0.09	5.6	4.4
III. Sheep tethering subsystem	2,593	1,404	2.5	0.060	0.78	0.24	86.5	0.05	3.4	2.6
IV. Sheep-Goat tethering subsystem	1,959	1,530	2.7	1.010	0.37	0.17	65.0	0.09	2.3	2.1
V. Goat-Sheep extensive subsystem	1,940	859	5.4	0.002	0.00	0.15	42.0	0.20	5.4	6.6
VI. Goat extensive subsystem	1,287	1,045	6.9	0.090	0.05	0.03	12.8	0.22	4.4	4.5

* Sheep1: ratio of sheep to cattle; Sheep2: percentage of sheep in small ruminant flocks (relative to goats); Sheep flock: sheep flock size; Cereal (ha): area of household under cereal plot. Enset: *Ensete ventricosum*.

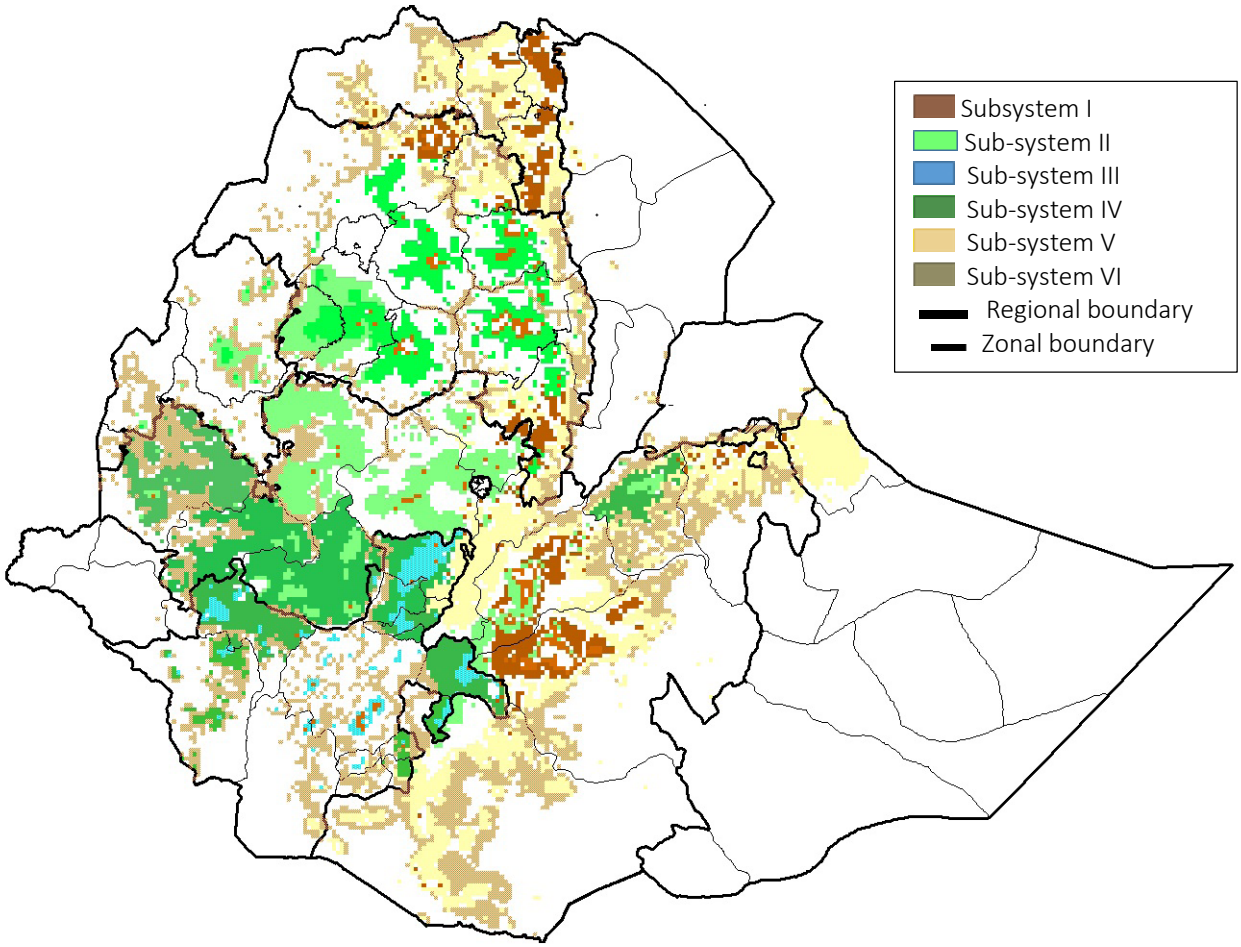
classification of small ruminant systems (Gizaw et al. 2015; Fig. 1 and Table 1) to structure the data into subsystems within the mixed crop-livestock system. The small ruminant systems could also be simplified into mixed crop-livestock systems in the sub-moist/dry highlands (subsystem I), in the wet highlands/midlands (subsystems II, III and IV), in the lowlands (subsystem V), and the pastoral/agropastoral systems (subsystem VI), as was used in the synthesis of the current paper. This classification also helps to relate the sheep breeds to systems/agroecologies. For instance, subsystem I is inhabited by short, fat-tailed sheep (Menz, Wollo, Farta, Sekota/Tigray Highland, Semien), and subsystems II and III by long, fat-tailed sheep (Horro, Bonga, Arsi-bale, Adilo/Doyo Gena).

2.3. Data analysis

The index scores were used in (a) descriptive analyses of production objectives and breeding objective traits across breeds and production systems/agroecologies and (b) disaggregated analyses by production system/agroecology and breeds. Inferential statistical analyses were conducted to infer the statistical significance of the respondents' rankings of production and breeding objectives.

The similarities and dissimilarities between livestock keepers' production objectives in the different systems/agroecologies and keeping different breeds was tested using the nonparametric Kendall's test statistic. Kendall's coefficient of concordance (Kendall's W) was used to test the agreement between the studies in the rankings of the traits. The Kruskal-Wallis test was used to test the significance of differences in production objective ranks between production systems/agroecologies; taking the ranks in each system as independent samples. For analysis of breeding objective traits, nominal logistic regression analysis was used. All tests were used as implemented in SPSS 20 (2011). For all analyses, production objectives and breeding objective traits, which were mentioned in at least 33% of the studies, were used in order to ensure enough samples were

Figure 1. Spatial characterization of six small ruminant subsystems in the mixed crop-livestock system in Ethiopia.



The white area is mainly the pastoral-agropastoral system.
Source: Adapted from Gizaw et al. (2015).

3. Results

3.1. Production objectives

All 93 studies reviewed in this paper described the production systems in which the studies were conducted, which indicates the relevance of production system settings to the production and breeding objectives of sheep and goat keepers in Ethiopia. As a descriptor of production systems, flock structures in the different production systems and agroecologies were summarized (Table 2). Within the mixed crop-livestock system, both sheep and goat flock sizes were larger in the lowlands than in the highlands. Within the highland mixed system, farmers in the sub-moist/dry zones kept more sheep than farmers in the wet zones. Goats are not kept in the wet highlands as our searches did not return any studies on goat keeping in the wet highlands.

The production objectives mentioned by sheep and goat keepers include both tangible and intangible benefits. The tangible benefits of keeping small ruminants include: generating income from the sale of live animals, producing meat, milk, fat tail (used to consume as a source of high-energy food), and manure for household use, and producing skin for both sale and household use. Small

Table 2. Flock structure of sheep and goat flocks in different production systems in Ethiopia.

		Number of animals				
Production system	Agroecology	< 6 months	6-12 months	Adult females	Adult males	Castrates
Sheep						
Mixed crop-livestock	Sub-moist highland	2.9	3.4	5.4	1.0	0.8
Mixed crop-livestock	Wet highland*	2.5	2.4	3.4	0.6	0.5
Mixed crop-livestock	Lowland	8.1	3.2	8.1	2.7	1.2
Pastoral/ agropastoral	Lowland	2.6	8.9	19.6	1.2	0.3
Goat						
Mixed crop-livestock	Sub-moist highland	3.0	3.0	4.1	0.8	2.6
Mixed crop-livestock	Wet highland	-	-	-	-	-
Mixed crop-livestock	Lowland	7.3	4.0	10.4	3.0	1.0
Pastoral/ agropastoral	Lowland	6.1	5.3	11.5	1.6	0.4

* Includes wet midlands.

ruminants also serve intangible functions as a form of capital store (mentioned in all 93 studies reviewed) and fulfilling social obligations (e.g. dowry and gifts). The objectives mentioned by the majority (at least 50%) of the studies reviewed were capital investment/saving, income generation, meat production, manure production, and social functions for keeping sheep, capital store, income generation, meat production, and milk production for keeping goats (although mentioned in only 37.5% of the studies). Skin, milk, fleece, and fat tail production were mentioned in, respectively, 27.9%, 24.6%, 4.9%, and 9.8% of the studies as sheep production objectives. For goat keeping, social function, manure, skin, and milk production were mentioned in 34.4%, 21.9%, 25.0%, and, 37.5% of the studies, respectively.

Using inferential statistical analysis of nonparametric tests for related samples including objectives mentioned in at least 50% of the studies (Table 3), sheep rearing objectives were grouped into three distinct groups, whereas goat rearing objectives were grouped into two groups. Cash income generation was the top production objective for sheep rearing; the difference between the ranks allocated by the sheep keepers for cash income generation being significantly higher than for all other objectives. Meat production and capital investment/saving were the second most important objectives for sheep keepers; the ranks allocated to meat production and capital investment/saving objectives being statistically similar. For goat keepers, the most important production objective was cash generation, but its average rank was not significantly different ($P > 0.05$) from the other objectives except the social function ($P = 0.027$) and the ranks of the other objectives were statistically similar to the objective of social functions ($P > 0.05$). However, the absence of significant differences between the goat keepers' objectives could be due to the small sample size; the studies which had common records being too few. This was confirmed by running the analysis with fewer objectives that had larger sample sizes (cash generation, meat production and capital), which resulted in significantly higher ranking for cash income compared

Table 3. Homogenous subsets of sheep and goat keepers' production objectives in Ethiopia identified based on statistical similarities of their ranks.

