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Design of community based breeding programs for two indigenous goat breeds of Ethiopia

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Dedication

To my beloved wife

Birhan Atena

&

My Children

Kirubel Solomon and Wdassie Solomon

Abbreviations and Acronyms

AMOVA	Analysis of molecular variance
CSA	Central Statistical Authority
DOARD	District office of Agriculture and Rural Development
FAO	Food and Agriculture Organization of United Nation
glm	Generalized Linear model
He	Expected heterozygosity
Ho	Observed heterozygosity
HWE	Hardy Weinberg Equilibrium
IPMS	Improving market success and productivity
K	Thousand
MAF	Minor Allele Frequency
MB	Mega Base
PCA	Principal Component Analysis
PPI	Pair of Permanent Incisors
ROH	Run of Homozygosity
RSK	Red Sokoto goats
SAS	Statistical system analysis
SHL	Sahel goats
SNP	Single Nucleotide Polymorphism
UPGMA	Unweighted Pair Group Method with Arithmetic mean
WAD	West African Dwarf goats

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Abstract

The objectives of this study were to describe the production systems, identify the breeding objectives traits, describe the morphological and molecular characteristics of Western Lowland and Abergelle goat breeds of Ethiopia to design community based breeding programs. 120 goat keepers were interviewed. Phenotypic characters of 534 Abergelle and 476 Western Lowland goats were measured. Genetic diversity of the two Ethiopian and three Nigerian goat types were assessed based on 47K Single Nucleotide Polymorphism markers. The breeding objective traits were investigated through own and group animals ranking experiments. Community based one tier breeding schemes with four different alternatives for the top three most important traits were simulated. The survey results indicated that goats were kept for multifunctional roles in both areas. Phenotypic characterization showed high variability within and between the studied breeds in qualitative and quantitative traits. Western Lowland goats are on an average not only bigger than Abergelle goats but also show considerably higher variation in body size. The genetic diversity analysis revealed that the studied goat populations were well differentiated based on their geographical location. Production and reproduction traits such as body size, twinning and milk yield were identified as important breeding objective traits in own flock ranking experiment while in group ranking experiment the observable characters like body size, body conformation and coat color were identified as breeding goal traits. Simulation results gave an acceptable range of genetic gains with little difference across the alternatives. Thus, the community based breeding programs with a few traits in the recording are considered feasible for genetic improvement of goats in the study areas and similar agro-ecological zones.

Key words: Goat; Breed; Genetic diversity; SNP; breeding objectives; Breeding Programs; Ethiopia

Zusammenfassung

Ziel der Arbeit ist die Entwicklung von dörflichen Zuchtprogrammen für zwei Regionen Äthiopiens. In der Studie wurden die Produktionssysteme beschrieben, Selektionskriterien und Zuchtziele der Bauern identifiziert und eine phenotpyische und molekulare Charakterisierung der Western Lowland und der Abergelle Ziege vorgenommen. Insgesamt wurden 120 TierhalterInnen befragt und von insgesamt 534 Abergelle Ziegen und 476 Western Lowland Ziegen Körpermaße genommen. Die genetische Diversität wurde von beiden äthiopischen Ziegenrassen mit Hilfe von SNP-Daten erhoben und mit drei nigerianischen Ziegenrassen verglichen. In einem Ranking-Experiment mit verschiedenen Tieren wurden die Selektionskriterien erhoben. Alternative Szenarien von dörflichen Zuchtprogrammen wurden simuliert. Die Ergebnisse der Umfrage ergaben, dass in beiden Studiengebieten Ziegen vielfältige Funktionen haben. Die phenotypische Charakterisierung zeigte, dass bei beiden Rassen eine hohe Variabilität sowohl innerhalb als auch zwischen den beiden Rassen besteht. Western Lowland Ziegen sind nicht nur größer als Abergelle Ziegen, sondern weisen auch eine höhere Variation in der Körpergröße auf. Die Studie zur genetischen Diversität zeigt, dass die Ziegenrassen sich klar voneinander abgrenzen. Produktions- und Reproduktionsmerkmale wie Körpergröße, Zwillingsrate und Milchleistung wurden als wichtige Merkmale in einem Rankingexperiment in der eigenen Herde identifiziert, während in einem anderen Rankingexperiment mit für die Befragten fremden Tieren andere Merkmale wie Körpergröße, Exterieur und Haarfarbe als wichtiger eingestuft wurden. Die Ergebnisse der Simulation zeigen in allen Varianten einen akzeptablen Zuchtfortschritt in allen Merkmalen. Es konnte gezeigt werden, dass auch mit der Erhebung von nur wenigen Merkmalen Zuchtfortschritte erzielt werden können.

