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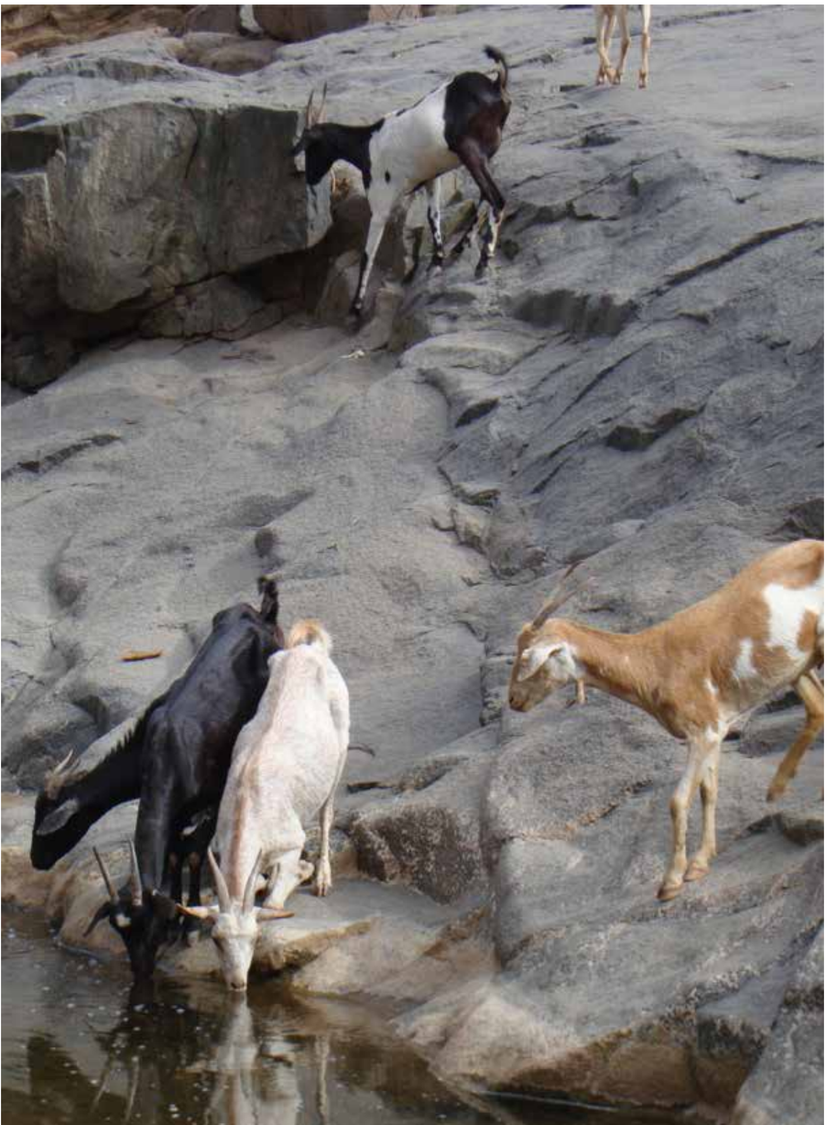

Genetic-phenotypic and production-system diversity in goat populations in Ethiopia: Options for sustainable production

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Acronyms

AI	Artificial insemination
ATA	Agricultural Transformation Agency of Ethiopia
BecA	Biosciences eastern and central Africa
CCPP	Contagious caprine pleuropneumonia
FMD	Foot-and-mouth disease
ICARDA	International Center for Agricultural Research in Dryland Areas
ILRI	International Livestock Research Institute
LIVES	Livestock and Irrigation Value chains in Ethiopian Smallholders
mtDNA	Mitochondrial DNA
m.a.s.l	Metres above sea level
m.b.s.l	Metres below sea level
OARI	Oromia Agricultural research Institute
PA	Peasant association
PPR	*Peste des petits ruminants*
SNP	Single nucleotide polymorphism
SNNPR	Southern Nation Nationalities and Peoples region

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Executive summary

This working paper synthesizes and analyses the genetic, morphological and production system characteristics of five indigenous goat populations of Ethiopia, namely Ambo, Gondar, Woyto-Guji, Arsi-Bale Highland and Arsi-Bale lowland goats. The paper is based on three MSc theses and one ongoing PhD study. Based on the analysis, the paper recommends intervention options for genetic improvement and conservation of the goat resources and for sustainable production systems under which the goat populations are raised. Morphologically, the majority of the Ambo goat population have a patchy coat colour pattern. Pure white and mixed coat colours describe the Gondar goat population and the majority of the goats are horned, males have ruff but not the females. Similarly, Woyto-Guji is described by patchy, plain and spotted coat colour. Both Arsi-Bale Highland and Lowland goat populations can be characterized dominantly by plain coat colour of black and white. However, the second dominant coat colour pattern in the highland and lowland goat populations, respectively, is patchy and spotted coat colour pattern. The molecular analysis revealed very narrow genetic differentiation with only two haplogroups or maternal origins (haplogroup A and G). The highest number of haplotypes was obtained in Gondar goat population and the lowest in Ambo. The demographic expansion analysis showed two recent and rapid expansion events of the goat populations. Most of the variation in the goat populations is explained by within population variation and the pair-wise population differentiation estimates were very low. This is because of the presence of large population admixture. The goat populations are kept in mixed crop–livestock and agro-pastoral production systems. The average household family size ranges from <5.0 for Arsi-Bale Highland and Lowland to 8.5±2.5 for Woyto-Guji areas. Highest average goat holding per house hold (31.3 goats) was reported in Woyto-Guji area and the lowest (10.5) in Arsi-Bale highlands. Cattle was ranked as the most important source of cash income and food source in Gondar goat and Ambo goat rearing areas whereas goat is significantly more important than other livestock species in Woyto-Guji area. The primary purpose of keeping goats is for cash income in all the study areas. Most of the households keep breeding flocks, female breeding goats constituting the highest proportion of the goat flocks. Natural pasture is the major feed source available for the goats in both dry and wet seasons except for Arsi-Bale Lowland goat population where tree leaves are the main feed sources. The goat keepers practice selection of breeding stock, body confirmation and growth rate being the primary selection criteria for breeding bucks and does. The major challenges of the goat production in all the study areas are disease, drought, feed and water shortages, in ranking order. The goat marketing practice is traditional in all the study areas. Genetic improvement options for these goat populations need to consider the production environments in which the populations are maintained. Selective breeding could be considered as a suitable breeding strategy with application of genomic and reproductive technologies as appropriate. Selective breeding together with intervention options to improve the production environment to overcome the production constraints ranked by farmers would contribute to designing sustainable production systems for the goat populations studied. For this, a parallel development in infrastructure and institutional framework is required.

1. Introduction

Goats (*Capra hircus*) are among the most important livestock species which highly contribute for the subsistence economy of poor farmers. They are considered most prolific ruminant among all domesticated ruminant species especially under harsh climatic conditions (Yadav and Yadav 2008). The wide adaptability of goats has helped them to stay in a wide range of agro-ecologies including extreme environmental conditions (Li et al. 2006). According to Rege and Lebbie (2000) goats arrived in Ethiopia through North Africa between 2000 and 3000 BC. In addition to being the historic root for livestock introduction into Africa, the highest ecological variation that ranges from 116 m.b.s.l to 4620 m.a.s.l. has contributed for the presence of very diverse farm animal genetic resources in Ethiopia (Ayalew et al. 2004). Goats are found in various production systems in Ethiopia as described by Gizaw et al. (2010) and Abegaz et al. (2014).

In Ethiopia, the goat population was estimated to be more than 25 million (FAOSTAT 2013). Based on physical description, this huge goat population has been classified in to 13 goat types (Farm-Africa 1996). These are Afar, Abergelle, Anglo-Nubian, Arsi-Bale, Begayit (Barka), Central Highland, Hararghe Highland, Kaffa, Long-eared Somali, Small eared Somali, Western Highland, Western Lowland and Woyto-Guji. These goat populations are found in various agro-ecologies. The existence of such a large gene pool in various agro-ecologies, which is believed to be evolved through the process of natural selection (Abegaz et al. 2008), is important for breed improvement and conservation and for development of a sustainable animal production system (Mahmoudi et al. 2011). However, molecular genetic characterization studies with microsatellite markers (Tesfaye 2004) and an ongoing research on Mitochondrial DNA (mtDNA) and genome-wide single nucleotide polymorphism (SNP) marker analyses (Getinet et al. *in press a*; Getinet et al. 2016) revealed that the genetic differentiation among the goat populations in Ethiopia appears very low. The same studies uncovered presence of high level of population genetic admixture caused most probably by migration (*Nm*=24).

Despite the populations admixture, goats in Ethiopia occupy an important niche in the smallholder production system mainly due to low initial capital requirement, ability to produce food at relatively low cost, production of milk and meat in readily useable quantities, relatively high rate of reproduction potential, marketability in a short period and ease of being managed by most family members (women, eldest and children) (Kevien and Wilson 2000).

Information on phenotypic and genetic diversity and population structure, and the production systems in which the goat populations are managed could greatly contribute to recognizing the goat resources including those with unique genetic characteristics and to designing rational and effective conservation and utilization programs. Therefore, based on information and data from MSc and PhD research projects, this paper aims to characterize goat populations in Ethiopia morphologically and genetically and their production systems, identify the major goat production constraints and forward intervention options for genetic improvement and conservation of the goat resources and develop sustainable goat production systems.

2. Goat populations and sources of information

2.1 Goat populations studied

Five indigenous goat populations were studied in this working paper. Maternal origin of Ethiopian goats was studied using genomic data from the 14 populations (Getinet et al. *in press a*; Figures. 1 and 2). A detailed genetic, phenotypic and production system diversities were analysed on five populations, namely Arsi-Bale Highland, Arsi-Bale Lowland, Woyto-Guji, Ambo and Gondar goat populations. All the goat populations, except Arsi-Bale Highland and Lowland goats, were selected since the populations were included by the Livestock and Irrigation Value chains in Ethiopian Smallholders (LIVES) and Biosciences eastern and central Africa (BecA)-ILRI Hub projects for genetic improvement through community-based breeding schemes. Arsi-Bale Highland goat was selected because of its unique feature, more importantly, farmers breed this goat for its fur production that serves for saddle in the highlands of Arsi and Bale. Moreover, both Arsi-Bale Highland and Lowland goats are least studied compared to the rest of indigenous goat populations in Ethiopia. All the goat populations included in this paper are found in various agro-ecologies ranging from very arid (Woyto-Guji goat) to Afro-alpine and Sub-afroalpine (Arsi-Bale highland goat) areas.