	Sheep rearing			Goat rearing	
Objectives/homogenous sets*	**1**	**2**	**3**	**1**	**2**
Income generation	1.31**			1.80	
Meat production		2.55		3.20	3.20
Capital (saving/investment)		2.65		2.60	2.60
Milk production				2.60	2.60
Manure production			4.22		
Social functions			4.26		4.80
Test Statistic	-	0.86	2.21	3.00	7.32
Sig. (2-sided test)	-	0.35	0.14	0.39	0.062
Adjusted Sig. (2-sided test)	-	0.66	0.31	0.39	0.062
Kendall's coefficient of concordance (W)		0.63		0.50	

* Homogeneous subsets are grouped based on absence of significant differences at 0.05 level of significance.

** Average ranks of objectives were derived from their index scores after converting into ranks.

to meat production (P = 0.018) and capital investment/saving (P = 0.000). The relatively higher Kendall's coefficient of concordance (Table 3) for sheep indicated a stronger agreement between the sheep studies than the goat studies in the rankings of the objectives.

The relative importance of sheep and goat keepers' production objectives in four production systems were assessed based on the percentage of studies in which the objectives were mentioned, and the scores allocated to the objectives (Table 4). Production objectives that were mentioned in most of the sheep studies reviewed (at least 70% of the studies) were: sheep functions as a form of capital (investment/saving), cash generators, manure, and meat producers in the sub-moist highland mixed crop-livestock system; capital, cash, and meat in both the wet highland and sub-moist lowland mixed crop-livestock system; and capital, cash, meat, social functions, and milk production in the dry lowland pastoral-agropastoral system.

A nonparametric statistical analysis was conducted to test the priority of production objectives within production systems. In the sub-moist highland mixed crop-livestock system, cash generation was a significantly more important objective than manure production (P = 0.027) and social functions (P = 0.000), but statistically equally important as the rest of the objectives (capital, meat, and manure production) in the sub-moist highlands. Similarly, capital investment/saving and meat production received significantly higher scores than social functions (P = 0.003, 0.44), but both were ranked equally with the other functions. In the wet highland mixed crop-livestock system, cash generation was a significantly more important objective than manure production (P = 0.000), social functions (P = 0.000), and capital storage (P = 0.017), but it was statistically equally as important as meat production, which was more important than social functions (P = 0.01) and manure production (P = 0.001). There were no significant differences between the scores allocated for the objectives in the lowland mixed crop-livestock and pastoral-agropastoral systems. There was very high agreement among the studies reviewed regarding the priority of objectives in the sub-moist highland, wet highland, and lowland mixed crop-livestock systems (W = 0.80, 0.68 and 0.80), but not in the pastoral-agropastoral system (W = 0.29).

A further nonparametric statistical analysis clustered the production systems into two groups based on the statistical similarity of the median scores, with respect to the production objectives that were significantly different within the systems (Table 5). For instance, the median of the scores earned by the objective of income generation was significantly higher in the wet highlands than in sub-moist highland mixed systems, but was statistically similar among all other pairs of systems.

The most important goat rearing objective of smallholder farmers in the highland/midland and lowland mixed crop-livestock systems is to generate cash income. Cash income as a major objective was mentioned in all the reviewed studies conducted in the sub-moist highlands and in 85.7% of the studies in the sub-moist lowlands, but only in 28.6% of the studies in the wet highlands. In the sub-moist highlands and lowlands, the second and third functions of goats were milk and meat production, respectively, while in the wet highlands, the second and third functions of goats were capital accumulation and social functions, respectively. In the pastoral-agropastoral system, milk production was the primary objective of keeping goats and was mentioned in all the studies reviewed (Table 4), whereas cash generation and meat production for home consumption was mentioned in only 37.5% of the studies reviewed.

For all sheep producers, their primary production objectives were similar, despite keeping the different sheep breeds (Table 6); namely, to generate cash income from the sale of live animals, to produce meat for home consumption, and to use sheep as a form of capital store. These functions received the highest scores and were also preferred or mentioned in all the studies reviewed. However, milk production is also an important production objective for respondents keeping Afar and Black Head Somali (BHS) sheep breeds, as sheep milk could be consumed by humans in the pastoral system. Milk production was also mentioned as a production objective by Bonga sheep keepers. However, increased milk production could not be a production objective as sheep milk is not consumed in the Bonga area. Increased milk production might have been mentioned as an objective in relation to increased lamb growth, in which case milk could be considered as a breeding rather than a production objective. Manure was mentioned as a production objective by Farta and Wahera sheep keepers.

For farmers and pastoralists keeping goats, milk production and generating income from the sale of live

Table 4. Sheep and goat keepers' production objectives in different production systems and agroecologies in Ethiopia.

Objective	Production system	Agroecology	Sheep rearing			Goat rearing		
			N	Mean score	% of studies	N [1]	Mean score	% of studies [2]
Cash	Mixed crop-livestock	Sub-moist highland	13	0.31	84.6	3	0.35	100.0
	Mixed crop-livestock	Wet highland [3]	31	0.43	71.0	7	0.46	28.6
	Mixed crop-livestock	Sub-moist Lowland	10	0.38	70.0	14	0.44	85.7
	Pastoral/agropastoral	Dry Lowland	7	0.31	85.7	8	0.36	37.5
Manure	Mixed crop-livestock	Sub-moist highland	13	0.11	84.6	3	0.12	100.0
	Mixed crop-livestock	Wet highland	31	0.05	58.1	-	-	-
	Mixed crop-livestock	Sub-moist Lowland	10	0.12	30.0	14	0.11	28.6
	Pastoral/agropastoral	Dry Lowland	7	0.03	42.9	-	-	-
Meat	Mixed crop-livestock	Sub-moist highland	13	0.21	84.6	3	0.19	100.0
	Mixed crop-livestock	Wet highland	31	0.22	71.0	7		
	Mixed crop-livestock	Sub-moist Lowland	10	0.18	70.0	14	0.22	78.6
	Pastoral/agropastoral	Dry Lowland	7	0.17	85.7	8	0.21	37.5
Milk	Mixed crop-livestock	Sub-moist highland	13	0.05	30.8	3	0.20	100.0
	Mixed crop-livestock	Wet highland	31	0.19	19.4	-	-	-
	Mixed crop-livestock	Sub-moist Lowland	-	-	-	14	0.21	42.9
	Pastoral/agropastoral	Dry Lowland	7	0.27	71.4	3	0.42	100.0
Skin	Mixed crop-livestock	Sub-moist highland	13	0.12	30.8	-	-	-
	Mixed crop-livestock	Wet highland	31	0.02	19.4	-	-	-

Skin (cont.)	Mixed crop-livestock	Sub-moist Lowland	10	0.06	40.0	14	0.03	50.0
	Pastoral/agropastoral	Dry Lowland	7	0.03	42.9	3	0.01	33.3
Social	Mixed crop-livestock	Sub-moist highland	13	0.06	61.5	-	-	-
	Mixed crop-livestock	Wet highland	31	0.10	54.8	7	0.13	28.6
	Mixed crop-livestock	Sub-moist Lowland	10	0.09	50.0	14	0.06	57.1
	Pastoral/agropastoral	Dry Lowland	7	0.08	85.7	3	0.01	33.3
Capital	Mixed crop-livestock	Sub-moist highland	13	0.24	84.6	3	0.12	100.0
	Mixed crop-livestock	Wet highland	31	0.18	71.0	7	0.41	28.6
	Mixed crop-livestock	Sub-moist Lowland	10	0.29	70.0	14	0.18	78.6
	Pastoral/agropastoral	Dry Lowland	7	0.14	85.7	8	0.02	12.5
Tail fat	Mixed crop-livestock	Sub-moist highland	13	0.01	7.7	-	-	-
	Mixed crop-livestock	Wet highland	31	0.09	6.5	-	-	-
	Mixed crop-livestock	Sub-moist Lowland	-	-	-	-	-	-
	Pastoral/agropastoral	Dry Lowland	7	0.08	42.9	-	-	-

[1] N number of studies reviewed. [2] percentage of studies in which the objectives were mentioned. [3] includes mid-lands.

© Credit to add

Table 5. Homogenous subsets of production systems with respect to similarity of sheep and goat keepers' production objectives in Ethiopia.

Income generation		[1] Similar group 1	Similar group 2
Mixed crop-livestock	Sub-moist highland	0.280	
Pastoral-agropastoral	Dry lowland	0.315	0.315
Mixed crop-livestock	Sub-moist lowland	0.390	0.390
Mixed crop-livestock	Wet highlands		0.430
Test Statistic		5.844	5.727
Significance (P)		0.054	0.057
Capital (investment/saving)		**Subset 1**	**Subset 2**
Pastoral-agropastoral	Dry lowland	0.110	
Mixed crop-livestock	Wet highlands	0.195	0.195
Mixed crop-livestock	Sub-moist highland	0.220	0.220
Mixed crop-livestock	Sub-moist lowland		0.280
Test Statistic		3.456	5.299
Significance (P)		0.178	0.071
Manure production		**Subset 1**	**Subset 2**
Pastoral-agropastoral	Dry lowland	0.03	0.10
Mixed crop-livestock	Wet highlands	0.04	0.13
Mixed crop-livestock	Sub-moist highland		0.424
Mixed crop-livestock	Sub-moist lowland		0.765
Test Statistic		2.154	5.727
Significance (P)		0.264	0.057

[1] Each cell shows the median score for the production objective.

Table 6. Farmers'/pastoralists' relative scoring (with number of studies in parentheses) of the objectives of keeping different sheep breeds in Ethiopia.