Schlagwörter: Äthiopien, Ziegen, Charakterisierung, Zuchtziele, SNP, Zuchtprogramm

1. Introduction

Ethiopia is a country in East Africa where agriculture is the main stay of the economy. More than 85% of the population depends on agriculture for their livelihoods. It provides 80 % of total employment and 85 % of export earnings. The livestock sub-sector has a share of 12-16% of the total Gross Domestic Product (GDP), 30-35% of agricultural GDP and more than 85% of farm cash income (IBC, 2004; Benin *et al*., 2006). Goat production is one of the integral parts of livestock farming activities of the country. Based on phenotypic and molecular characterization, there are four families and 12 different types (FARM-Africa, 1996; Tesfaye, 2004) and 29.9 million goats in Ethiopia (CSA, 2010a) which are distributed throughout the country. The majority of the goat population is found in large flocks in the arid and semi-arid Lowlands. Goats in the highlands are widely distributed in the mixed crop-livestock production systems with very small flock size (Tsegahun *et al.*, 2000). Almost all goat population is managed by resource poor smallholder farmers and pastoralists under traditional and extensive production systems.

In traditional production systems, small ruminant are not bred for a specific purpose rather they are kept for multipurpose functions. They provide multiple roles for their owners such as source of income, food (meat and milk), manure, insurance against crop failure and cultural value (Jaitner, *et al*., 2001; Herpa and Adane, 2008; Legesse *et al*., 2008; Assen and Aklilu, 2012). The growing demands of meat products at the domestic as well as international markets also increase the importance of goat in the national economy of the country. According to CSA (2012) out of 5,187,044 slaughtered animals in the year 2012/2013, 1,771,527 are goats. More than 90% of export trade value of live animal/meat and skin and hide also comes from small ruminants. Special features of goats among the livestock species are small body size, less space requirement, low feed requirement, use poor quality forage and fast turnover make them widely acceptable species in tropical harsh climatic condition (Peacock, 2005; Mekasha, 2007).

Despite of the large population of goats and the roles of goats at household and national level, the productivity and the contribution of goat to the country economy is far below the potential. At optimum level the county has a potential of annual production of 1.1 million goats for domestic market and 2 million goats for international market but the current annual off take is only 35% with the average 10 kg of carcass weight (Herpa and Adane, 2008). Goat production in Ethiopia is constrained by many biological, environmental and socio-economical factors. Among them, lack of systematic breeding programs is an important constraint.

Therefore, there is a need to design and implement the appropriate breeding strategies to improve the livelihoods of the small holder farmers and to satisfy the growing demand of meat for domestic consumption and international market. However, there is no systematic goat breeding program is in place and goat is the most neglect livestock species in research and development endeavors (Tsegahun, *et al*., 2000). There have been a few attempts of genetic improvement program of goats through upgrading the exotic genetic blood levels. The noticeable example is the FARM-Africa dairy goat development project in south and eastern part of the country. The aim of the project was to improve the milk yield of the local breeds through crossing with exotic Anglo-Nubian goats (Gebremeskel, 2000). However it was reported that crossbred goats did not perform better than indigenous goats if both groups were kept in similar management levels (Ayalew *et al*., 2003). In general, many small ruminants cross breeding programs in tropical country were not successful because of the incompatibility of the genotype with the farmers breeding objectives, management methods and the prevailing environment of the tropical low input production systems (Ayalew et al., 2003; Wollny, 2003; Kosgey et al., 2006).

Thus, selective pure breeding of the adapted indigenous breeds is the best possible option of genetic improvement in the tropical countries. Indigenous breeds in harsh tropical environmental conditions have special adaptive features such as tolerance of a wide range of disease, water scarcity tolerance and ability to better utilize the limited and poor quality feed. This makes them survive and be productive in the prevailing environment (Baker and Gray, 2004; Kosgey and Okeyo, 2007). To efficiently utilize these special features of indigenous breeds, there is a need of planning and implementing viable breeding programs that fit to the existing low input production systems.