The naming of the five goat populations in this paper follows the nomenclature used in the original studies by Netsanet (2014), Alubel (2015) and Hussein (2015). The naming of the Gondar and Ambo populations was based on the sampling sites of Alubel (2015) and Netsanet (2014) studies. The sampling sites were Armacheho area in Amhara region for Gondar goat; Meta-Robi area in Oromia region for Ambo goat; Konso area in Southern Nation Nationalities and Peoples region (SNNPR) for Woyto-Guji goat; and highland and lowland Peasant Associations (PA) in Lemu Blbilo, Honkole Wabe, Agarfa and Gasera areas in Oromia region for Arsi-Bale Highland and Lowland populations.

2.2 Sources of information

The main sources of information and data for this paper were three MSc theses and one ongoing PhD work (Getinet unpublished). Ambo and Woyto-Guji goat populations were studied by Netsanet (2014), Arsi-Bale Highland and Lowland goat populations by Hussein (2015) and Gondar goat population by Alubel (2015). The MSc theses studied morphological, phenotypic and production system characteristics of the five goat populations. Information and data from the ongoing PhD work by Getinet were used to describe the molecular genetic characteristics of the goat populations, except Arsi-Bale Lowland goat, in Ethiopia. In addition, various documents were utilized to discuss the study results. The information was synthesized to describe the characteristics of the goat populations and their production systems and identify major constraints and opportunities for each production system. Indices were calculated for ranked data to provide ranking of the reasons of keeping goat, goat breeding objective, buck and doe selection criteria, contribution of different farming activities to the family food and income and major goat production constraints. Finally, based on analysis of the information compiled, possible interventions were suggested.

3. Characterization of goat populations

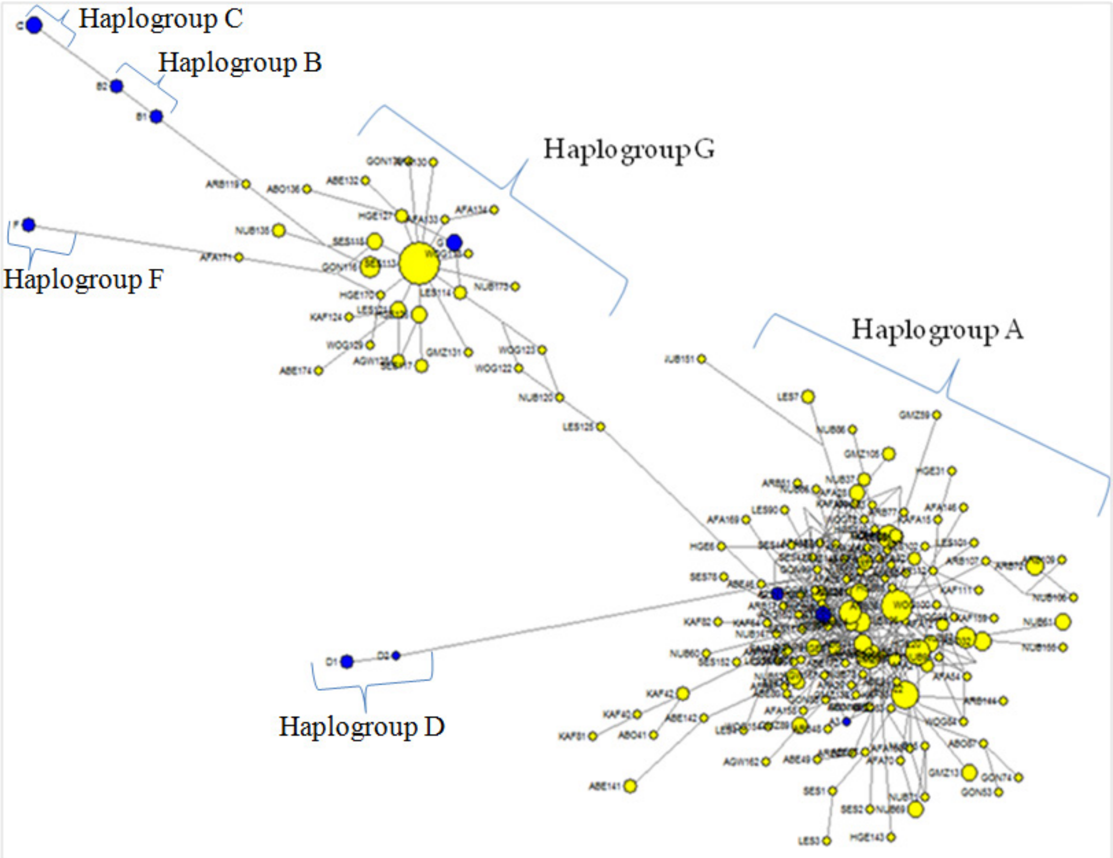
3.1 Maternal origins of Ethiopian goat populations

Goats are believed to be the first ruminant animal to be domesticated 10,500 years ago around the Fertile Crescent (Zeder and Hesse 2000). There are two suggested wild species of the genus *capra* (*C.aegagrus* and *C.falconari*), with most closest candidate *C.aegagrus*, which domestic goat gene pool were derived from (Mannen et al. 2001). Based on mtDNA analysis, six haplogroups or wild common ancestors of domestic goat: haplogroup A, B (with B1 and B2 sub groups), C, D, F and G were globally detected (Luikart et al. 2001; Sultana et al. 2003; Joshi et al. 2004; Chen et al. 2005; Sardina et al. 2006; Naderi et al. 2007).

The origins of Ethiopian indigenous goat populations remained unknown until recently despite the fact that the country served as one of the main gates of livestock species into African continent. A recent study conducted on 14 indigenous goat populations of Ethiopia revealed that two maternal origins (haplogroup A and G; Figures 1 and 2) were detected which are believed to arrive from Egypt following the Nile delta and from Yemen and the nearby region crossing the Red Sea (Getinet et al. *in press a*). These haplogroups were previously reported in Egypt (Naderi et al. 2007). In addition, there is no any molecular clue about the second route of introduction from South East Asia following Indian Ocean and Red Sea to Ethiopia (Getinet et al. *in press a*). Moreover, haplogroup G has not been detected in Asia and elsewhere in the world except in Middle East (only in Iran, Saudi Arabia), Turkey and in Egypt (Naderi et al. 2007) and in Kenya (Kibegwa et al. 2015).

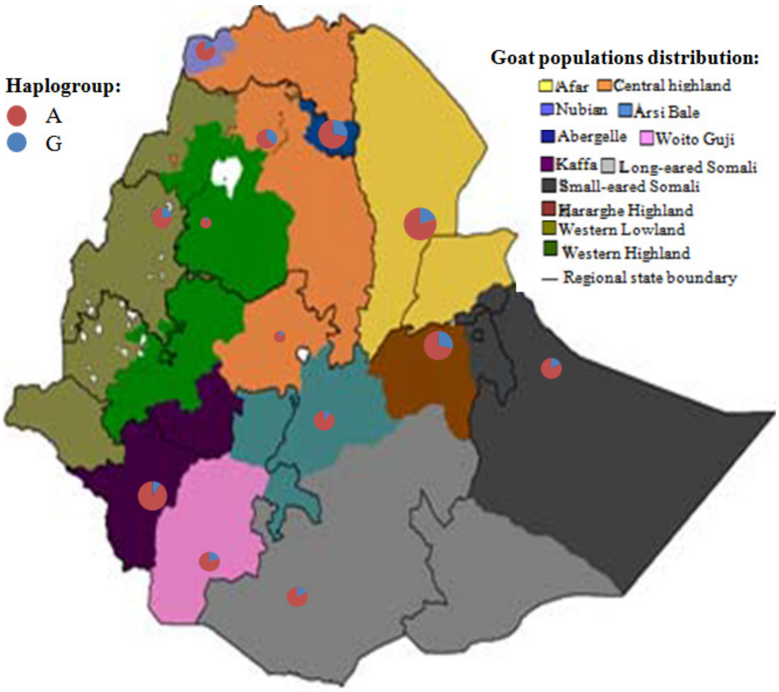
Presence of more number of haplogroups highly contributes to a wider gene pool of goat populations in a country and provides more opportunity to design alternative breed improvement and conservation strategies (Getinet et al. *in press b*). In this regard, Asian goat populations are highly differentiated because of presence of all the six haplogroups (Chen et al. 2005; Naderi et al. 2007). Only haplogroup A arrived in Latin and Central America (Amillis et al. 2008). In Ethiopia, in addition to other contributing factors like population migration, arrival of only two haplogroups (maternal origins) from centre of domestication could have contributed for the narrow average genetic distance (F_{ST}: 0.026) of Ethiopian goat populations (Getinet et al. 2016). This suggests to be prudent in designing improvement programs for the goat populations in Ethiopia.

Figure 1: Network diagram of the identified haplogroups (maternal origins) in Ethiopian indigenous goat populations.



Key: Yellow nodes represent haplotypes and blue nodes represent reference haplotypes from the respective haplogroups.
Source: Getinet et al. (*in press a*).

Figure 2: Distribution of identified haplogroups A and G in Ethiopian goat populations.



Source: Getinet et al. (*in press a*); Gizaw et al. (2009)

3.2 Phenotypic characterization of goat populations

Morphological characterization

Physical description of a population is one of the methods of population identification found in a certain geographical region (Galal et al. 1996). Physical characteristics of the five goat populations studied are described below (Table 1).

Gondar goat population: Gondar goat population is found mainly in highland areas of north and south Gondar, Amhara state, Ethiopia. This goat is also found partly in lowlands of north Gondar. Previous reports (Farm Africa 1996) grouped the goat population found in this area together with Ambo goat and was named Central Highland goat. According to Alubel (2015) who morphologically studied the goats found in Lay-Armacheho area of Gondar, a majority of the goats are horned, males have ruff but not the females, and the adult animal body weight is estimated at 33.9 kg. Pure white and mixed coat colours describe the population (Figure 3). These coat colours equally describe both female and male animals.