	N*	Income	Meat	Capital store	Social function	Manure	Skin	Milk	Wool	Tail fat
Afar	6	0.37(6)*	0.19(6)	0.24(6)	0.07(6)	0.11(2)	0.02(4)	0.45(1)	-	-
Arsi-Bale	8	0.38(8)	0.28(8)	0.16(8)	0.16(8)	0.04(8)	0.03(4)	0.02(5)	-	0.12(2)
BHS	4	0.35(4)	0.13(4)	0.21(4)	0.08(4)	0.03(2)	-	0.22(4)	-	0.01(1)
Bonga	6	0.36(6)	0.17(6)	0.23(6)	0.06(3)	0.06(3)	0.03(1)	0.36(3) †	-	-
Farta	2	0.28(2)	0.23(2)	0.20(2)	0.14(2)	0.16(2)	-	-	-	-
Gumz	1	0.43(1)	0.19(1)	0.37(1)	-	-	-	-	-	-
Horro	9	0.54(9)	0.22(9)	0.14(9)	0.04(8)	0.04(8)	0.02(3)	-	-	0.09(2)
Menz	3	0.37(3)	0.17(3)	0.25(3)	0.04(2)	0.12(3)	-	-	0.08(2)	-
Sekota	2	0.25(2)	0.24(2)	0.26(2)	0.07(1)	0.13(2)	0.06(1)	0.17(1)	-	-
Washera	1	0.28(1)	0.22(1)	0.21(1)	0.13(1)	0.16(1)	-	-	-	-
Wollo	4	0.25(4)	0.20(4)	0.26(4)	0.06(1)	0.11(4)	0.15(4)	-	0.06(1)	0.01(1)

N: number of studies. * Figures in parentheses are number of studies in which the objective is identified as important. BHS: Black Head Somali sheep breed.

Table 7. Farmers/pastoralists' relative scoring (with number of studies in parentheses) of the objectives of keeping different goat breeds in Ethiopia.

Breed	N*	Income	Meat	Capital store	Social function	Manure	Skin	Milk
Abergelle	1	0.41(1)*	0.07(1)	0.01(1)	-	0.21(1)	-	0.30(1)
Arsi-Bale	4	0.33(4)	0.18(4)	0.09(2)	0.05(2)	0.09(1)	0.05(2)	0.39(4)
Begait	1	0.45(1)	0.19(1)	0.01(1)	-	-	0.003(1)	0.35(1)
CHG	9	0.38(9)	0.24(6)	0.33(8)	0.08(7)	0.08(2)	0.04(4)	0.15(4)
Gumz	3	0.64(3)	0.24(3)	0.11(3)	0.02(2)	0.014(1)	0.01(1)	-
Hararghe highland	2	0.39(2)	0.22(2)	0.04(2)	-	0.17(2)	-	0.17(2)

N: number of studies. * Figures in parentheses are number of studies in which the objective is identified as important. CHG: Central Highland Goat breed.

animals were the primary objectives of keeping goats of all breeds (Table 5). However, use of goats as capital store and manure producers are also important purposes for some of the farmers keeping Central Highland goat (CHG), Abergelle, and Harerghe highland breeds (Table 7).

3.2. Breeding objectives

3.2.1. Farmers and pastoralists trait preference

In terms of the number of studies they were mentioned in (Fig. 2), body size (expressed as either body size, body conformation or appearance in different studies), coat color, growth rate, and mating ability (also expressed as libido in some studies) were the most important ram and buck breeding objective traits for sheep and goat keepers in Ethiopia. Body size, coat color, growth rate, and libido were mentioned in 81.3%, 78.1%, 50%, and 100% of the goat studies, respectively and in 86.4%, 86.4%, 69.5%, and 100% of the sheep studies, respectively. However, the traits that were ranked most important by the goat keepers were body size, coat color, growth rate and tolerance/resistance to disease, with index scores (derived from the goat keepers' rankings of these traits) of 0.41, 0.24, 0.16, and 0.28, respectively. The traits that received the highest scores as ram breeding traits were body size, coat color, growth rate,

Figure 2. (a) Percentage of studies mentioning traits as ram and buck breeding objectives and (b) average scores allocated to ram and buck breeding objectives by sheep and goat keepers in Ethiopia.

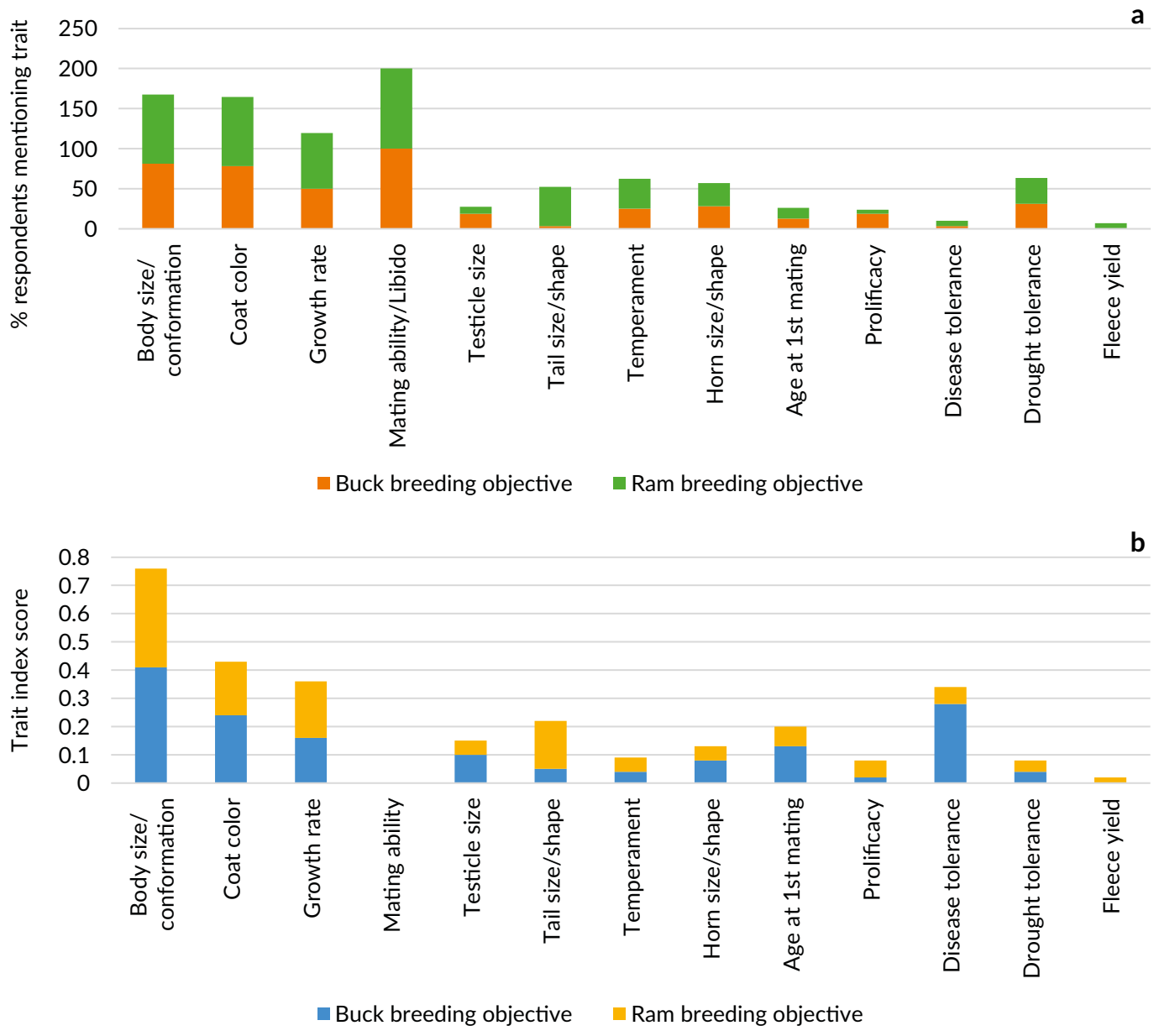
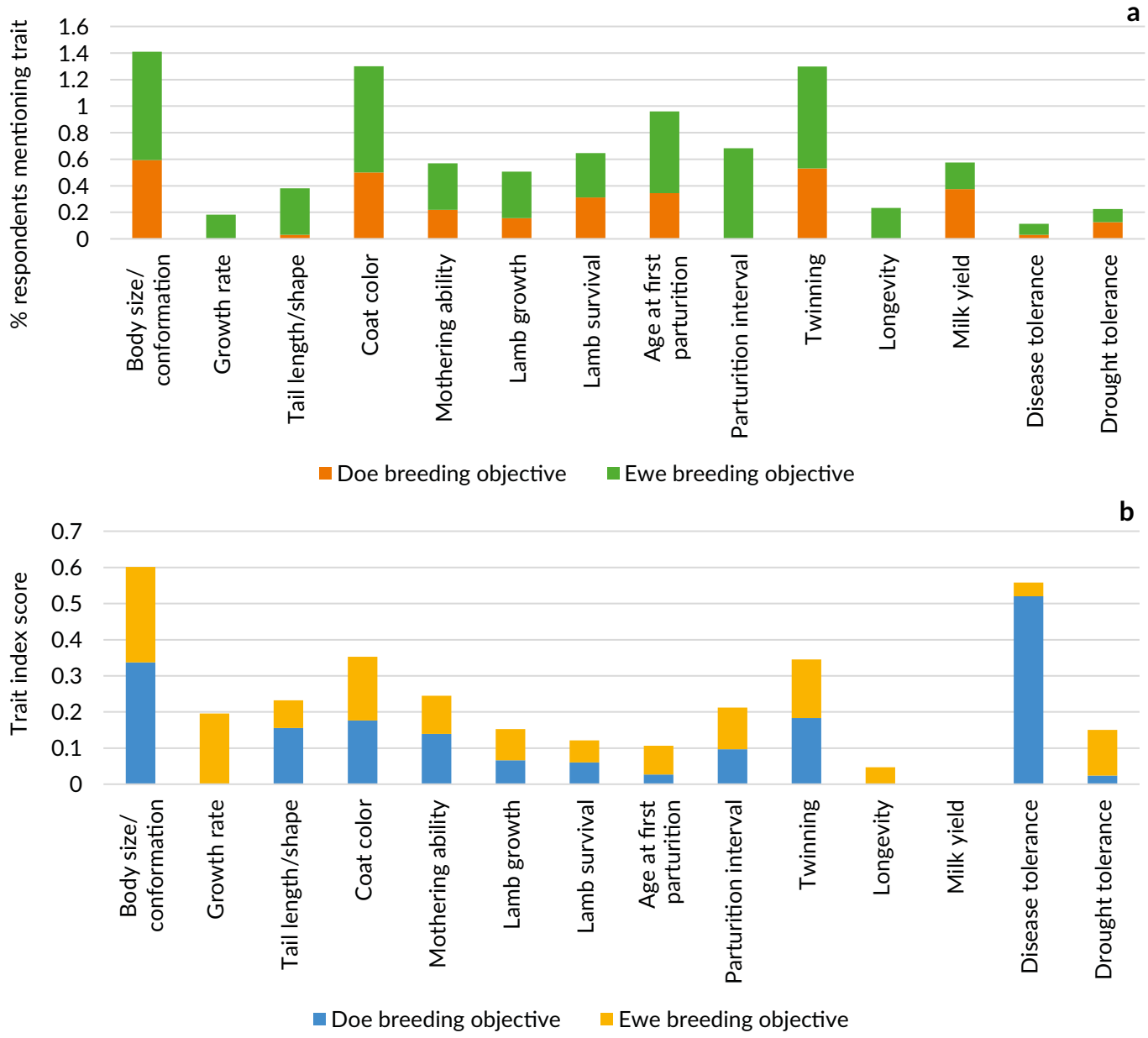


Figure 3. (a) Percentage of studies mentioning traits as doe and ewe breeding objectives and (b) average scores allocated to doe and ewe breeding objectives by sheep and goat keepers in Ethiopia.



and tail size/shape, with scores of 0.35, 0.19, 0.20, and 0.17, respectively (Fig. 2).