The recent approach of establishing community based breeding programs is advocated for low input traditional smallholder farming systems (Sölkner *et al*., 1998; Kahi *et al*., 2005; Haile *et al*., 2009, Wurzinger *et al*., 2011). This is because community based breeding programs take into account the indigenous knowledge of the communities on breeding practices and breeding objectives (Gizaw *et al*., 2013).The community-based breeding strategies also consider the production system holistically and involve the local community at every stage, from planning to operation of the breeding program (Baker and Gray, 2004). Breeding programs involve the description and decisions about a series of interacting components. Among them the most important components to be considered in breeding program design are: description of production environment and production system, characterization of the available local genotype, definition of breeding objectives, identification of traits to be selected, decision about breeding methods and breeding population and understanding of structure and organization of people involved (Iñiguez, 1998; Sölkner *et al*., 1998; FAO, 2010). Thus, this study was aimed to develop appropriate community based breeding programs for Western Lowland and Abergelle goat breeds of Ethiopia with the following specific objectives:

- To describe the production system
- To describe the morphological characteristics
- To characterize the genetic diversity of five African goat populations by genome wide (47K) SNP markers
- To identify the breeding objective traits of Western Lowland and Abrgelle goat keepers by participatory live animal ranking approaches
- To simulate the appropriate breeding schemes for two indigenous goat breeds in two different agro ecological zones of Ethiopia

Thesis outline

This thesis has five main sections. The first section is the introduction; it deals with the status of goat production in Ethiopia, limitations of goat production, goat genetic improvement interventions, justification of the study and the objectives of the study. The second part is the literature review which includes the goat genetic resources of Ethiopia and their production system, methods of breed characterization, the performance and the population parameters of important traits of Ethiopian and other tropical goats. The available genetic improvement strategies for tropical countries are also discussed. The materials used in this study and the methods that have been used to collect data, the statistical tools and analytical methods are presented in part three. The results and discussion of the study are provided in part four. The conclusions drawn from this study are presented in section five. The list of references cited and appendix are provided at the end.

2. Literature review

2.1. Goat genetic resources in Ethiopia

Goats (Capra hircus) are believed to have been the first ruminant animal domesticated. It is also believed that the first goats reached Ethiopia from the North between 2000 and 3000 B.C. (Rege and Lebbie, 2000). Due to a great variation in climate and topography and proximity to the historical root of livestock domestication of Africa, Ethiopia endows large and very diverse farm animal genetic resources (Ayalew, 2004). The goat population of Ethiopia is estimated at 29.9 million (CSA, 2010a). It is believed that these goats have evolved through a process of natural selection that resulted in goats selected for adaptation and survival rather than production *per se*. (Peacock, 1996; Abegaz *et al*, 2008). Thus, most tropical goats are mainly nondescript. Domestic goats have been classified by varying criteria but four commonly used classification methods are: classification based on origin, utility, body size and shape and length of ears. Indigenous African goats are mainly categorized in two groups that are long-eared and short-eared. Based on their size, they also classified in three types; large goat types in Sahara and South Africa, intermediate type of East and North-central Africa and the dwarf goat type of humid West Africa (Devendra, 1978). According to the FARM-Africa (1996) goat breed survey report, indigenous Ethiopian goats have been phenotypically classified into four families and 12 types (Table 1). However, Tesfaye (2004) reported only eight distinctively different breeds based on microsatellite markers analysis: Arsi-Bale, Gumuz, Keffa, Long-Ear Somali, Woyto-Guji, Abergelle, Afar and Highland Goats.

Table 1. Goat breeds of Ethiopia and their geographical distribution

Family name	Breed name	Other Local name	Distribution
Nubian family	Nubian	Barka, Begayit	West Tigray
Rift valley family	Afar	Adal, Denakil	Afar region, Northern and Western Hararghe
	Abergelle		Along Tekeze river Tigray region, Wag Himra, East Gondar
	Arsi-Bale	Gishe, Sidamo	Arsi, Bale and Western Hararghe
	Woyto-Guji	Woyto, Guji, Konso	South Omo, Southern Sidama and Wolayita
Somali family	Hararghe Highland		Hararghe
	Short –eared Somali	Denghier	Northern and Eastern Ogaden
	Long-eared Somali	Degheir, Digodi, Melebo	Ogaden, Lowland of Bale and Borena
Small east African family	Centeral highland	Brown	Centeral highlands, West of the rift valley Wollo, Gondar and Shoa
	Western highland		Highland of South Gondar, Gojam, Wollega and West Shoa
	Western Lowland	Gumuz	Along the area bordering the Sudan
	Keffa		Highlands and Lowlands of Keffa and South Shoa Zone

Source: Farm-Africa (1996); Gizaw *et al*. (2010a)

2.2. Ethiopian small ruminant production system

Livestock production systems in tropical countries are complex by nature and show great variation within and between regions. They depend on integration with crop production, climatic condition, management practice, local resource availability, production objectives of the owners, availability of technologies and government policy (Othere, 1998).