Ambo goat population: Ambo goat, which was grouped under Central Highland goat in former classification (Farm Africa 1996), is distributed in West Showa of Oromia region. The majority of the goats (75.7%) have patchy coat colour patterns in both sexes, 20.3% plain and 4% spotted (Netsanet 2014). Among goats with plain coat colour pattern, 18.3% are brown, 1.7% white and 1.7% black. Fifteen per cent of the goats have brown coat with black patches and 10% of the goats have white coat with black patches. Most of the males (84.4%) have spiral horns while the rest have curved ones, whereas 61.2% and 38.8% of the females have curved and spiral horns, respectively (Figure 3). Orientation of the horns is backward in 93.3% and upward in 5.7% of the goats. All animals have concave head profile, pendulous (83.3%) and semi-pendulous (16.7%) and ear orientation type, straight (76.3%) and dipped (23.7%) back profile. Males have wattle (85%), beard (93.8%) and ruff (53.1%) while the majority of the females had no beard (57%) and ruff (96.3%).

Woyto-Guji goat population: Woyto-Guji goat population is distributed in Gamu-Gofa and eastern Sidamo (Guji) including Jinka valley in SNNPR state (Farm Africa 1996). Woyto-Guji goats are characterized by curved and backward oriented horns, with 97.4% of both males and females being horned, concave head profile, semi-pendulous ear type, and straight back profile in 81.4% of the population and curved or dipped back profile in 18.6% of the goats (Figure 3). In addition, majority of the males have beard (65.8%) and ruff (68.4%) but no wattle while majority of sampled females had no beard (88.2%) and ruff (98.9%). Almost all (99.3%) sampled goats in both sexes had no wattle (Biruh 2013; Netsanet 2014).

Arsi-Bale (Highland and Lowland) goat populations: The goat populations are distributed in the highland and lowlands of Arsi and Bale, Oromia state. According to Hussein (2015), the goat population has a wide range of coat colours. Both highland and lowland goat populations can be explained dominantly by plain coat colour (black and white) pattern. However, while patchy and spotted coat colours are the second and third dominant patterns in the Highland goat, spotted are the second and third dominant patterns in lowland goat population (Figure 3). The dominant colour identified by Hussein (2015) for the highland goat contradicts with previous report of Farm Africa (1996). In the latter report, the dominant colours of the highland goat were found to be plain black, white, red-brown and grey and mixed colours of black and white with patches of other colours. This might be because of high level of population in-and-out migration among Arsi-Bale Highland goat and the nearby populations for the last few decades. This hypothesis is supported by Getinet et al. (2016) report of 42.5, 19.3, 28.8, 24.3, and 33.7 level of population migration per generation (Nm) among Arsi-Bale Highland goat with Hararghe Highland, Long-eared Somali, Short-eared Somali, Woyto-Guji, and Ambo goat populations, respectively. Hair size of the Arsi-Bale goat is the other unique feature of the highland goat population. It is covered with long wavy and glossy hair (mean hair length of 13.8 cm). However, the Arsi-Bale Lowland goat has smooth and short hair which is in agreement with other rift valley family goat types (Woyto-Guji goat, Afar goat) (Farm Africa 1996; Kassahun and Solomon 2008; Seifemichael et al. 2014; Yaekob Lorato et al. 2015).

Table 1: Distribution and physical description of five goat populations in Ethiopia

Population	Distribution area	Physical description	Source
Ambo (Central Highland)	West Shewa	Dominantly patchy coat colour with some plain (brown, brown and black) and spotted; males possess spiral (84.4%) and curved (15.6%) horn whereas most females have curved (61.2%) and some have spiral (38.8%) horn shape; horn orientation is backward (93.3%), upward (5.7%); concave head profile, pendulous (83.3%) and semi-pendulous (16.7%) ear orientation type, straight (76.3%) and dipped (23.7%) back profile; males have wattle (85%), beard (93.8%) and ruff (53.1%) while majority of females had no beard (57%) and ruff (96.3%).	Netsanet 2014
Gondar (Central Highland)	Highlands and lowlands of Gondar	90.38% horned, semi-pendulous, majority males have ruff but not females, adult body weight (33.95 kg), body length (61.44 cm), HW (71.02 cm), CG (74.9 cm), chest width (15.48 c m), PW (12.2 cm), horn length (15.74 cm), EL (15.04 cm), scrotal circumference (24.52 cm). The population can be described with white coat colour (21.66%) and its combination with other coat colours (55.09 %).	Alubel 2015
Woyto-Guji	South Omo, Southern Sidamo and Wolayta	Overall coat colour patterns for both sexes were patchy (67.4%), plain (24.9%) and spotted (7.6%). Plain coat colour types are black, brown and white observed in sampled goat with the proportion of 11.6, 8.6 and 5.6%, respectively. 97.4% of both sexes possess curved and backward oriented horn, own concave head profile, semi-pendulous ear orientation, 81.4% of them straight back profile but 18.6% curved or, majority the males have beard and ruff but no wattle while majority females have no beard and ruff	Biruh 2013; Netsanet 2014
Arsi-Bale Highland	Highland of Arsi and Bale	Dominantly plain coat colour (black and white) pattern followed by patchy and rarely spotted. Among coat colours, the dominated colours of the highland goat were showed followed by black with patchy, white with patchy, red-brown and grey; long wavy and glossy hair (mean=13.8 cm); Horned (98.1%), straight horn shape followed by curved and spiral with horn orientation of upward followed by backward; short size wattle, have ruff, dominantly sloping rump profile.	Hussein 2015; Getinet et al. 2016
Arsi-Bale Lowland	Lowlands of Arsi, Bale, Hararghe and mid rift valley of Ethiopia and characterized by	Small body size, short legs, short ears, both short and long hair as well as their glossy, wavy and gray colour dominantly plain (white) coat followed by black, black with spotted and patchy colour; the lowland goat had smooth with short hair in agreement with other rift valley family goat types; Horned (93.1%); dominantly curved horn (long for males) shape followed by straight, while spiral horn shape was observed in the lowland study area; dominantly semi-pendulous ear orientation followed horizontally, pendulous and erect; long wattle, no ruff, dominantly roofy rump profile.	Workneh 1992; Farm Africa 1996; Hussein 2015 Umeta et al. 2011

Figure 3: Representative animals from each goat population.

Gondar goat buck

Gondar goat does

Ambo goat does

Arsi-Bale Highland goats

Arsi-Bale Lowland flock

Woyto-Guji goat buck

Woyto-Guji goat doe

Photo credit: Getinet Mekuriaw (Arsi-Bale Highland, Gondar and Ambo goat populations); Netsanet Zergaw (Woyto-Guji goat); Hussein Hassen (Arsi-Bale Lowland goat)

Growth and reproductive performance

Ambo goat population have the highest and Arsi-Bale goat the lowest birth weights among the five populations studied (Table 2). Arsi-Bale goat remained inferior to the other populations in body weights and weight gains until six months of age. Although Ambo goats have higher birth weight than Gondar, they have slower growth rate and lower weight at six months of age than Gondar goats. Woyto-Guji goats are inferior in body weights to both Gondar and Ambo populations, but they have higher reproductive performance with kidding interval of 5.47±0.96 months compared to 6.6±1.37 for Ambo and 8.58±2.02 for Gondar populations. The results for Ambo and Gondar populations, which have been categorized under one population by previous studies, is indicative of genetic differences between the populations which was also corroborated by the molecular genetic variation observed in this study.

Table 2: Productive and reproductive performances of the goat populations

Trait	Ambo	Woyto-Guji	Gondar	Arsi-Bale‡
Birth weight kg	2.68±0.04*	2.03±0.04*	2.31±0.04**	1.91 ± 0.03†
Weight at 3 months in kg	11.49±0.47*	9.04±0.18*	10.67± 0.17**	-
Weight at 6 months in kg	15.73±0.54*	9.42±0.19*	17.53±0.24**	6.65 ± 0.19†
Weight at 9 months in kg	-	-	22.66±0.44**	9.03 ± 0.29†
Weight at 12 months in kg	-	-	-	14.32 ± 0.40†
Weight gain (birth–3months) in gm	77.67±1.88*	73.93±2.01*	92.62±1.84**	-
Weight gain (3–6 months) in gm	65.4±2.84*	31.92±2.33*	75.47±1.93**	-
Weight gain (6–9 months) in gm	-	-	61.65±2.78**	-
Average daily milk yield in litre		0.075±0.0052*	-	-
Kidding interval in months	6.6±1.37*	5.47±0.96*	8.58±2.02**	-
Age at first kidding in months		21.97±0.41††		14.7±0.14†††

Key: Adapted from: *=Netsanet et al. (2016); **=Alubel (2015); †=Bedhane et al. (2013); ††=Biruh (2013); †††=Tesfaye (2010); ‡=Sampling was undertaken in the Rift Valley region of Ethiopia.

3.3 Genetic characterization and demographic expansion

Genetic diversity of Ethiopian indigenous goat populations (eleven goat populations) was first characterized in 2004 (Tesfay 2004) using microsatellite markers and clustered in to eight entities though the population structure analysis. This same study does not support the classification into eight breeds or breed groups. With the same marker, Chenyambuga et al. (2004) and Hassen et al. (2012) carried out the study of genetic diversity of two and six indigenous goat populations, respectively. Estimates of genetic diversity parameters are given in Table 3.