Doe and ewe breeding objective traits are shown in Fig. 3. In terms of the respondents' ranking/scoring, disease tolerance, body size, twinning, twinning ability, coat color, and mothering ability are the most important doe traits. Judging from the highest scores from respondents, the priority ewe breeding objectives are body size, growth rate, coat color, twinning, and drought tolerance. In terms of the frequency of studies in which traits were mentioned, body size, coat color, and twinning ability were mentioned most frequently as breeding objectives for both does and ewes; in 59%, 82%, and 50% of the studies for does, and in 80%, 53%, and 77% of the studies for ewes.

Using nominal regression analysis of the ranking of ram breeding objective traits showed that body size was significantly (P = 0.00 – 0.04) more likely to be ranked in the top three most preferred traits compared to all other traits; the odds ratio ranging from 0.001 to 0.108 (Table 8). Similarly, the likelihood of sheep keepers including the traits listed in Table 8 in their three top preferred traits was significantly lower than the odds for coat color, except for body size and growth rate. Body size was

Table 8. Odds of a ram breeding trait receiving higher ranks (first to third) than lower ranks (fourth to k, K= number of traits) in reference to body size and coat color.

	Reference trait: body size/conformation				Reference trait: coat color			
Ranked in top three traits [a]	B	Std. Error	Sig. (P)	Exp(B)	B	Std. Error	Sig. (P)	Exp(B)
Intercept	3.93	1.01	0.00	-	1.70	0.38	0	
Age at first mating	-5.03	1.30	0.00	7.0E-03	-2.80	0.90	0.002	0.061
Coat color	-2.23	1.08	0.04	1.1E-01	0[b]	-	-	-
Disease tolerance	-24.18	0.00	-	3.2E-11	-21.95	0.00	-	2.9E-10
Drought tolerance	-6.07	1.26	0.00	2.0E-03	-3.84	0.84	0.00	0.021
Growth rate	-2.63	1.08	0.02	7.2E-02	-0.40	0.54	0.45	0.667
Horn size/presence	-6.70	1.44	0.00	1.0E-03	-4.48	1.10	0.00	0.011
Libido	-6.36	1.18	0.00	2.0E-03	-4.13	0.71	0.00	0.016
Prolificacy	-24.18	0.00	-	3.2E-11	-21.95	0.00	-	2.9E-10
Tail size	-3.53	1.08	0.00	0.029	-1.29	0.53	0.015	0.273
Testicle size	-5.32	1.51	0.00	5.0E-03	-3.09	1.18	0.009	0.045
Size/conformation	0[b]	-	-	-	2.23	1.08	0.039	9.273

[a] The reference category is: 4th-12th rank.

[b] This parameter is set to zero because it is redundant.

found to be 9.3 times more likely (P = 0.039) than coat color to be ranked among the top three traits.

Similar preferences of traits were observed for ewe traits (Table 9). Calculation of the odds of traits being ranked in the top three showed that body size was more likely than all other ewe traits, except growth rate, to be ranked first to third (P = 0.000 to 0.023). Twinning rate was also more likely to be among the top three most preferred traits compared to other ewe traits. However, the comparison of twinning rate with coat color, disease tolerance, drought tolerance, ewe growth rate, milk yield, and mothering ability was not accurate due to the small sample size as indicated by the high standard errors of the parameter estimates. Similarly, coat color was more preferred than most other traits, but its comparison with some of the traits was not reliable (Table 9).

Trait groups were created by combing similar traits, namely adaptation traits (tolerance to diseases, tolerance to drought, survival, mothering ability), meat production/size/growth traits (body size, ram growth rate, ewe growth rate, lamb/kid growth rate), reproduction traits (libido/mating ability, testicle size, age at first mating/parturition, prolificacy, lambing interval, twinning rate, longevity), aesthetic/appearance traits (horn size/shape, coat color, tail size/shape), and milk yield. Ram size/growth traits were about 99, 79, and 98 times more popular as top traits than adaptation, aesthetic, and reproduction trait groups (Table 10). Similar preferences were expressed by buck breeders, but aesthetic traits were equally as popular as size/growth traits. For ewes and does, size traits are 84, 54, 71, and 58 times more popular for ewes and 96, 14, 84, and 21 times more popular for does than

Table 9. Odds of ewe breeding traits receiving higher ranks (first to third) than lower ranks (4th to k, K= number of traits) in reference to body size, twinning rate and coat color.

	Reference trait: body size/conformation				Reference trait: twinning rate				Reference trait: coat color			
	B	Std. Error	Sig.	Exp(B)	B	Std. Error	Sig.	Exp(B)	B	Std. Error	Sig.	Exp(B)
Intercept	1.79	0.41	0.00		0.63	0.31	0.04		0.51	0.30	0.09	-
Age at first mating	-2.53	0.54	0.00	0.08	-1.36	0.47	0.00	0.26	1.25	0.46	0.01	0.29
Coat color	-1.28	0.51	0.01	0.28	-0.12	0.43	0.78	0.89	0[c]	-	-	-
Disease tolerance	-22.00	0.00	-	0.00	15.94	946.3	0.99	0.00	15.8	946.3	0.99	0.00
Drought tolerance	-3.40	1.17	0.00	0.03	-2.24	1.14	0.05	0.11	2.12	1.14	0.06	0.12
Ewe growth rate	0.51	1.13	0.65	1.67	1.67	1.09	0.13	5.33	1.79	1.09	0.10	6.00
Lamb growth rate	-2.96	0.66	0.00	0.05	-1.79	0.60	0.00	0.17	1.67	0.59	0.01	0.19
Lamb survival	-3.18	0.69	0.00	0.04	-2.02	0.64	0.00	0.13	1.90	0.63	0.00	0.15
Lambing interval	-2.67	0.53	0.00	0.07	-1.51	0.46	0.00	0.22	1.39	0.46	0.00	0.25
Longevity	-3.58	0.87	0.00	0.03	-2.42	0.82	0.00	0.09	2.30	0.82	0.01	0.10
Milk yield	-1.79	0.71	0.01	0.17	-0.63	0.66	0.34	0.53	0.51	0.65	0.43	0.60
Mothering ability	-2.08	0.60	0.00	0.13	-0.92	0.54	0.09	0.40	0.80	0.53	0.13	0.45
Tail length	-2.71	0.63	0.00	0.07	-1.55	0.57	0.01	0.21	1.43	0.57	0.01	0.24
Twinning rate	-1.16	0.51	0.02	0.31	0[c]	-	-	-	0.12	0.43	0.78	1.13
Size/conformation	0[c]	-	-	-	1.16	0.51	0.02	3.20	1.28	0.51	0.01	3.60

Table 10. Sheep and goat keepers' preferences for trait groups measured by the odds of allocating higher ranks (rank first to third) to trait groups in reference to size/growth trait group in Ethiopia.

	B	Std. Error	Sig. (P)	Exp(B)	B	Std. Error	Sig. (P)	Exp(B)
	Ram breeding objectives				Ewe breeding objectives			
Intercept	2.13	0.34	0.00		0.87	0.24	0.00	
Adaptation traits	-4.48	0.81	0.00	0.01	-1.86	0.40	0.00	0.16
Aesthetic/ appearance traits	-1.57	0.39	0.00	0.21	-0.78	0.34	0.02	0.46
Reproduction traits	-4.19	0.55	0.00	0.02	-1.25	0.30	0.00	0.29
Milk yield					-0.87	0.63	0.17	0.42
Size/growth traits	0 [b]	-	-	-	0 [b]	-	-	-
	Buck breeding objectives				Doe breeding objectives			
Intercept	1.61	0.41	0.00		1.34	0.50	0.01	
Adaptation traits	-3.91	1.13	0.00	0.02	-3.18	0.80	0.00	0.04
Aesthetic/ appearance traits	-0.39	0.58	0.50	0.68	-0.16	0.76	0.84	0.86
Reproduction traits	-1.99	0.53	0.00	0.14	-1.86	0.59	0.00	0.16
Milk yield					-0.24	0.84	0.78	0.79
Size/growth traits	0 [b]							

adaptation, aesthetic/appearance, reproduction, and milk traits, respectively (Table 10).

The agreement between the studies reviewed in the rankings of traits was evaluated using Kendall's coefficient of concordance (W), which ranges from zero (no agreement) to 1.0 (complete agreement). Kendall's W for goat and sheep studies, respectively, was 1.0 and 0.38 between the rankings of body size and growth rate, 0.69 and 0.92 for body size and coat color, 0.06 and 0.048 for growth and coat color, 0.82 and 1.0 for size and libido, 0.49 and 0.84 for coat color and libido, 1.0 and 1.0 for size and horn, and 1.0 and 0.94 for coat color and horn.

Ranking of ram breeding objective traits as shown by the index scores derived from the ranking provided by the sheep keepers (Table 11) were largely similar across all breeds. The most important traits common to all breeds were body size, coat color, growth rate, and tail size/ shape. Ram mating ability/libido was ranked the first and fourth most important trait for Wollo and Arsi-Bale breeds, respectively. Horn size/shape for Arsi-Bale and age at first mating for the Sekota breed were ranked the second most important traits. Goat keepers' buck breeding traits receiving the highest scores of importance were body size, coat color, growth rate, mating ability/libido, disease and drought tolerance, horn size/shape, age at first mating, and testicle size (Table 12). However, some of the traits were preferred in only a few breeds, as shown in Table 11.