Goat production and livestock systems at large in Ethiopia have evolved largely as a result of natural production environments and socio-economic circumstances of farmers/pastoralists (Gizaw, *et. al*., 2010). Ethiopian small ruminant production systems are broadly classified into "modern" and "traditional" (Tibbo, 2006; Legesse, 2008). The "modern" system is practiced only in few places such as government ranches and in small scale urban production systems while most of small ruminant production depends on the traditional extensive system of production (Tibbo, 2006; Gizaw, *et al*., 2010a). Common features of traditional production systems are limited number of animals per unit area, low productivity per animal, relatively limited use of improved technology and use of on farm by products rather than purchased inputs (Gizaw *et al*., 2010a).

According to the degree of integration with crop production and contribution of livelihood, level of input and intensity of production, agro ecology, length of growing period and relation to land and type of commodity to be produced, mobility and duration of movement, the traditional production system is sub divided into three systems (Abegaz *et al*., 2008). These are mixed crop-livestock, pastoral and agro pastoral system.

Mixed crop-livestock system is commonly practiced in the most crop dominant area of high land and mid-altitude of the country, with altitude ranges of 1500 to 3000 m. The area receives good amount of rainfalls and has moderate temperature. Goats are kept by smallholders and graze together with sheep and/or other livestock species like cattle. The integration and the importance of small ruminants (goat) in the system varies from place to place. The integration is lower in south part of the country where the perennial crop production is more important and small ruminants are less important. In the dry highland area of the Northern part of the county, goat plays a great role where crop production is unreliable (IBC, 2004; Gizaw *et al*., 2010a).

The pastoral system is practiced by pastoral people in very dry parts of the country at altitudes below 1500 m. The areas are not suitable for crop production and receive less than 500mm of precipitation. The livelihoods of the pastoral people depend entirely on livestock and more than 50% of the household income and 20% of the food comes from the livestock or livestock related activities. Goats are kept by nearly all pastoralists with higher flock size, often in mixed flocks with sheep. High mobility of animals in search of feed and water is common in the system (IBC, 2004; Abegaz *et al*., 2008).

Agro pastoral system is practiced in the semi-arid part of the country. Comparing to the pastoral system the area receives relatively higher rain and people and animals are less mobile. The system is characterized by high degree of dependency on milk and meat production and 10-50% of the income is derived from livestock production. In this system there is some crop agriculture practice along with the livestock production (IBC, 2004; Abegaz *et al*., 2008).

Differently from the above classification, Legesse (2008) classified the small ruminant production systems of the country into four sub systems based on the dominant agricultural activities: Small ruminant in annual crop based systems located Northern, Northwestern, and central highlands; small ruminant perennial crop-based, mostly found in Southern and

Southwestern highlands; Small ruminants in cattle based systems, these systems usually exist in agro pastoral and semi-arid areas; small ruminant dominated systems; found in pastoral and arid areas of Eastern and Northeastern Ethiopia, where sheep and goats are the dominant livestock species.

2.3. Performance of indigenous goats

Evaluations of the performance of economically important traits of the livestock are very useful inputs for planning a breeding program. The most important traits of livestock are broadly classified into two categories: production and reproductive traits.

2.3. 1 Growth performance

Growth performance traits are the most important traits for meat production. To increase economic return from goat production requires improvements in market weight of kids and mature goats. Growth performance may be separated in pre-weaning (birth weight, weaning weight and pre weaning growth rate) and post weaning (six months weight, yearling weight and mature weight). The growth performance of goats is affected by many genetic and non genetic factors. The early stage of growth performance of kids is largely influenced by genotype and the milk yield of the does. Parity, type of birth, sex, season and year of birth also influence the growth performance of goats (Dadi *et al.,* 2012; Bedhane *et al*., 2013; Derbie and Taye, 2013). The mean birth weight, weaning weight, six months and yearling weight of some indigenous Ethiopian goat breeds are presented in Table 2.

Table 2. Birth, weaning, six months and yearling weight of some of Ethiopian goat breeds

Breed	Management type	BWT	WWT	SMW	YWT	Source
Abergelle	Traditional	1.91	6.84	9.13	14.25	Deribe and Taye (2013)
Western Lowland	Traditional	2.28	12.00	NA	NA	Tsegaye (2009)
Central high land	Traditional	2.32	7.17	9.30	13.04	Getachew et al (2006)
Central high land	Traditional	2.01	9.02	13.82	20.61	Deribe (2008)
Arsi-Bale	Station	NA	6.95	9.00	14.31	Dadi *et al* (2008)
Arsi-Bale	Station	1.91	6.65	9.00	14.32	Bedhane *et al* (2013)
Arsi-Bale	Traditional	2.80	8.39	NA	NA	Weldu *et al*. (2004)
Keffa	Traditional	2.78	9.00	NA	NA	Shenkute, (2009)
Somali	Station	3.19	11.67	NA	NA	Zeleke, 2007