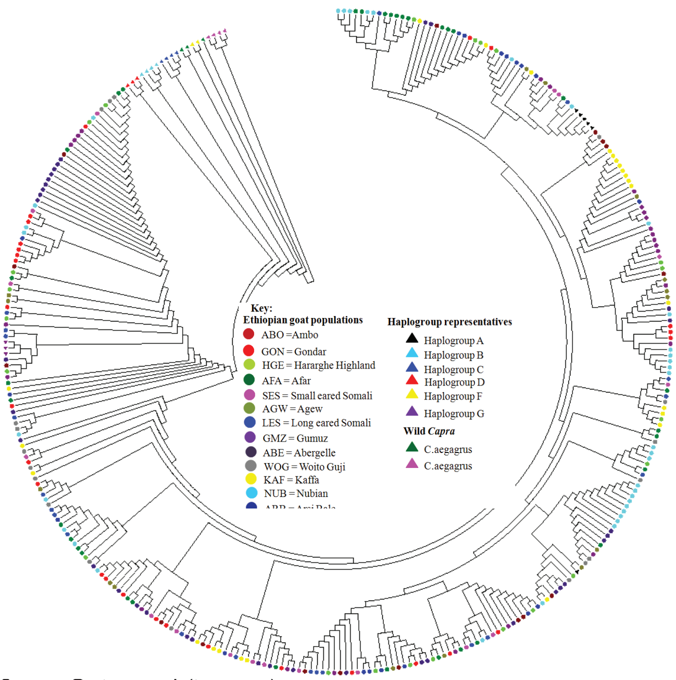
Table 3: Genetic diversity of goat populations studied

Population	MNA	H_E	H_O	Marker	Author
Arsi-Bale	5.33	0.610	0.580	Microsatellite	Tesfaye 2004
Central Highland	5.13	0.570	0.530	Microsatellite	Tesfaye 2004
Woyto-Guji	5.67	0.580	0.540	Microsatellite	Tesfaye 2004
Arsi-Bale Highland		0.367	0.381	SNP	Getinet et al. 2016
Ambo		0.371	0.381	SNP	Getinet et al. 2016
Gondar		0.378	0.381	SNP	Getinet et al. 2016
Woyto-Guji		0.373	0.381	SNP	Getinet et al. 2016

Key: Arsi-Bale goat were sampled in the rift valley area; MNA=Mean number of alleles; HE=expected heterozygosity, HO=Observed heterozygosity

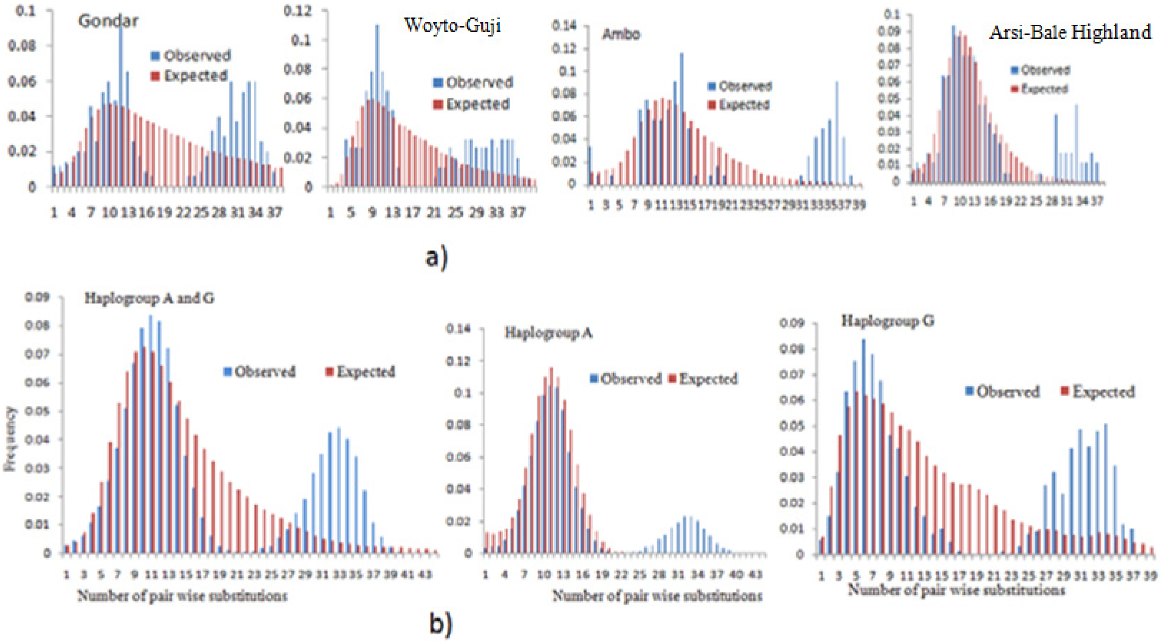
In both microsatellite and SNP marker sets, high estimates of heterozygosities were observed in the goat populations studied (Table 3). Diversity estimates from microsatellite markers are higher than estimates observed by SNPs. This is due to multi-allelic nature of microsatellite markers, whereas SNPs are bi-allelic in nature. On the other hand, mtDNA analysis of Ethiopian indigenous goat populations was carried out recently and high haplotype diversity was observed (Table 4). However, most of the variation is explained by within population and the pair wise population differentiation estimates were very narrow (Tables 5 and 6; Tesfaye 2004; Getinet et al. 2016). This is because of the presence of high population admixture: the average estimate of level of migration per generation was 24 (Figure 4; Getinet et al. 2016). Moreover, the demographic expansion analysis of mtDNA strengthens this argument. The overall and haplogroup demographic expansion diagrams show presence of two major recent expansions (Figure 5). From the populations, trend of the second expansion of Woyto-Guji goat population occurred recently like the other goat populations but happened slowly. Moreover, few number of haplogroups that arrived in Ethiopia could have led the country originally to have narrow gene pool.

Figure 4: NJ tree of Ethiopian indigenous goat populations: based on hypervariable 1 of mtDNA.



Source: Getinet et al. (*in press a*)

Figure 5: Trend of goat populations' expansion: a) goat populations; b) 14 Ethiopian indigenous goat populations grouped into two maternal origins.



Source: Adapted from Getinet et al. (*in press a*)

Table 4: Genetic diversity of goat populations' mtDNA haplotypes

Population	N	S	H	H/N	Hd	π	No. of haplotypes (%)		K
							Haplogroup A	Haplogroup G	
Arsi-Bale Highland	20	69	18	0.90	0.98947	0.01309	16(88.89)	2(11.11)	13.84737
Ambo	16	68	13	0.81	0.96667	0.01701	11(84.62)	2(15.28)	17.99167
Gondar	27	70	24	0.89	0.98860	0.01760	16(65.22)	8(34.78)	18.62108
Woyto-Guji	18	63	18	1.00	1.00000	0.01640	14(77.78)	4(22.22)	17.35294
Overall	81	174	73	0.90	0.98619	0.01603	57(79.13)	16(20.85)	16.95327

Key: S = No. of Polymorphic/Indel/missing Sites; K=Average no.of differences; h = Number of haplotypes, Hd = Haplotype diversity, Pi (π) = Nucleotide diversity; HGH=Hararghe Highland; LES=Long eared Somali; SES=Small eared Somali; π =nucleotide diversity

Source: Getinet et al. (*in press a*)

In a previous report (Farm Africa 1996), both Ambo and Gondar goat populations were categorized under one group called Central Highland goat. Similarly, the pairwise comparison analysis in a recent study (Getinet et al. 2016) showed that the genetic distance between Gondar and Ambo goat population is very minimal (F_{ST}=0.010); however, still Gondar goat is more close to Abegelle goat than with Ambo (F_{ST}=0.008) (Table 5). Overall, the pairwise differentiations obtained among the goat populations studied is below the threshold of minimal standard. According to Weir (1996) and Kalinowski (2002), the population differentiation is considered as very minimal if the F_{ST} value estimation is less than 0.05, moderate if the differentiation is $0.05 < F_{ST} \leq 0.25$ and highly differentiated if the F_{ST} value is greater than 0.25. However, F_{ST} about 0.15 is still considered to be an indication of significant differentiation among populations (Frankham et al. 2002).

Table 5: Genome wide population differentiation: pair-wise (F_{ST}) (below diagonal) and Reynolds' (above diagonal) genetic distances

Population	Arsi-Bale Highland	Abergelle	Ambo	Gondar
Arsi-Bale Highland		0.022	0.015	0.019
Abergelle	0.022		0.015	0.008
Ambo	0.015	0.015		0.010
Gondar	0.019	0.008	0.010	

Source: Getinet et al. 2016

Table 6: Nei's standard genetic distance (D_S) (above diagonal) and Nei's D_A genetic distance (below diagonal) genetic distances of the three goat populations based on SSR markers

Population	Arsi-Bale*	Central Highland	Woyto-Guji
Arsi-Bale		0.019	0.012
Central Highland	0.039		0.036
Woyto-Guji	0.030	0.050	

*=Sampling was carried out in the Rift Valley region of Ethiopia, most likely belonging to the Lowland Arsi-Bale type

Source: Tesfaye 2004

4. Characterstics of goat production systems

4.1 General description of production systems

The production systems of indigenous goat populations in Ethiopia are described by Gizaw et al. (2010) and Abegaz et al. (2014). The characteristics of the production systems of the goat populations in the current study are described in Table 7. All the goat populations, except Woyto-Guji are managed under mixed crop–livestock production system. Crop production is as important as, and sometimes more important than, livestock production in the mixed crop–livestock system. However, in Woyto-Guji area, livestock is more important than crop production. The Woyto-Guji area is characterized by agro-pastoral production system with medium scale of livestock (goat production in particular), whereas small-scale production is common for all other goat populations studied.

Similarly, in the production area of Arsi-Bale goat populations, mixed crop and livestock production system is the dominant farming system. Livestock production is an important component and well integrated with crop production. Livestock species kept by the farmers comprise cattle, sheep, goats, equines and chicken; while camel was common in the lowland area. The major farming activities in the highland study area were mixed crop–livestock production system, whereas the lowland farmers practiced dominantly (83.1%) mixed crop and livestock farming followed by livestock rearing alone (16.9%). Main crops grown in the highland were wheat and barley (85%) followed by faba bean (6%), field pea (5%) and linseed (4%) whereas wheat (55%), maize (20%), sorghum (15%) and teff (10%) were the main crop grown in the lowland. The Highland Arsi-Bale goat can be grouped as alpine goat and the goat population is known with course hair fibre where its economic importance has remained overlooked not only by development agents but also by researchers.

In the lowland goat population, utilization of goat milk is common and meat production is also one of the main purposes for rearing the goat populations. The purpose of keeping goats in highland systems is mainly meat production for sale.