Table 11. Farmers' and pastoralists' preference scoring (with number of studies in which traits were mentioned in parentheses) of ram breeding objective traits for different breeds of Ethiopia.

Trait/breed	Afar	Arsi-Bale	Begait	BHS	Bonga	Farta	Gumz	Horro	Menz	Sekota	Washera	Wollo
N	7	8	1	4	7		1	18	5	2		4
Body size/ conformation	0.36 (7)	0.38(7)	0.19(1)	0.28(3)	0.29(6)	-	0.32(1)	0.40(18)	0.32(4)	0.24(2)	-	0.24(3)
Coat color	0.19 (7)	0.21(8)	0.18(1)	0.14(3)	0.19(6)	-	0.21(1)	0.19(18)	0.15(4)	0.08(1)	-	0.20(3
Growth rate	0.22(6)	0.17(7)	0.21(1)	0.23(3)	0.15(5)	-	0.18(1)	0.21(11)	0.21(3)	0.12(2)	-	0.23(3
Mating ability	0.06(7)	0.16(8)	-	0.04(4)	0.09(7)	-	0.09(1)	0.02(18)	0.04(5)	0.07(2)	-	0.24(4)
Testicle size	-	0.05(5)	-	-	-	-	-	-	-	-	-	-
Tail size/shape	0.15(4)	0.15(3)	0.20(1)	0.12(2)	0.20(4)	-	0.14(1)	0.19(11)	0.13(4)	-	-	-
Temperament	-	0.04(7)	-	0.05(3)	0.08(4)	-	-	0.01(4)	-	0.05(1)	-	0.08(3)
Horn size/ shape	0.01(2)	0.30(1)	-	-	0.01(3)	-	-	0.04(7)	0.03(3)	0.08(1)	-	-
Age at first mating	-	-	-	-	-	-	0.06(1)	0.06(6)	-	0.18(1)	-	-
Prolificacy	-	0.05(2)	-	-	0.10(1)	-	-	-	-	-	-	-
Disease tolerance	-	-	-	-	-	-	-	0.06(3)	0.06(1)	-	-	-
Drought tolerance	0.05(5)	0.01(2)	-	0.09(3)	0.03(1)	-	-	0.03(6)	0.07(1)	0.06(1)	-	-
Fleece yield	-	-	-	-	0.03(1)	-	-	-	0.02(3)	-	-	-

N: number of studies reviewed. BHS: Black Head Somali sheep breed.

Table 12. Farmers' and pastoralists' preference scoring (with number of studies in which traits were mentioned in parentheses) of buck breeding objective traits for different breeds of Ethiopia.

Trait/Breed	Abergelle	Arsi-Bale	Begait	CHG	Gumz	Hararghe highland	Long-eared Somali	Short-eared Somali
N of studies	2	4	1	14	1	2	1	1
Body size/ conformation	0.37(2)	0.35(4)	0.33(1)	0.46(14)	0.33(1)	0.35(2)	0.39(1)	0.37(1)
Coat color	0.25(1)	0.24(4)	0.09(1)	0.26(14)	0.23(1)	0.26(2)	0.24(1)	0.11(1)
Growth rate	0.09(1)	0.05(4)	0.23(1)	0.23(5)	0.22(1)	0.09(2)	0.29(1)	0.20(1)
Mating ability	0.26(2)	0.07(4)	0.18(1)	0.10(18)	0.05(3)	0.04(2)	0.04(1)	0.12(1)
Testicle size	-	0.10(4)	-	-	-	0.11(2)	-	-
Tail size/shape	-	-	-	0.05(1)	-	-	-	-
Temperament	-	0.04(4)	-	0.08(2)	-	0.02(2)	-	-
Horn size/ shape	0.02(1)	-	0.04(1)	0.15(3)	0.02(1)	0.19(1)	-	0.01(1)
Age at first mating	-	-	-	0.17(3)	-	-	-	-
Prolificacy	-	0.027(3)	-	0.03(1)	-	-	-	0.03(1)
Disease tolerance	0.28(1)	-	-	-	-	-	-	-
Drought tolerance	0.03(1)	-	0.13(1)	0.03(7)	0.01(1)	-	-	-

CHG: Central Highland Goat breed.

Table 13. Farmers' and pastoralists' preference scoring (with number of studies in which traits were mentioned in parentheses) of ewe breeding objective traits for different breeds of Ethiopia.

Trait/breed	Afar	Arsi-Bale	Begait	BHS	Bonga	Farta	Gumz	Horro	Menz	Sekota	Washera	Wollo
N *	7	7	1	4	6	2	1	15	5	2	1	3
Body size/ conformation	0.26(7)	0.36(7)	0.27(1)	0.14(1)	0.22(5)	0.22(2)	0.2(1)	0.3(15)	0.16(4)	0.22(2)	0.22(1)	0.20(3)
Growth rate	-	-	0.14(1)	0.16(1)	-	0.20(2)	-	0.2(5)	0.29(1)	-	0.17(1)	-
Tail length	0.07(4)	-	0.14(1)	0.01(1)	0.11(3)	-	-	0.08(10)	0.05(2)	-	-	-
Coat color	0.13(7)	0.20(7)	0.14(1)	0.17(3)	0.2(6)	0.16(2)	0.16(1)	0.22(13)	0.12(3)	0.05(1)	0.16(1)	0.15(3)
Mothering ability	0.16(2)	0.07(5)	-	-	0.08(3)	-	0.19(1)	0.08(6)	0.22(2)	0.08(2)	-	-
Lamb growth	0.11(2)	0.06(5)	-	-	0.08(5)	-	0.10(1)	0.08(6)	0.15(1)	0.17(1)	-	-
Lamb survival	0.06(4)	0.03(6)	-	-	0.04(1)	-	-	0.08(6)	0.1(2)	0.07(1)	-	-
Age at first mating	0.09(6)	0.04(1)	0.15(1)	0.04(3)	0.10(5)	-	0.06(1)	0.07(12)	0.08(3)	0.10(2)	-	0.08(3)
Lambing interval	0.17(7)	0.05(5)	-	0.02(2)	0.11(6)	0.09(2)	0.13(1)	0.06(10)	0.22(3)	0.17(1)	0.12(1)	0.24(3)
Twinning rate	0.10(7)	0.22(4)	-	0.17(4)	0.16(6)	0.23(2)	0.16(1)	0.14(12)	0.18(5)	0.09(1)	0.22(1)	0.26(3)
Longevity	0.04(1)	-	-	0.06(3)	0.09(4)	0.01(2)	-	0.01(2)	0.02(1)	-	0.02(1)	-
Milk yield	0.22(2)	0.11(4)	-	0.15(3)	0.11(1)	-	-	-	0.01(1)	0.11(1)	-	-
Disease resistance	-	-	-	-	-	0.01(1)	-	0.06(3)	-	-	0.01(1)	-
Drought tolerance	-	-	-	0.37(1)	0.02(1)	0.05(2)	-	-	0.21(1)	-	0.06(1)	-

N: number of studies reviewed. BHS: Black Head Somali sheep breed.

Table 14. Farmers' and pastoralists' preference scoring (with number of studies in which traits were mentioned in parentheses) of doe breeding objective traits for different breeds of Ethiopia.

Trait/Breed	Abergelle	Arsi-Bale	Begait	CHG	Gumz	Hararghe highland	Long-eared Somali	Short-eared Somali
N	2	1	1	11	1	2	1	1
Body size/ conformation	0.21(1)	0.13(1)	0.33(1)	0.4(11)	0.16(1)	0.31(2)	0.31(1)	0.28(1)
Tail length	0.16(1)	-	-	-	-	-	-	-
Coat color	0.06(1)	0.08(1)	-	0.21(9)	0.07(1)	0.26(2)	0.17(1)	0.02(1)
Mothering ability	0.06(1)	0.11(1)	0.12(1)	0.35(1)	0.15(1)	0.09(2)	-	-
Lamb growth	0.07(1)	0.08(1)	-	-	0.11(1)	0.04(2)	-	-
Lamb survival	-	-	0.08(1)	0.03(5)	-	0.12(2)	0.14(1)	-
Age at first mating	-	-	0.04(1)	0.03(7)	-	-	-	0.02(1)
Lambing interval	0.14(2)	0.07(1)	0.04(1)	0.12(8)	0.08(1)	0.01(1)	-	0.03(1)
Twinning rate	0.12(1)	0.15(1)	0.23(1)	0.20(9)	0.34(1)	0.09(2)	0.07(1)	0.22(1)
Milk yield	0.30(2)	0.20(1)	0.17(1)	0.16(3)	0.02(1)	0.08(2)	0.21(1)	0.37(1)
Disease resistance	0.52(1)	-	-	-	-	-	-	-
Drought tolerance	0.06(1)	-	-	0.01(3)	-	-	-	-

N: number of studies reviewed. CHG: Central Highland Goat breed.

Ewe breeding objectives included both body size/growth rate and reproduction traits (Table 13). Milk yield is more important for Afar and BHS sheep keepers and drought tolerance for BHS and Menz sheep keepers. For goat keepers (Table 14), besides body size/growth rate and reproduction traits, milk yield is highly important for keepers of Abergelle, Arsi-Bale, Begait, Long-eared Somali, and Short-eared Somali breeds. Resistance to disease was mentioned by Abergelle goat keepers only.

In general, ram breeding objectives identified by sheep keepers in both the mixed crop-livestock systems and pastoral-agropastoral systems were similar, when breeding objective traits mentioned in at least 50% of the studies reviewed in the current study are considered. The traits included body size, coat color, growth rate, mating ability, testicle size, tail size/shape, drought tolerance, temperament, and horn size/shape (Table 14). Tolerance to drought was more important in the lowland than in the highland mixed crop-livestock system. However, the top four ranked traits were body size, coat color, growth rate, and tail size/shape in both the lowland and in the highland mixed crop-livestock systems. For pastoralists/agropastoralists, the most important traits that received higher scores were body size, growth rate, tail size/shape, and drought tolerance for pastoralists and body size, growth rate, and coat color for agropastoralists (Table 15).

Nominal logistic regression analysis of the rankings of trait groups indicated that body size/growth trait group was significantly more likely to be ranked in the top three most preferred sheep traits. The odds of adaptation traits and aesthetic/appearance traits being ranked as first to third important traits as compared to size/growth traits

Table 15. Ram breeding objectives in different livestock production system-agroecology settings in Ethiopia.

	% of studies trait is mentioned				Average scores of traits			
	* MHL	MLL	AP	P	MHL	MLL	AP	P
No. of studies	43	9	3	4	43	9	3	4
Body size	86.0%	88.9%	100.0%	75.0%	0.35	0.34	0.34	0.38
Coat color	86.0%	88.9%	100.0%	75.0%	0.18	0.21	0.25	0.10
Growth rate	67.4%	77.8%	100.0%	50.0%	0.20	0.22	0.11	0.18
Mating ability	100.0%	88.9%	100.0%	100.0%	0.00	0.00	0.00	0.00
Testicle size	7.0%	0.0%	66.7%	0.0%	0.05	0.00	0.06	0.00
Tail size/shape	51.2%	33.3%	33.3%	75.0%	0.17	0.11	0.07	0.19
Temperament	39.5%	11.1%	100.0%	25.0%	0.05	0.08	0.07	0.01
Horn size/shape	34.9%	0.0%	0.0%	50.0%	0.06	0.00	0.00	0.01
Age at first mating	16.3%	11.1%	0.0%	0.0%	0.08	0.06	0.00	0.00
Prolificacy	4.7%	0.0%	33.3%	0.0%	0.09	0.00	0.01	0.00
Disease tolerance	9.3%	0.0%	0.0%	0.0%	0.06	0.00	0.00	0.00
Drought tolerance	27.9%	55.6%	33.3%	25.0%	0.03	0.05	0.08	0.17
Fleece yield	9.3%	0.0%	0.0%	0.0%	0.02	0.00	0.00	0.00

* MHL: mixed crop-livestock system in the highlands, MLL: mixed crop-livestock system in lowlands, AP: agropastoral, P: pastoral.

Table 16. Buck breeding objectives in different livestock production system-agroecology settings in Ethiopia.

	% of studies trait is mentioned				Average scores of traits			
	* MHL	MLL	AP	P	MHL	MLL	AP	P
No. of studies	11	13	2	6	11	13	2	6
Body size	72.7%	76.9%	100.0%	100.0%	0.43	0.41	0.41	0.39
Coat color	72.7%	76.9%	50.0%	100.0%	0.28	0.19	0.45	0.24
Growth rate	18.2%	61.5%	0.0%	100.0%	0.09	0.20	0.00	0.13
Mating ability	100.0%	100.0%	100.0%	100.0%	0.00	0.00	0.00	0.00
Testicle size	18.2%	7.7%	0.0%	50.0%	0.11	0.13	0.00	0.09
Tail size/shape	9.1%	0.0%	0.0%	0.0%	0.05	0.00	0.00	0.00
Temperament	18.2%	23.1%	0.0%	50.0%	0.02	0.07	0.00	0.04
Horn size/shape	18.2%	30.8%	0.0%	50.0%	0.30	0.03	0.00	0.01
Age at first[t] mating	27.3%	7.7%	0.0%	0.0%	0.17	0.00	0.00	0.00
Prolificacy	0.0%	7.7%	0.0%	83.3%	0.00	0.06	0.00	0.02
Disease tolerance	0.0%	0.0%	50.0%	0.0%	0.00	0.00	0.28	0.00
Drought tolerance	27.3%	46.2%	0.0%	16.7%	0.03	0.05	0.00	0.01
Fleece yield	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00

* MHL: mixed crop-livestock system in the highlands, MLL: mixed crop-livestock system in lowlands, AP: agropastoral, P: pastoral.

was only 7.120E-011 and 2.403E-010 (P = 0.000) in the mixed crop-livestock system in the sub-moist subalpine highlands. Aesthetic/appearance traits were equally important as size/growth traits in the wet highlands (odds ration = 0.39, P = 0.051). In the pastoral-agropastoral system, adaptation and aesthetic/appearance traits were equally important as size/growth traits (odds ration = 0.22, P > 0.05), but reproduction traits were ranked lower than size/growth traits (odds ration = 0.063, P = 0.014).

Goat keepers in the lowlands mixed crop-livestock system assigned significantly lower ranks of importance to adaptation and reproduction traits compared to size/growth traits (odds ration = 0.033, P = 0.006 and odds ration = 0.14, P = 0.014 respectively), but similar ranks to aesthetic/appearance and milk yield as size/growth traits (P > 0.05). Pastoralists/agropastoralists also ranked size/growth traits as significantly (P = 0.000) more important traits than other trait groups.

For goat keepers, 72.7% to 100% of the studies conducted in the highland mixed crop-livestock system included body size, coat color, and mating ability as buck breeding objective traits (Table 16). However, the top ranked traits were body size, horn size/shape, age at first mating, coat color, and testicle size. In the lowland mixed crop-livestock system, 61.5% to 100% of the studies mentioned body size, coat color, mating ability, and growth rate as buck breeding objective traits, but the top ranked traits were body size, coat color, growth rate, and testicle size. For pastoralists, buck breeding objective traits mentioned in at least 50% of the studies were body size, coat color, mating ability, growth rate, testicle size, temperament, horn size, and prolificacy, whereas

Table 17. Ewe breeding objectives in different livestock production system-agroecology settings in Ethiopia.

	% of studies trait is mentioned				Average scores of traits			
	* MHL	MLL	AP	P	MHL	MLL	AP	P
Number of studies	43	9	3	4	43	9	3	4
Body size/ conformation	81.4	88.9	66.7	75.0	0.265	0.271	0.405	0.145
Growth rate	18.6	11.1	0.0	25.0	0.211	0.140	0.000	0.156
Tail length/shape	37.2	33.3	0.0	50.0	0.075	0.073	0.000	0.090
Coat color	76.7	88.9	100.0	75.0	0.190	0.153	0.207	0.057
Mothering ability	37.2	11.1	66.7	50.0	0.100	0.190	0.050	0.160
Lamb growth	41.9	33.3	0.0	0.0	0.083	0.107	0.000	0.000
Lamb survival	32.6	44.4	66.7	0.0	0.065	0.063	0.025	0.000
Age at first lambing	60.5	88.9	33.3	50.0	0.080	0.098	0.030	0.035
Lambing interval	67.4	77.8	66.7	50.0	0.105	0.181	0.020	0.120
Twinning	76.7	77.8	33.3	100.0	0.165	0.137	0.150	0.170
Longevity	23.3	0.0	33.3	50.0	0.049	0.000	0.070	0.040
Milk yield	11.6	0.0	100.0	100.0	0.000	0.000	0.000	0.000
Disease tolerance	9.3	0.0	0.0	0.0	0.045	0.000	0.000	0.000
Drought tolerance	9.3	0.0	0.0	25.0	0.082	0.000	0.000	0.372

* MHL: mixed crop-livestock system in the highlands, MLL: mixed crop-livestock system in lowlands, AP: agropastoral, P: pastoral.

for agropastoralists, body size, coat color, mating ability, and disease tolerance were the traits mentioned at least in 50% of the studies reviewed. However, the traits ranked top by pastoralists were body size, coat color, and growth rate and the traits ranked top by agropastoralists were body size, coat color, and resistance to diseases.

Ewe traits mentioned as breeding objectives in at least half of the studies reviewed were body size/conformation, coat color, age at first lambing, and lambing interval in mixed crop-livestock system in the highlands (Table 17). However, traits with the highest scores (above 0.10) were, in order of importance: body size/conformation, growth rate, coat color, mothering ability, lambing interval, and twinning ability. In mixed crop-livestock system in the lowlands, traits frequently mentioned (50% of the studies) were body size/conformation, coat color, age at first lambing, lambing interval, and twinning rate, but those with the highest scores were body size/conformation, growth rate, coat color, mothering ability, lamb growth, lambing interval, and twinning rate. The most frequently mentioned traits in the agropastoral system were body size/conformation, coat color, mothering ability, lamb survival, lambing interval, and milk yield, but the top-ranking traits were body size/ conformation, coat color, and twinning rate. In the pastoral system, body size/conformation, tail length/shape, coat

Table 18. Doe breeding objectives in different livestock production system-agroecology settings in Ethiopia.

	% of studies trait is mentioned				Average scores of traits			
	* MHL	MLL	AP	P	MHL	MLL	AP	P
Number of studies	11	13	2	6	11	13	2	6
Body size/ conformation	54.5	69.2	50.0	50.0	0.343	0.350	0.300	0.302
Growth rate	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
Tail length/shape	0.0	7.7	0.0	0.0	0.000	0.156	0.000	0.000
Coat color	45.5	61.5	0.0	50.0	0.290	0.123	0.000	0.132
Mothering ability	27.3	30.8	0.0	0.0	0.177	0.112	0.000	0.000
Lamb growth	18.2	23.1	0.0	0.0	0.035	0.087	0.000	0.000
Lamb survival	36.4	23.1	0.0	50.0	0.080	0.036	0.000	0.060
Age at first parturition	27.3	38.5	0.0	50.0	0.033	0.032	0.000	0.011
Parturition interval	36.4	53.8	100.0	33.3	0.108	0.079	0.210	0.029
Twinning	54.5	53.8	50.0	50.0	0.135	0.194	0.470	0.160
Longevity	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
Milk yield	18.2	46.2	50.0	50.0	0.000	0.000	0.000	0.000
Disease tolerance	0.0	0.0	50.0	0.0	0.000	0.000	0.520	0.000
Drought tolerance	18.2	7.7	0.0	16.7	0.015	0.055	0.000	0.012

* MHL: mixed crop-livestock system in the highlands, MLL: mixed crop-livestock system in lowlands, AP: agropastoral, P: pastoral.

color, age at first mating, lambing interval, twinning rate, longevity, and milk yield were the most frequently mentioned traits in the reviewed studies, whereas the top-ranking traits in terms of the sheep keepers scores were body size/conformation, growth rate, mothering ability, lambing interval, twinning, and drought tolerance. Doe breeding objective traits in different production system-agroecologies are presented in Table 18.