Table 7: Characteristics of production systems of five goat populations in Ethiopia

Population	Production system	Environment	Characteristics of production system respect to goat production		Source
			Main products	Scale of production and management	
Arsi-Bale Highland	Mixed crop–livestock	Sub-alpine (>3000m)	Meat, fibre, skin	Small scale	Farm Africa 1996; Hussein 2015
Arsi-Bale Lowland	Mixed crop–livestock	-	Meat, skin, milk	Small scale	Farm Africa 1996; Umeta et al. 2011; Hussein 2015
Ambo	Mixed crop–livestock	Highland (>2000m)	Meat, skin,	Small scale	Farm Africa 1996; Netsanet 2014
Gondar	Mixed crop–livestock	Highland (1500-2500m)	Meat and skin	Small scale	Farm Africa 1996; Alubel 2015
Woyto-Guji	Pastoral	Arid and Semi-arid (≤1000)	Meat, skin and milk	Medium scale	Farm Africa 1996; Netsanet 2014

4.2 Family size, land and livestock holdings

Family size is one of the major factors which determine the socioeconomic status of a family. The largest average family size is reported for Konso area where Woyto-Guji goat is found; whereas the lowest average family size is reported for the highland and lowland of Arsi and Bale areas (Table 8). The low level of education available in the agro-pastoral community in Konso may have contributed to the low level of awareness to family planning and larger family size than the other areas. On the contrary, total land holding in Konso area is very small compared to the rest of the study areas, and the average crop land holding per household is 0.18 ha. The reason could be lack of crop production practice by agro-pastorals because of crop failure following recurrent droughts. Furthermore, the agro-pastoral areas need larger grazing resources than the cropping systems. Shrinking arable lands due to land degradation and large family sizes could also be the reason for the small land holding in this area (Netsanet 2014). Moreover, Alubel (2015) observed that in addition to the human population density (average family size in Gondar goat sampling area being 7.1) expansion of the existing and newly established towns, delineation of large tracts of land for forestry which is closed to livestock, establishment of public service institutes (school, clinic, farmers' training centres), land degradation and soil erosion are some of the factors mentioned by the goat keepers for the decline of landholding per household in Armacheho area where Gondar goat population is reared.

The average goat holding in the study areas is highest in Woyto-Guji area, followed by the Arsi-Bale lowland area. The average goat flock size in monitored households in Armacheho area was 13.8± 9.4 (Alubel 2015). However, this may not represent the average flock size of the area since the households with relatively large goat flock sizes were purposely selected for the flock monitoring study. Goat keeping is the most important livestock species numerically in all the study areas. Goat keeping is highly important for Woyto-Guji goat keeping agro-pastoralists in konso area.

Cattle production is the major contributor to cash income and as family food source in the form of milk in Armacheho and Meta Robi areas (Table 9). However, as the numerical values indicate (Table 8), goat keeping is the most important enterprise for agro-pastoralists who rear Woyto-Guji goats in Konso area. The higher importance of cattle in the highland mixed crop–livestock systems might be due to the contribution of cattle for crop production and the high sale value of cattle compared to small ruminants.

Table 8: Family size, land holding and livestock holding per household

	Gondar (Alubel 2015)	Ambo (Netsanet 2014)	Woyto-Guji (Netsanet 2014)	Arsi-Bale (Hussein 2015)	
				Highland	Lowland
Family size	7.1±2.9	7.34±3.25	8.52±2.46	<5.0	<5.0
Total land (ha)	3.3±2.5	2.49	1.56		
Cattle	9.6±7.2	6.35±3.71	8.83±9.83	-	-
Goat	10.5±7.5	12.73±8.0	31.25±22.46	10.5	26.73
Sheep	1.3±2.5	0.96±2.12	7.23±7.86	-	-

Table 9: Index derived from farmers, ranking of importance of livestock species as cash income and as a food source

Livestock	Armacheho	Meta Robi	Konso
Cattle	0.46	0.33	0.27
Goat	0.35	0.31	0.34
Sheep	0.02	0.06	0.20
Others	0.16	0.29	0.19

Source: Netsanet (2014) for Meta Robi and Konso; Alubel (2015) for Armacheho areas

4.3 Flock structure and objectives of production

Most of the animals kept by farmers in the study areas are female animals aged one year and above (Table 10). Male animals aged six months to one year are the least animals kept in the flocks in Gondar and Ambo goats. Male animals are the first to be sold for immediate cash needs and they could be sold as early as 6 months of age. Such practice of selling young male animals has a consequence of losing male animals with high genetic merits that can be used to improve the genetics of the village flocks. Highest number of male animals above one year age are kept in Woyto-Guji and Arsi and Bale Lowland goats compared to Gondar and Ambo goats. Irrespective of the smallest average flock size of Ambo goat in Meta Robi area compared to Woyto-Guji goat in Konso and Arsi-Bale goat in lowland of Arsi and Bale areas, highest number of castrated males are kept in each household implying there is better understanding and practice of fattening male animals in Meta Robi area. However, both male and female animals, which are below six months of age, are least represented in the flock structure in Arsi-Bale Highland goat.

The main purpose of goat production in Armacheho and Arsi-Bale highland areas is to generate cash income from sale of live animals (Table 11). Goats are also a source of family meat consumption in these areas. Whereas, farmers in Arsi-Bale lowland area keep goats primarily for milk production for home consumption. Goats also function as saving accounts and source of cash from sale of live animals and probably milk.

Table 10: Mean (± standard errors) number of goats of different sex and age groups in the study areas (with total number of goats in parentheses)

Age group	Gondar (Alubel 2015)	Ambo (Netsanet 2014)	Woyto-Guji (Netsanet 2014)	Arsi-Bale (Hussein 2015)	
				Highland	Lowland
Male kids < 6 months	1.87±1.91(215)	2.47±1.54(232)	2.96±2.26(0338)	0.29(024)	1.99(183)
Female kids < 6 months	1.75±1.70(201)	2.49±1.45(254)	3.36±2.22(0383)	0.45(037)	2.18(201)
Male 6 months–1 year	0.81±1.29(094)	1.81±1.27(087)	3.91±3.33(0399)	1.17(096)	3.37(310)
Female 6 months–1 year	1.32±1.66(153)	2.51±2.68(158)	4.99±4.12(0574)	2.08(171)	5.21(479)
Male > 1 year	1.01±1.51(116)	1.82±1.31(111)	4.90±7.43(0514)	1.20(102)	3.92(392)
Female > 1year	3.58±3.22(404)	5.4±4.26(616)	12.23±8.63(1431)	5.08(417)	8.94(823)
Castrate	0.22±0.59(025)	2.21±1.44(053)	2.52±1.66(0116)	0.17(014)	1.12(103)
Total	10.56±11.88(1208)	18.71±13.95(1511)	34.87±29.65(3755)	10.5(861)	26.73(2460)

Table 11: Indexes derived from farmers ranking of goat production objectives

Production objectives	Armacheho (Alubel 2015)	Arsi-Bale(Hussein 2015)	
		Highland	Lowland
Sale/cash Income	0.64	0.48	0.27
Manure	0.00	-	-
Meat	0.29	0.17	0.03
Milk	0.00	0.0	0.39
Saving	0.07	0.17	0.22
Wealth status (prestige)	-	0.11	0.09

4.4 Major feed and water resources

The major feed sources of the goat populations in the five study areas in both wet and dry seasons are summarized in Table 12. Fewer feed alternatives are available for the Gondar goats in Armacheho area than in the other areas. Natural pasture, which is commonly important in all the study areas, and fallow land are the major feed sources for the goat populations in Armacheho during wet season. However, crop aftermath is replaced by grazing on fallow land in this area during the dry season. More feed resources are available in Ambo (Meta-Robi area) and Woyto-Guji (Konso area) for goat populations compared to Armacheho and Arsi-Bale. Natural pasture and crop residue are most important feed sources in Konso during wet season and hay and natural pasture during the dry season in order of importance. In the highlands of Arsi-Bale area, natural pasture, shrub and bush during wet season and shrub, bush and crop residue in the dry season are the major feed sources in order of importance. However, in lowlands of Arsi and Bale, the major feed sources are tree leaves in both seasons. Shrubs, bushes and tree leaves, which are more suitable to the feeding behaviors of goats, are more available in Arsi-Bale areas than in the other areas studied in this paper.

Table 12: Indexes derived from farmers, ranking of the major feed resources across study areas

Feed resources	Armacheho (Alubel 2015)	Meta Robi (Netsanet 2014)	Konso (Netsanet 2014)	Arsi-Bale	
				Highland	Lowland
Wet season					
Natural pasture	0.58	0.49	0.57	0.50	0.32
Fallow land	0.42	0.16	0.17		
Local brewery			0.02		
Hay		0.05	0.02		
Crop residue		0.13	0.23		
Established pasture		0.004	-		
Shrub and bush				0.42	0.18
Tree leaves				0.08	0.60
Dry season					
Natural pasture	0.83	0.18	0.30	0.11	0.28
Hay	0.00	0.16	0.47		
Crop residue	0.00	0.07	0.18	0.20	0.39
Crop aftermath	0.17				
Fallow land		0.07	0.02		
Local brewery		0.05	0.02		
Established pasture		0.01	0.01		
Concentrates		0.10	0.003		
Shrub and bush				0.42	0.18
Tree leaves				0.08	0.60

The water sources for livestock include spring water, river, pond, streams and water well (Table 13). Among these, river is the major water source in all the study areas except for Meta Robi where stream is most important during wet season. The importance of rivers increase during the dry season. Frequency of watering varied among the study areas. During wet season, water is freely available in most of the areas studied. The frequency is reduced to once a day during the dry season. In Konso where the Woyto-Guji goat is reared, water is not available freely even during the rainy season and 72% of the households responded that goats are watered once every other day during the dry season (Netsanet 2014). Similar situations were reported for goats in lowlands of Arsi-Bale areas in the same season. This implies that water shortages are among the major challenges in Konso and Arsi-Bale lowland areas.

Table 13: Major sources of water in the study areas expressed as percentages (N)

Attribute	Source of water	Armacheho (Alubel 2015)	Meta Robi (Netsanet 2014)	Konso (Netsanet 2014)	Arsi-Bale (Hussein 2015)	
					Highland	Lowland
Source of water						
Wet season	Spring water	16.1	20.0(24)	-	8.0(7)	5.4(5)
	River	58.5	31.7(36)	45.0 (39)	62.5(55)	57.6(53)
	Ponds	-	-	24.0 (20)	0	0
	Streams	25.4	48.3(58)	28.3 (34)	29.6(26)	37.0(34)
	Water well	-	-	12.4 (15)		
Dry season	Spring water	4.2	-	11.6 (14)	8.0(7)	9.8(9)
	River	95.8	74.0(88)	70.4 (84)	64.8(57)	57.6(53)
	Ponds	-	-	18.0 (21)	0	7.6(7)
	Streams	-	-	-	27.3(24)	25.0(23)
	Water well		5.8(7)	18.0 (21)	-	-
Frequency of watering						
Wet season	Freely available	85.6	56.7(68)	-	100.0(88)	100.0(92)
	Once day	14.4	32.5(39)	84.6 (99)	0	0
	Every other day	-	5.0(6)	15.4 (18)	0	0
	Once in 3 days	-	5.8(7)	-	0	0
Dry season	Freely available	34.7	26.3(31)	-	88.6 (78)	9.8(9)
	Once day	65.3	35.6(42)	29.6 (34)	11.4(10)	18.5(17)
	Every other day	-	5.9(7)	62.6 (72)	0	71.7(66)
	Once in 3 days	-	6.7(8)	7.8 (9)	0	0

4.5 Farmer practice of selective breeding

The selection criteria used by farmers to select breeding bucks and does varied across the study areas. Body conformation is the major criterion for selecting breeding bucks and does for Gondar goat population in Armacheho district (Table 14). This is similar to the selection criteria for Arsi-Bale goat populations in both agro-ecologies (Hussein et al. 2015). Twining ability and frequency of kidding are the second and third criteria to select does in Gondar goat; whereas in buck, growth rate and coat colour are the second and third criteria. However, twining ability, body conformation and frequency of kidding for does and growth rate for bucks are the first, second and third selection criteria for Ambo goat population in Meta Robi, respectively.