3.2.2. Economic value of traits

Almost all the studies reviewed in the current study used a similar approach, which was ranking of traits by sheep/goat keepers. Using this information, index scores were calculated for each trait. Very few studies used bio-economic modelling to derive economic values of traits, which helps to rank the relative importance of traits, their relative weights for constructing multi-trait selection indexes, as well as returns to investment in selection programs (Gebre 2009; Abrham et al. 2019; Gizaw et al. 2018). Based on their economic values, the top three traits for Menz sheep identified by Gebre (2009) were lamb survival, lambing interval, and litter size, while Gizaw et al. (2018) identified lamb survival, lambing interval, and six-month weight/growth rate. The top three traits identified in Abrham et al. (2019), which looked at Begait goats, were litter size, six-month weight, and kid survival.

4. Discussion

4.1. Production objectives

Priorities within sheep and goat keepers' production objectives are determined by the production systems/agroecologies. Choices of agricultural enterprises are determined by the production environment, traditional practices, socio-economic circumstances, and geographic locations which determine access and availability of inputs, services, and profitable markets. These factors also determine farmers' and pastoralists' production objectives and strategies, which in turn determine their breeding objectives.

Most of the studies reviewed in this paper defined production systems in Ethiopia as mixed crop-livestock production, pastoral, and agropastoral systems. However, some of the studies considered agroecological zones within the mixed crop-livestock system by stratifying the sampling frame across agroecologies. (e.g. Zeryhun, 2006). For instance, a study in the highlands/midlands and lowlands of Sekota district showed that goat keepers production objectives differed significantly, with only 31.5% of the goat keepers in the highlands milking their goats compared to 100% in the lowlands (Zerihun 2006). This signifies the importance of considering agroecologies as a component of production systems in defining breeding objectives. Furthermore, agroecology is a major determinant of the type of livestock breeds that could be kept, and the genetic merits/demerits of breeds in turn determine breeding objectives.

Flock structure is a major descriptor of production systems. The proportions of ewe/doe flock and yearling male and female animals are indicative of the production objectives. The flock structures described in the studies reviewed here are in agreement with earlier studies in Ethiopia, Burundi, Rwanda, and Kenya, where flock sizes decrease as altitude increases since these elevated areas have a population of farmers which greatly outnumber the people of the lowlands (ILCA 1979; Wilson 1982; Bayer 1984). These trends reflect system differences which change from pastoral in the dry areas to agropastoral or agricultural in the better endowed zones (Wilson 1986). However, in Ethiopia, with the altitude ranges above 2500m (subalpine highlands) the sheep flock sizes tend to increase per household, although there exists a higher population density (Mekoya 1999; Gizaw 2008). The current review and previous studies indicate the need for a detailed understanding of production systems and agroecologies when defining clusters of uniform groups for defining relevant breeding objectives.

Sheep and goat keepers' breeding objectives are determined by their production objectives. It has been stated that sheep and goat keepers in traditional livestock systems have diverse and multiple production objectives. In the current study, it was clearly shown that the primary small ruminant production objective of smallholder farmers and pastoralists in Ethiopia is invariably similar across breeds, agroecologies, or production systems; namely, generating cash income from sale of live animals, which received by far the highest ranks of importance compared to the other functions of small ruminants. In previous studies across eight districts of Ethiopia, varying in production systems and agroecologies, generating cash income was found to be 30.5% to 54.0% more important than the other functions of small ruminants (Tsedeke 2007; Shenkute 2009; Tsegaye 2009).

4.2. Breeding objectives

4.2.1. Trait rankings

In this paper, a clear breeding objective of smallholder sheep and goat farmers and pastoralists has emerged from the analysis of several studies. The aim of sheep and goat keepers in Ethiopia is generally meat production. Selection for body size is the top priority breeding objective trait for both smallholders and pastoralists. The emphasis on body size could be explained by the focus on market value of individual animals, rather than productivity at flock level, which is determined by reproductive rates and survival, although some of the comparison between the traits was not reliable due to small sample sizes and resulting high standard errors. A greater emphasis on individual animals' body size and a lesser emphasis on reproduction rates could also be contrary to farmers/pastoralists' second most important production objective, which is the financial function of small ruminants, which serve as a form of savings and capital investment. Selection for size may not also result in efficient production systems, depending on the natural resource endowment and availability of external inputs in the area. In a study of Menz sheep keepers breeding objectives (Gizaw et al.

2018), growth rate, survival, and lambing interval formed the high priority traits, whereas body size was ranked lower. If combined optimally in selection index, growth rate, survival, and lambing interval could form optimal breeding objectives, increasing system efficiency. This may reveal that if probed appropriately, farmers' breeding goals could be geared towards improving the efficiency of meat production.

The high priority given to coat color in the current study may be interpreted differently across breeds and production systems. Such appearance traits as coat color and horn could be related to the aesthetic value of the breeds for the traditional communities keeping the different breeds, as farmers would prefer to maintain their desired coat colors in their flocks. However, coat color and tail may also be related to market values of

animals of specific coat color. For instance, Menz sheep farmers have less preference for black coat color as such animals have less market value, but unfortunately, black animals are heavier than other animals (Gizaw et al. 2011). A strategy to consider might be to develop black sheep lines targeting export markets and local markets that may not have prejudice to black sheep. Although it was not described in the studies, some of the aesthetic/appearance traits could be proxy traits for production traits. For instance, tail size in ewes is known to be related to reproduction ability. For local markets, independent culling against less preferred qualitative traits could be adopted before or after selection for quantitative production traits through the use of selection indexes.

Sheep and goat keepers breeding objectives vary slightly across production systems/agroecology. The results strongly indicate that adaptation traits are as important as production traits for sheep breeding but not for goat breeding in the pastoral-agropastoral systems. This could be due to the higher adaptive ability of goats, which can thrive well in drier areas while browsing on bushes, which are the main all-season feed in dry/arid areas. Nonetheless, size/growth traits are more popular across the production systems/agroecologies in general. The results on preferences for adaptation traits in this study need to be interpreted with caution, as adaptation is expected to be a priority trait in marginal agroecologies and low input systems. In most of the studies reviewed, the breeding objective traits were identified and ranked based on selection criteria, so the respondents might have assigned lower ranks to traits of adaptation such as tolerance to drought and diseases, since they may not select for these traits directly but through other indicator traits which might not be included in the preference lists of traits. The current results contrast with a previous study, which showed farmers living in harsh environments valued functional traits, such as disease resistance, more than performance traits (Woldu 2016). The conventional definition of breeding objective is to develop vital animals which will ensure that profit is as high as possible under future commercial conditions of production (Graser et al. 2006). However, biological and economic aspects alone may not fully describe the objectives of smallholders and pastoralists when the multi-purpose functions of small ruminants, including the use of small ruminants as capital store and investment, are considered. Yet, sheep and goat keepers in Ethiopia do consider market/consumer preferences, as their breeding objective traits specify coat color as the second most important trait and also include tail and horn size, which do not bear any relation to productivity but determine market values.

Appearance traits such as coat color and tail condition, besides body size, significantly affect the implicit prices of indigenous sheep (Zelalem et al. 2012) and the choice of sheep purchased (Terefe et al. 2012) in Ethiopia. However, the effect of appearance traits on prices appears to vary across geographic regions. For instance, coat color was not found as a determinant of goat prices in a study in semi-arid lowland, arid lowland, and highland markets in Ethiopia (Woldu 2016). These research findings justify farmers/pastoralists' rationale in defining their breeding objectives. However, farmers/pastoralists' economic considerations in defining their breeding goals are based on current market conditions because of a lack of access to information on future market trends. It is important that breeding objectives be defined based on long-term trends, since genetic improvement programs are long-term investments and the benefits (the genetic gains) are realized in the distant future.

This review work indicates that methods and approaches in future research on definition of breeding objectives need to improve. Presentation of breeding objective traits or selection criteria to respondents might have been confusing in most of the studies reviewed. For instance, pedigree was included in the list of breeding objective traits in most studies, but was also defined as a source of information for selecting candidate animals. Secondly, similar traits were presented as different traits such as ewe growth rate and lamb growth rate. This might have resulted in a biased ranking of traits based on index scores derived from the respondents' rankings. Our results also raise questions regarding the need for definition of breeding objectives at district level, which is currently the trend, and whether research on breeding objective definition should continue for each breed, given the similarity of objectives of sheep/goat keepers in similar production systems/agroecologies

4.2.2. Trait weights

Livestock breeding objectives in Ethiopia are almost exclusively defined using participatory approaches based on farmers/pastoralists' opinions. Almost all the studies reviewed in this paper used a similar approach, which was ranking of traits by sheep/goat keepers from which

index scores were calculated, representing weighted averages of all rankings for a trait by all respondents (Bett et al. 2009). Trait ranking is just the first step in defining breeding objectives and would not enable the construction of selection indexes for multi-trait selection programs, which require the traits identified to be weighted according to their relative importance. However, if a quantitative method such as proportional piling is used, a participatory approach with farmers' interviews could also be used to derive some form of trait weights. Gizaw et al. 2018 compared economic values of traits and farmers' trait preferences using proportional piling and found a moderate congruence between the rankings of the traits across the two methods; the correlation between economic values of traits and farmers' trait weights being 0.59±0.23.

Economic values of traits serve the purpose of ranking the relative importance of traits, as well as their weights, for constructing multi-trait selection indexes. Designing breeding programs for structured breeding programs with designing tools such as ZPLAN (Williams et al. 2008) also require economic values of traits as inputs. Research on defining breeding objectives for small ruminants in Ethiopia using economic values of traits (Gebre 2009; Woldu 2016; Abrham et al. 2019; Gizaw et al. 2018) is very limited

4.3. Implications for designing breeding programs

In almost all studies reviewed, breeding objective traits were identified for male and female breeding stock separately. It can also be observed from farmers/pastoralists' ranking of traits that reproduction traits are considered largely as female traits. However, it is known that the impact of the male breeding stock on flock genetic merit is greater than the female breeding stock. And it is known that under village conditions, selection is mainly on the male side and selection intensity on the female side in central nucleus programs is also low. Such disaggregation of traits could thus have implications for the genetic progress that could be achieved from designed breeding programs. The disaggregation of breeding objectives into male and female breeding objectives may also complicate the interpretation of farmers' overall breeding objectives. For instance, the priority of buck and doe breeding objective traits, e.g. size traits in bucks and milk and size traits in does needs to be combined, which may result in an overall breeding objective of developing dual purpose goats. In general, the approach followed in the reviewed studies in defining breeding objectives seems to be for systems designed to produce specialized sire and dam lines, with the emphasis on production performance traits in the male line and reproduction traits in the female line, which is not the case in Ethiopia; especially in the smallholder system.