According to Tesfaye (2012), milk production, family history, twinning ability, physical size and conformation, mothering ability, kid growth rate, coat colour and kidding interval for females and coat colour, family history, testicular characteristics, libido, growth rate, prolificacy and disposition/character for males are selection criteria for Arsi-Bale goat in the rift valley region. The priority criteria for Woyto-Guji goat population is a bit different, particularly for bucks. Growth rate takes the first priority, and coat colour and body conformation together are the second priority; whereas, in the same goat population, body conformation is the first selection criterion, and twining ability and frequency of kidding are the second and third criteria of selecting does.

Coat colour, as the second priority of selecting bucks in Woyto-Guji goat population, might be because of predators' problem. Similar observation was reported for Abergelle goat population where coat colour plays significant role (the first priority) for selection of breeding animals (Alubel 2015). In most cases, white coat coloured animals are not preferred by farmers in Abergelle area since such animals can be easily visible by predators from distant places. Given the variable criteria employed in the study areas, the main source of selection of the breeding animals is from own flock in all goat populations. This highly leads production and reproduction potential of the breeding animals to deteriorate because of fixation of undesirable alleles (Pemberton 2004; Dorji et al. 2012).

Table 14: Ranking (index) breeding bucks and does selection criteria

Criteria	Gondar (Alubel 2015)	Ambo (Netsanet 2014)	Woyto-Guji (Netsanet 2014)
Doe			
Milk production	0.00	-	0.13
Twining ability	0.29	0.25	0.23
Body conformation	0.34	0.24	0.27
Frequency of kidding	0.19	0.22	0.19
Coat colour	0.07	0.19	-
Growth rate	0.11	0.07	-
Good browser	0.00	0.12	-
Hardship tolerance	0.00	-	-
Horn shape	-	-	0.003
Disease resistance	-	0.18	
Buck			
Coat colour	0.13	0.35	0.29
Body conformation (size)	0.43	0.39	0.29
Growth rate	0.22	0.21	0.40
Milk production	0.00	-	-
Libido	0.04	0.04	0.07
Kid body size when born	0.03	-	0.034
Good browser	0.00	-	0.05
Resistance to disease	0.02	0.004	0.09
If born as twin	0.12		
Long horn		-	0.01

4.6 Characteristics of goat marketing

Goat market characteristics, marketing systems and the whole value chain in Ethiopia have been well described by Abegaz et al. (2014). The authors generalized that the present system of goat production and marketing in Ethiopia is characterized by substantial variations in animal availability, body weight and condition at slaughter, and carcass characteristics.

Farmer goat marketing practices in the Armacheho area in the current study (Alubel 2015) depend on negotiation without having prior information on current market prices. In addition, marketing is highly dependent on the few holidays and festivals. During the rest of the year, farmer market participation depends on the need for immediate cash. The priority animals for sale are male animals between the age of six months and one year, old does and old bucks as first, second and third priority, respectively. In Armacheho area, Gondar type goat keepers would sell kids aged less than six months since some of the kids could attain market weight of about 15 kg before six months of age.

In Arsi-Bale Highland and Lowland goats, there is informal market in the nearby towns throughout the year (Hussein 2015). However, it is neither an organized form of marketing system nor competitive. Instead, farmers sell their goat mainly for traders, butchers, consumers and to lesser extent to other farmers. In most cases, farmers prefer to sell their animals during holidays and festivals like in Armacheho area, and in rare cases in other off days when they face financial constraints. In contrast to Armacheho area, the priority animals supplied to markets in Arsi and Bale areas are yearling males which are not desirable for breeding purposes, culled old males and old females. Arsi-Bale farmers thus maintain their breeding flock by retaining outstanding males in the flock and sell the undesirable ones. However, they do not get reliable and adequate market information.

The Arsi-Bale Lowland goats are more preferred by buyers to Arsi-Bale Highland goat since the former has a relatively high dressing percentage and good meat quality. This could be because of more nutrient mobilization for development and growth of hair fibres in the Highland goats. Rather farmers in the highland area are more interested on Arsi-Bale Highland goat for saddle cover from its hairy skin than for meat. Price of the hairy skin from matured animal values ETB 200 – 800 depending on the coat colour where white colour is most preferred (Hussein 2015 and personal observation). Further research is required to maintain and improve the fibre production characteristics of the Arsi-Bale Highland goats.

Netsanet (2014) reported that there was significant variation in the selling age of Ambo and Woyto-Guji goats. The average market ages of male and female goats in Woyto-Guji area were 26.4 and 30.3 months, respectively. In Meta Robi, the respective ages were 9.06 and 9.49 months for males and females, respectively. However, young Woyto-Guiji goats could also be marketed if urgent cash needs arise. Unlike in Armacheho area, Netsanet (2014) and Hussein (2015) reported that there are local traders and brokers in Arsi-Bale, Ambo and Woyto-Guji goat markets.

4.7 Goat production constraints and opportunities

Major production constraints

An understanding of the relative importance of system-specific constraints is fundamental prior to initiating any genetic improvement and other value chain interventions for a sustainable goat production system. In the study areas, different authors reported various constraints as challenges for livestock production in general and goat production in particular (Table 15). Occurrence of various diseases is the common and first priority challenge for all goat populations except Arsi-Bale Highland and Lowland goats. Theft and predator for Gondar goat population (Alubel 2015), drought and lack of superior genotype for Ambo goat population (Netsanet 2014), and drought and feed shortages together and water shortages for Woyto-Guji goat population are the second and third potential challenges in those areas. Similarly, feed shortages, drought and predator for Arsi-Bale Highland goat and water shortages, drought and feed shortages together and disease for Arsi-Bale Lowland goat are the first, second and third constraints, respectively (Hussein 2015). This report contrasts with Umeta et al. (2011) who reported disease as the first challenge in rift valley area for the Arsi-Bale goat.

Table 15: Major goat production constraints

Constraint	Districts				
	Armacheho (Alubel 2015)	Ambo (Netsanet 2014)	Konso (Netsanet 2014)	Arsi-Bale (Hussein 2015)	
				Highland	Lowland
Drought	0.02	0.15	0.220	0.26	0.23
Feed shortages	0.03	0.25	0.220	0.49	0.23
Water shortages	0.02	0.05	0.130	0.04	0.42
Disease	0.38	0.25	0.310	0.10	0.08
Predator	0.13	0.07	0.080	0.11	0.04
Market	0.01	0.08	0.030	-	-
Labour shortages	0.09	0.07	0.003	-	-
Lack of superior genotype	0.02	0.14	0.002	-	-
Theft	0.30	0.001	-	-	-

Index is derived from farmers' rankings of the constraints

The major diseases affecting the goat populations are shown in Table 16 and the major ones are the following: Coenurosis, FMD and anthrax in Armacheho area; Contagious caprine pleuropneumonia (CCPP), internal and external parasites and *peste des petits ruminants* (PPR) in Meta Robi; CCPP, Internal and external parasite and trypanosomiasis in Konso; CCPP, internal and external parasite and PPR in Highlands of Arsi and Bale; CCPP, PPR and anthrax in Lowlands of Arsi and Bale areas. Umeta et al. (2011) also reported that anthrax and diarrhea as the major diseases in the rift valley area, at Arsi Negelle in particular. The rift valley is one of the breeding tracts of the Lowland Arsi-Bale goats. Absence and/or limited veterinary clinics in the study areas together with poor veterinary and weak extension services have contributed to the occurrence of the diseases. The impact of the diseases is also aggravated by shortages of quality feed, poor husbandry practices and the climate which is favourable for the multiplication disease pathogens.

Table 16: Ranking (index) of major goat diseases according to prevalence by respondents in the study areas

Disease	Armacheho (Alubel 2015)	Meta Robi (Netsanet 2014)	Konso (Netsanet 2014)	Arsi-Bale (Hussein 2014)	
				Highland	Lowland
CCPP	0.02	0.23	0.4	0.28	0.37
PPR		0.14	-	0.19	0.29
Anthrax	0.12			0.15	0.23
Pasteurellosis	0.06	0.03	0.02	0.13	0.09
Parasites (Internal and external)	0.05	0.21	0.19	0.25	0.01
Foot rot	0.02	0.08	0.03		
Coenurosis	0.27	-	0.06		
FMD	0.17				
Yenefas Beshita†	0.11				
Tryps		0.02	0.18		
Brucellosis		-	0.03		
Diarrhea		0.08	0.02		
Goat pox		0.11	-		
Liver worm		0.01	0.07		

Key: CCPP=Contagious caprine pleuropneumonia; PPR=*Peste des petits ruminants*; FMD=Foot-and-mouth disease; †=the local name for respiratory diseases.

Opportunities

The establishment of the new Livestock and Fisheries resources development Ministry and the road map for livestock development in the second phase of the country's Growth and Transformation Plan (GTP II) is a great opportunity for livestock development in Ethiopia. There are ongoing research and development projects initiated by various national and international institutes. ILRI's LIVES project is involved in goat value chain development in Meta Robi area with Ambo goat type. The project has also established cooperative breeding villages for the genetic improvement of the population through selective breeding. Similarly, International Center for Agricultural Research in Dryland Areas (ICARDA) and ILRI-BecA have also established cooperative breeding villages for Gondar and Woyto-Guji goats, respectively. A genetic improvement program for Arsi-Bale goat is under way at Adami-Tulu Research Centre of OARI.

5. Intervention options

5.1. System-specific interventions

The results of the studies synthesized in this paper clearly show that there are variations in morphology which is an expression of selective adaptation and performance characteristics of the goat populations studied. There is also high variation in the production systems and the environments in which the populations are reared. Above all, there is variation in the constraints the goat keepers face in the different production systems described in this paper. This would call for a system-specific strategy for the development of the goat populations and their production environment and systems.

Intensification: System-specific interventions need also to consider the degree of farm intensification. The production resources (including animal/breed resources, farm labour, land), the environmental resources (including feed resources and climatic conditions), production performance, the cultural goat management practices, access to inputs and markets need to be considered to design sustainable intensification of the goat production systems described in the current study. The characteristics of the different systems may determine whether a system is amenable to intensification or would be economically more sustainable as extensive production system. For instance, Metawi, (2001) found that introduction of four technological packages (preventive health care, introduction of improved breed genes, enhancing nutritive value of crop by-products, and supplementary feeding during the critical periods) would respond differently under smallholder, semi-intensive and extensive/transhumant production systems in terms of the interventions impact on economic sustainability of the systems.

Research needs: The purpose of a system-specific approach is to ensure that the planned interventions enhance the sustainability of the existing production system. Analysis of sustainability need to consider the technical, economic, social and environmental aspects. This requires a good understanding of the nature and complexity of each production system. Research on methods to assess sustainability of intervention packages and identification of packages for the various production systems is in order.

5.2. Options for utilization of the goat genetic resources

Conservation-based genetic improvement: The results of the current studies showed that there are variations between the goat populations studied, though the low level of genetic differentiation between the goat populations may not warrant considering each population as a distinct management unit. However, since the populations vary in their performance merits (which is partly genetic) and are reared by different communities with different production objectives and under different production systems, it would be justified to plan for each population as a distinct management unit.

A rational utilization of genetic resources is a key component for maintaining sustainability in livestock production systems. The strategy for a sustainable utilization of the goat resources would depend on the need to conserve the unique and adaptive genetic merits of the indigenous breeds, the production resources and the production system characteristics. For instance the unique characteristics of the Highland Arsi-Bale goats which are adapted to the subalpine highlands of the Bale mountains and their unique gene for production for fibre is valuable for the community maintaining the breed need to be conserved. Extensive production systems like in Konso area with large flocks, limited feed resources and less opportunity for intensification due to limited access for inputs and markets may not be feasible for introduction of new genes from improved breeds.

A feasible genetic improvement option for the goat resources in marginal environments and low-input systems would be exploitation of the within-breed genetic variation through selective breeding. Community-based selection programs could also be considered as a form of *in-situ* conservation of the genetic resources. *Ex-situ* breed conservation and improvement option could be suggested, particularly for Arsi-Bale Highland goat population, since the population size is comparatively small. Such a nucleus scheme could be more sustainable if it is well linked with the community flocks. Various breeding schemes suitable to smallholder systems have been suggested (Gizaw et al. 2014). Introduction of exotic genes needs a careful consideration of not only the production systems in general but also the farm topologies, which entails categorizing farms with sufficient production resources and access to inputs and markets. In general crossbreeding could be a more feasible option if it is targeted to (semi-)intensive systems or to systems which are more amenable to intensification.

Genetic diversity, production systems and climate change: Environmental changes resulting from adverse climate changes will influence the sustainability of current production systems. High potential breeds and high input systems may not be sustainable or be efficient producers in the face of adverse climate changes. Conservation of livestock breeds developed and managed under low input systems could be a safe guard against future unfavourable climate changes and ensure sustainability of livestock systems.

Use of genomic and biotechnology tools: Genomic tools have been efficiently utilized to characterize Ethiopian livestock breeds' genetic diversity which can be used in designing conservation strategy. However, the application of genomic tools for genetic improvement, such as genome wide selection and marker assisted selection, may not be realistic in the near future. Yet, there are cases where the technology is applied directly in genetic improvement programs such as determination of exotic blood levels in crossbred populations (Tesfaye 2015).

Reproductive technologies have been tried to accelerate genetic progress in small ruminant breeding. These include hormonal oestrous synchronization and artificial insemination. Oestrous synchronization has been successfully tested in sheep (Zeleke et al. 2015) and artificial insemination (AI) is being evaluated to accelerate dissemination of rams improved through selected breeding and exotic rams. These technologies can be introduced in the ongoing goat breeding programs.

5.3 Value chain development approach for sustainable goat production

Interviewed farmers in this study identified market one of their challenges and their marketing practice is traditional with little access to market information. Appropriate utilization of the available genetic resources and the application of improved technologies and practices have been the focus of research and development efforts to increase production and productivity. However, accessibility and affordability of inputs and access to profitable markets would definitely limit adoption of improved technologies and practices. Thus interventions at key leverage points across the value chain need to be introduced to increase productivity and farmer incomes.

Delivery of health services: Disease is the top constraint for goat production in most of the study areas. CCPP and PPR and parasites (both external and internal) are the major diseases afflicting the goat populations. These diseases can be controlled through strategic prevention, i.e. vaccinations and strategic deworming and spraying. However, this requires efficient health service delivery either through efficient public service or through reliable private service providers.

Delivery of feeds, fodder development and feeding interventions: High energy and protein feeds such as concentrates and local brewery byproducts are not accessible to the goat keepers in the study areas (Table 16). Feeds with high nutritive value are the major inputs for intensive goat production including finishing of marketable kids. A promising intervention for facilitating feed delivery to smallholders in remote areas could be opening feed shops in district towns as small businesses. This has been tested by the LIVES project successfully. Fodder development (particularly fodder legumes) in the mixed crop–livestock system is also feasible if appropriate entry points (e.g. live fences, soil conservation structures) are identified. Improvement of the quality of crop residues (a major feed resource in mixed crop–livestock system) through urea and effective micro-organism treatment and conservation in small-scale silage bags are interventions tested proved effective. In extensive grazing systems, proper range management, conservation of local forests and shrubs, utilization of sub-marginal lands for shrub development through community action could be feasible options.

Improved management practices: Management practices for a sustainable goat production system could include practices that yield the maximum economic benefit to the producers and that minimize the impact of goat rearing on the environment. Such practices would include the utilization of feed resources that are of little value to other livestock such as shrubs and bushes, invasive weeds that could invade productive lands, and appropriate grazing management to avoid land degradation, water harvesting alternatives like ponds, wells, etc. particularly in pastoral areas, e.g. Konso area, introducing semi-intensive farming system in mixed crop–livestock production systems.

Access to profitable markets: Access to profitable markets could act as a pull factor for adoption of improved technologies and practices. Producers need to be provided with market information, linked to niche markets and more profitable markets beyond the local primary markets. However, smallholders' scale of production may not allow marketing of their produce to distant markets as the overhead marketing cost is high. Collective actions in such marketing cooperatives would be a solution. However, all these interventions need to be preceded by production of goats that meet the requirements of the various market outlets.

5.4 Policy support for goat development

Policy support seems in place for livestock development in Ethiopia as expressed by the establishment of the Livestock and Fisheries Ministry and the publication of the Ethiopia livestock master plan. Policy support areas may include regulation of the management of the genetic resources, human resource development which is lacking in the livestock sector, long-term commitment to livestock projects (particularly genetic improvement and conservation), market infrastructure development and implementation of the marketing regulation proclamation, value chain governance, institutional development particularly for genetic resource management, and the delivery of services to smallholders.

Reference

Abegaz, S., Abebe, G. and Awgichew, K. 2008. Sheep and Goat Production Systems in Ethiopia. In: Yami, A. and Merkel, R.C. (eds), *Sheep and goat production handbook for Ethiopia*. Ethiopian sheep and goat productivity improvement program (ESGPIP), pp 27–38.

Abegaz, S.K., Mwai, O., Grum, G., Haile, A., Rischkowsky, B.A., Solomon, G. and Dessie, T. 2014. *Review of goat research and development projects in Ethiopia*. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute.

Alemu, Y. 2008. *Sheep and goat production handbook of Ethiopia: Nutrition and Feeding of Sheep and Goats*. Ethiopian sheep and goat improvement program (ESGIP).

Alubel, A. 2015. *On-farm phenotypic characterizations and performance evaluation of Abergelle and Central highland goat breeds as an input for designing community-based breeding program*. MSc thesis. Haramaya University, Haramaya, Ethiopia.

Amills, M., Ramı´rez, O., Toma`s, A., Badaoui, B., Marmi, J., Acosta, J., Sa`nchez, A. and Capote, J. 2008. Mitochondrial DNA diversity and origins of South and Central American goats. *Animal Genetics,* 40, 315–322.

Ayalew, W., Getahun, E., Tibbo, M., Mamo, Y. and Rege, J.E.O. 2004. Current states of knowledge on characterization of farm Animal Genetic Resource in Ethiopia. In: *Proceeding of the eleventh annual conference of the Ethiopian society of animal production* (ESAP), 28–30 August 2004. Addis Ababa, Ethiopia. pp. 1-2.

Baker, R.L. and Gray, G.D. 2003. Appropriate breeds and breeding schemes for sheep and goats in the tropics: The importance of characterization and utilizing disease resistance adaptation to tropical stress. In: Sani, R., Gray G D., R.L. Baker (eds) Better worm control for Small Ruminant in *Tropical Asia, J. Australian Centre for International Agricultural Research*. 14:8–13.

Bedhane, M., Haile, A., Dadi, H. and Alemu, T. 2013. Traits in Arsi-Bale Goat in Ethiopia. *J. Anim. Sci. Adv.* 3(9):439–448.

Biruh, T. 2013. *Phenotypic and production system characterization of Woyto Guji Goats in lowland areas of south Omo zone*. MSc thesis, Submitted to the School of Graduate Studies of Haramaya University, Ethiopia.

Chen, S.Y., Su, Y.H., Wu, S.F., Sha, T. and Zhang, Y.P. 2005. Mitochondrial diversity and phylogeographic structure of Chinese domestic goats. *Mol Phylogenet Evol* 37(3): 804–814.

Chenyambuga, S.W., Hanotte, O., Hirbo, J., Watts, P.C., Kemp, S.J., Kifaro, G.C., Gwakisa, P.S., Petersen, P.H. and Rege, J.E.O. 2004. Genetic characterization of indigenous goats of Sub-Saharan Africa using microsatellite DNA markers. *Asian-Australasian Journal of Animal Science* 17:445–452.