Community-based sheep and goat breeding programs in Ethiopia are largely limited to single trait selection (Gizaw et al. 2013; unpublished communications). Our results show that these breeding programs need to be transformed into multi-trait selection programs, so that the improved genetics would be fit for their environment and both current and future market demands. These programs are also currently relying on farmers' subjective traits such as body conformation, which is mainly related to body size. Although such appearance traits have high congruence with body weights (Gizaw et al. 2011), traits like growth rates, which ranked second to third in the current study, need to be considered for improving the efficiency of the selection programs. Another consideration in designing multi-trait selection would be combining the multiple traits in the selection index, which requires weighting of the traits; something most of the studies reviewed lacked. This needs further research, which may include evaluation of index scores derived from farmers/pastoralists' rankings to use as trait weights. The presence of both nominal (e.g. coat color, farmers' body conformation traits) and scale traits (growth rates, body weights) in the top ranked traits also poses a challenge in multi-trait selection schemes. Independent culling method has been suggested for nominal traits (Gizaw et al. 2011; Mirkena et al. 2012). In general, devising new and improving existing methods and approaches for utilizing the information generated from breeding objective studies to design breeding programs need to be the next steps

5. Conclusions and recommendations

Conclusions:

- The primary small ruminant production objective of sheep and goat keepers in Ethiopia is to generate cash income from the sale of live animals. Use of animals as capital store, savings, and investment is also a high priority objective.

- Based on the breeding objective traits or the selection criteria of sheep and goat keepers in Ethiopia, smallholders' and pastoralists' small ruminant breeding objective can be defined generally as production of meat animals that could fetch good market prices.

- There are slight variations across production systems and species. While the general definition of breeding objective in (2) applies mainly to smallholder sheep keepers in the highlands, the pastoralists/agropastoralists' aim is to produce sheep that are well adapted to their production environment and at the same time fetch higher market prices.

© Credit to add

- Goat breeding objectives are similar to sheep breeding objectives, except that goat keepers in the lowland mixed crop-livestock system prefer to breed dual purpose meat-milk animals.

- Body size/growth, reproduction, adaptation, and aesthetic (also related to the market value of animals) traits are all mentioned. However, body size traits are by far the priority selection objectives of both smallholder farmers and pastoralists.

- The low ranking of adaptation traits might be complicated by the fact that objective traits (desires) are derived from selection criteria (practices) of the respondents.

Recommendations:

- Attempts to define breeding objectives at district level may not be recommended. Breeding objectives may be defined at breed level with sound sampling strategy considering production systems, agroecologies, and farmers' cultural values.

- Multi-trait selection programs are recommended considering the high-ranking traits. This requires revising the existing breeding programs.

- Simulated alternative breeding program designs need be evaluated to design breeding programs including the top-ranking traits.

- Studies are recommended on selection schemes for nominal and scale traits in a multi-trait selection program.

- Studies on derivation of economic weights for designing central nucleus breeding programs using design tools (e.g. ZPLAN) or relative weights for multi-trait selection under village conditions are recommended.

- Further studies to refine the importance of adaptation traits, particularly in marginal areas, must be carried out.

References

Abrham, H., S. Gizaw and M. Urge. 2019. Simulated alternative breeding schemes for optimizing Begait goat improvement programs in Western Tigray, northern Ethiopia. *Agricultural Systems* 176: 102669.

Bayer, U. 1984. Traditional small ruminant production. 2nd ILCA/ NAPPI symposium on livestock production in the sub-humid zone of Nigeria, 30th Oct.–2nd Nov. 1984.

Bett, R.C., I.S. Kosgey, A.K. Kahi and K.J. Peters. 2009. Analysis of production objectives and breeding practices of dairy goats in Kenya. *Tropical Animal Health and Production* 41: 307–320.

CSA (Central Statistical Agency). 2017. Agricultural Sample Survey. Report on Livestock and livestock characteristics (Private peasant holdings). *Statistical Bulletin* 588: 98.

Fikru, S. and K. Gebeyew. 2015. Sheep and Goat Production Systems in Degehabur Zone, Eastern Ethiopia: Challenge and Opportunities. *Journal of Advances in Dairy Research* 3: 134.

Gebre, K.T. 2009. Estimates of economic values for important traits of two indigenous sheep breeds of Ethiopia. MSc thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Gizaw, S., A. Abebe, A. Bisrat, T. Zewdie and A. Tegegne. 2018. Defining smallholders' sheep breeding objectives using farmers' trait preferences versus bio-economic modelling. *Livestock Science* 214: 120–128.

Gizaw, S., D. Hoekstra, B. Gebremedhin and A. Tegegne. 2015. Classification of small ruminant production sub-systems in Ethiopia: Implications for designing development interventions. LIVES Working Paper 5. International Livestock Research Institute (ILRI): Nairobi, Kenya.

Gizaw, S., T. Getachew, S. Goshme, A. Valle-Zárate, J.A.M. van Arendonk, S. Kemp, A.O. Mwai and T. Dessie. 2013. Efficiency of selection for body weight in a cooperative village breeding program of Menz sheep under smallholder farming system. *Animal* 11: 1–6.

Gizaw, S., T. Getachew, A. Haile and T. Dessie. 2011. Congruence between selection of breeding rams based on breeding values for production traits and farmers ram choice criteria. *Animal* 5(7): 995–1001.

Gizaw, S. 2008. Sheep Resources of Ethiopia: Genetic Diversity and Breeding Strategy. PhD thesis. Wageningen University: The Netherlands.

Graser, H., J. James and J. van der Werf. 2006. Optimal Designs of Breeding Programs: Lecture Notes. Animal Genetics and Breeding Unit. Armidale Animal Breeding Summer Course. https://jvanderw.une.edu.au/BPDesignHG.pdf.

ILCA. 1979. (International Livestock Centre for Africa). Small Ruminant production in the humid tropics. System Study No 3. ILCA, Addis Ababa, Ethiopia.

Mekoya, A. 1999. Husbandry practices and productivity of sheep in Lallo-Mama Mider Woreda of central highlands of Ethiopia. MSc thesis. Haramaya, Ethiopia: Haramaya University.

Mirkena, T., G. Duguma, A. Willam, W. Wurzinger, A. Haile, B. Rischkowsky, A.M. Okeyo, M. Tibbo and J. Solkner. 2012. Community-based alternative breeding plans for indigenous sheep breeds in four agro-ecological zones of Ethiopia. *Journal of Animal Breeding and Genetics* 129: 244–253.

Shapiro, B., G. Gebru, S. Desta, A. Negassa, K. Negussie, G. Aboset and H. Mechale. 2015. Ethiopia livestock master plan. International Livestock Research Institute (ILRI): Nairobi, Kenya.

Shenkute, B. 2009. Production and marketing systems of small ruminants in Goma District of Jimma Zone, western Ethiopia. MSc thesis. Hawassa University: Awassa, Ethiopia.

Taye, M. 2008. On-farm performances of Washera sheep at Yilmanadensa and Quarit Districts of the Amhara National Regional State. MSc thesis. Awassa, Ethiopia: Hawassa University.

Terefe, G., T. Teklue and K. Shimelis. 2012. Study on common phenotypic traits for purchasing sheep and their association with price and purpose of purchase in four markets of East Showa Zone. *Ethiopian Veterinary Journal* 16: 15–26.

Tsedeke, K. 2007. Production and marketing systems of Sheep and Goats in Alaba, southern Ethiopia. MSc thesis. Hawassa University: Awassa, Ethiopia.

Tsegaye, T. 2009. Characterization of goat production systems and on- farm evaluation of the growth performance of grazing goats supplemented with different protein sources in Metema Woreda, Amhara region, Ethiopia. MSc thesis. Haramaya University: Haramaya, Ethiopia.

Williams, A., G. Nitter, H. Bartenchlager, K. Karras, E. Niebel and H-U. Graser. 2008. ZPLAN-manual for a PC-program to optimize livestock selection schemes.

Manual Version 2008 for Source Code “z10.for”. Institute of Animal Production in the Tropics and Subtropics. Universität Hohenheim, Stuttgart, Germany.

Wilson, R.T. 1982. Husbandry, nutrition and productivity of goats and sheep in Tropical Africa. Pages 61-75 in Small Ruminant Breed Productivity in Africa (R.M. Gatenby and J.C.M. Trail, eds.). ILCA: Addis Ababa, Ethiopia.

Wilson, R.T. 1986. Management. Pages 17-39 in Sheep Production in the Tropics and Subtropics, Tropical Agriculture Series (R. M. Gatenby, ed.). Longman Ltd.: New York, USA.

Woldu, T. 2016. Optimizing community-based breeding for indigenous goat breeds in Ethiopia. PhD thesis. Faculty of Agricultural Sciences at the University of Hohenheim: Stuttgart.

Zelalem Terfa, Aynalem Haile, Derek Baker, Girma Tesfahun Kassie. 2012. Sheep market participation of rural households in Western Ethiopia. *African Journal of Agricultural Research* 7(10):1504-1511.

Zeryhun, M. 2006. Goat husbandry practices and productive performances in Sekota Woreda of Amhara Region. MSc thesis. Haramaya, Ethiopia: Haramaya University.

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is a non-profit, CGIAR Research Center that focusses on delivering innovative solutions for sustainable agricultural development in the non-tropical dry areas of the developing world. We provide innovative, science-based solutions to improve the livelihoods and resilience of resource-poor smallholder farmers. We do this through strategic partnerships, linking research to development, and capacity development, and by taking into account gender equality and the role of youth in transforming the non-tropical dry areas.
www.icarda.org

CGIAR is a global research partnership for a food-secure future. CGIAR science is dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources and ecosystem services. Its research is carried out by 15 CGIAR centers in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations and the private sector.
www.cgiar.org