Dorji, N., Duangjinda, M. and Phasuk, Y. 2012. Genetic characterization of Bhutanese native chickens based on an analysis of Red Junglefowl (Gallus gallus gallus and Gallus gallus spadecieus), domestic Southeast Asian and commercial chicken lines (Gallus gallus domesticus). *Genetics and Molecular Biology*, 35(3):603–609.

Farm-Africa. 1996. *Goat types of Ethiopia and Eritrea. Physical description and management systems*. Published jointly by FARM-Africa: London, UK and ILRI (International Livestock Research Institute): Nairobi, Kenya.

Frankham, R., Ballou, J.D. and Briscoe, D.A. 2002. Introduction to Conservation Genetics. *Cambridge Univ. Press*, Cambridge, UK.

Galal, E.S.E., Metawi, H.R.M., Aboul-Naga, A.M. and Abdel-Aziz, 1996. Performance and factors affecting the smallholder sheep production system in Egypt. *Small Rumin. Res.* 19:97–102.

Getinet, M. and Adebabay, K. 2015. A review on indigenous cattle genetic resources in Ethiopia: adaptation, status and survival. Online *J. Anim. Feed Res.* 5(5):125–137.

Getinet, M., Kassahun, T., Tadelle, D., Mwai, O., Djikeng, A., Osama, S., Netsanet, Z., Alubel, A., Achieng, G., Tutah, J., Mutai, C., Njuguna, J., Birungi, J. and Mwacharo, J. *in press a. Mitochondrial DNA analysis of Ethiopian indigenous goat populations revealed maternal origins and recent demographic expansion with high within genetic diversity*.

Getinet, M., Wenguang, Z., Okeyo, M., Tadelle, D., Appolinaire, D. and Kassahun, T. *in presss b. Documenting radiocarbon evidences, Y-chromosome, Mitochondria DNA and autosomal markers on origin of domestication and routes of goat global divergence: A review*.

Getinet, M., Joram, M.M., Kassahun, T., Tadelle, D., Mwai, O., Djikeng, A., Liu, B., Osama, S., Grossen, C. and Zhang, W. 2016. High density SNP chips array uncovers genetic diversity and population structure of 16 Ethiopian and Chinese goat populations. *International goat genome consortium: Twenty-fourth plant and animal genome conference*, 9–13 January 2016. San Diego, USA.

Gizaw, S. 2009. Goat breeds of Ethiopia: A guide for identification and utilization. Ethiopian sheep and goat productivity improvement program. *Techinical bulletin*, Number 27.

Gizaw, S., Azage, T., Gebremedhin, B. and Dirk, H. 2010. *Sheep and goat production and marketing systems in Ethiopia: Characteristics and strategies for improvement.* IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project. Working Paper 23. ILRI (International Livestock Research Institute): Nairobi, Kenya. 58 pp.

Hassen, H., Lababidi, S., Rischkowsky, B., Baum, M. and Markos, T. 2012. Molecular characterization of Ethiopian indigenous goat populations. *Trop Anim Health Prod*. 44:1239–1246.

Hussein, H.T. 2015. *Phenotypic characterization and breeding practices of Arsi-Bale goat population in selected districts of Arsi and Bale zones, Oromia regional state, Ethiopia*. MSc thesis. Bahir Dar University, Bahir Dar, Ethiopia.

Joshi, M.B., Rout, P.K., Mandal, A.K., Tyler-Smith, C., Singh, L. and Thangara, K. 2004. Phylogeography and origin of Indian domestic goats. *Mol Biol Evol* 21(3):454–462.

Kalinowski, S.T. 2002. Evolutionary and statistical properties of three genetic distances. *Mol Ecol* 11(8):1263–73.

Kassahun, A. and Solomon, A. 2008. *Sheep and goat production handbook for Ethiopia. Breeds and genetic improvent of sheep and goat. P5 and 81*.

Keiven, G.P. and Wilson, R.P. 2000. *Introduction to Animal Science*. New York, USA: John Wiley and sons Inc. 562p.

Li XL, Wu ZL, Liu, Z.Z., Gong, Y.F., Zhou, R.Y. and Zheng, G.R. 2006. SNP Identification and Analysis in Part of Intron 2 of Goat MSTN Gene and Variation within and among Species. *Journal of Heredity* 97(3).

Luikart, G., Gielly, L., Excoffier, L., Vigne, J.D., Bouvet, J. and Taberlet, P. 2001. Multiple maternal origins and weak phylogeographic structure in domestic goats. *PNAS*. 98(10):5927–5932.

Luikart, G., Fernández, H., Mashkour, M., England, P.R. and Taberlet, P. 2006. *Origins and Diffusion of Domestic Goats Inferred from DNA Markers Example Analyses of mtDNA, Y chromosome, and Microsatellites. Documenting documentations: New genetic and archaeological paradigms*. Berkeley Los Angeles, USA, London, UK:University of California press.

Mannen, H., Nagata, Y. and Tsuji, S. 2001. Mitochondrial DNA Reveal That Domestic Goat (Capra hircus) are Genetically Affected by Two Subspecies of Bezoar (Capra aegagurus). *Biochemical Genetics*, 39(5/6).

Mahmoudi, B., Babayev, M.S., Hayeri, K.F., Pourhosein, A. and Daliri, M. 2011. Breed characteristics in Iranian native goat populations. *Journal of Cell and Animal Biology*, 5(7):129–134.

Metawi, H.R. 2011. Economic sustainability of goat production under different production on systems in Egypt. In: Bernués A., Boutonnet J.P., Casasús L., Chentouf, M., Gabiña, D., Joy, M., López-Francos, A., Moran d-Fehr, P., Pacheco, F. (eds) *Economic, social and environmental sustainability in sheep and goat production systems*. Zaragoza, Spain: CIHEAM/FAO/CITADGA. p.185–190 (Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 100.

Naderi, S., Rezael, H., Taberlet, P., Zundel, S., Rafat, S., Naghash, H., El-Barody, M.A.A., Ertugrul, O. and Pompanon, F. 2007. Large-scale mitochondrial DNA analysis of the domestic goat reveals six maternal lineages with high haplotype diversity. *PLoS ONE* 10:e1012.

Netsanet, Z. 2014. *On-farm phenotypic characterizations and performance evaluation of Central highland goat and Woyto-Guji goat types for designing community-based breeding strategies*. MSc thesis. Haramaya University, Haramaya, Ethiopia.

Pemberton, J. 2004. Measuring inbreeding depression in the wild: the old ways are the best. *Trends in Ecology and Evolution* 19:613–615.

Rama, P.J., Suhas, S.J., Vani, Y.K. and Ashish, K.S. 2015. Strategies for improving feed and fodder production and utilization for enhanced milk and meat from livestock in India: A review. *International Journal of Basic and Applied Sciences* 4(2).

Rege, J.E.O. and Lebbie, S.H.B. 2000.The goat resource of Africa, origin, distribution and contribution to the national economies. In: *Seventh international conference on goats*, 15–21 May 2000, Tours, France, pp927-931.

Sardina, M.T., Ballester, M., Marmi, J., Finocchiaro, R., van Kaam, J.B.C.H.M., Portolano, B. and Folch, J.M. 2006. Phylogenetic analysis of Sicilian goats reveals a new mtDNA lineage. *Anim Genetics* 37(4):376–378.

Seifemichael, M., Kefelegn, K., Negassi, A. and Banerjee, A.K. 2014. *Variability in Linear Body Measurements and their Application in Predicting Body Weight of Afar Goats in Ethiopia*. Haramaya University, Haramaya, Ethiopia.

Sultana, S., Mannen, H. and Tsuji, S. 2003. Mitochondrial DNA diversity of Pakistani goats. *Anim Genetics* 34(6):417–421.

Tesfaye, A.T. 2004. Genetic characterization of indigenous goat populations of Ethiopia using microsatellite DNA markers. A PhD thesis submitted to the national dairy research institute, Deemed University. Karnal-Haryana, India.

Tesfaye, K. 2010. *Assessment of on-farm breeding practices and estimation of genetic and phenotypic parameters for reproductive and survival traits in indigenous Arsi-Bale goats*. MSc thesis, Submitted to the School of Graduate Studies of Haramaya University, Ethiopia.

Tesfaye, K., Aynalem, H., Hailu, D. and Tesfaye, A. 2012. Genetic and phenotypic parameter estimates for reproduction traits in indigenous Arsi-Bale goats. *Tropical Animal Health Production*, 44:1007–1015.

Tesfaye, G. 2015. *Genetic diversity and admixture analysis of Ethiopian Fat-tailed and Awassi sheep using SNP markers for designing crossbreeding schemes*. University of Natural Resources and Life Sciences, Vienna, Austria.

Umeta, G., Feyisa, H., Misgana, D. and Merga, M. 2011. Analysis of goat production situation at Arsi Negele Woreda, Ethiopia. *Journal of Stored Products and Postharvest Research*, 2(8):156–163.

Weir, B. 1996. *Genetic Data Analysis II: Methods for Discrete Population Genetic Data*. Sunderland, Massachusetts, USA: Sinauer Associates Inc. 445 pp.

Workneh, A. 1992. *Preliminary survey of indigenous goat types and goat husbandry practices in Southern Ethiopia*. M.Sc. Thesis, Alemaya University of Agriculture, Haramaya, Ethiopia.

Yadav, A. and Yadav, B.R. 2008. DNA Fingerprint: Genetic relationship in six Indian goat breeds. *Indian J. Biotechnol.* 7:487–490.

Yaekob, L., Kirman, M.A. and Birhanu, B. 2015. *Morphological Characterization of Indigenous Woyto-Guji Goat Breed in Loma District, Southern Ethiopia.* Jimma, Ethiopia: Jimma University, College of Agriculture and Veterinary Medicine.

Zeder, M. and Hesse, B. 2000. The initial domestication of goats (Capra hircus) in the Zagros Mountains 10,000 years ago. *Sciences* 287:2254–2257.

Zeuner F.E. 1963. *A history of domestic animals*. London, UK: Hutchinson and Co. Ltd.

Zeleke, M., Habtemariam, A., Tegegne, A. and Dagne, M. 2015. Estrus response and fertility of Menz and crossbred ewes to single prostaglandin injection protocol. *Tropical Animal Health and Production*, DOI: 10.1007/s11250-015-0919-z.

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