Note: BWT= Birth weight; WWT=Weaning weight; SMWT= Sex months weight; YWT= Yearling weight; NA= Not available

2.3.2 Reproductive performance

Reproductive performance is an important criterion when evaluating the structure of the strength and weakness of the breeds in particular production environments (Browing *et al*., 2006). It has high impact on overall flock productivity. Mukasa Mugerwa *et al*. (2002) stated that reproduction failure is the first indicator of decreased flock productivity. Litter size, age at first kidding and kidding interval are economically important reproductive traits. A range of 1 to 1.7 litter size was reported from on station, on farm monitoring and breed survey studies for different Ethiopian goat breeds (Table 4). The litter size is largely influenced by ovulation rate. The ovulation rate of the does is highly influenced by the breed and improvement could be achieved by selection (Ibrahim, 1998). Age at fist kidding is an indication of the overall flock productivity. The lifetime production can be increased by decreasing first kidding age. A wide range of 375 to 854 day of age at first kidding (Table 3) were reported in different management and breeds of Ethiopian goats which is influenced by genotype, management, season and type of birth (Derbie 2008; Kebede et al. 2012a). Kidding interval is the interval between two kidding. A doe with long kidding interval has lower overall production index (Ibrahim, 1998). Mean litter size, age at first kidding and kidding interval of some of Ethiopian goat breeds from different references are summarized in Table 3.

Table 3. Reproductive performance of some of Ethiopian goat breeds under different management condition

Breed	Management type	LS	AFK (days)	KI (days)	Source
Abergelle	Traditional	1.04	448	339	Deribe (2008)
Central high land	Traditional	1.42	NA	248	Getachew *et al*. (2006)
Central high land	Traditional	1.16	408	308	Deribe (2008)
Arsi-Bale	Station	1.64	854	293	Dadi *et al*. (2008)
Arsi-Bale	Station	1.60	575	280	Kebede *et al*. (2012a)
Keffa	Traditional	1.70	375	237	Shenkute (2009)
Western Lowland	Traditional		408	252	Tsegaye (2009)

LS= Litter size; AFK=Age at first kidding; KI=Kidding interval

2.3. 3 Milk production

Goat provides milk mainly for the resource poor farmers. In the central rift valley, in Eastern, Southeastern and Northeastern part of the country, goat milk is consumed by farming community (Workneh *et al*., 2004). Very limited information is available about milk performance characters of Ethiopian goats. A comparison made between Somali goat breeds and their crosses with Anglo-Nubian goats showed that the mean daily milk was higher (330 vs 837ml) for crossbred goats (FARM-Africa, 1995). Bedhane et al. (2012) reported 209 gram of daily milk yield, 86 days of lactation length and 18 kg of lactation milk yield for Arsi-Bale goats under station management. In a comparison study between pure breed Adal and Quarterbred with Saanen, quarterbred Saanen gave more lactation milk yield (31 kg) than the Pure Adal goat (24 kg) and 84 days lactation length were reported for both genotypes (Banerjee *et al*., 2000).

2.4. Population parameters of tropical goats

Variations in the performance of traits within and between breeds are important raw materials in animal breeding. Heritability and additive genetic correlation of the traits are the most important population parameters of within breed variation in animal breeding (Rege *et al.* 2006).

2.4.1. Heritability

The heritability (h^2) of a trait, a central concept in quantitative genetics, is the proportion of variation among individuals in a population that is due to variation in the additive genetic effects (i.e., breeding values of individuals that determine reproductive efficiency of goat production. Falconer and Mackay, 1996). A reliable estimate of heritability will help to decide which breeding program should be used. If the trait heritability is high, mass selection with little pedigree records may be enough for rapid selection response. On the other hand, if the heritability of a trait is low, response from selection on individual records will be slow. It needs accurate pedigree records, family selection or even progeny testing (Legates and Warwick, 1990).The heritability estimates of traits performance of Ethiopian goat is very scant and only available for Arsi-Bale goat breeds. Bedhane *et al*. (2013), Bedhane *et al*. (2012) and Kebeda *et al*. (2012a) estimate heritability of growth traits, milk traits and reproductive traits of Arsi-Bale goat in Adami-Tulu research center, respectively. They also estimate the genetic and phenotypic correlation of these traits. The heritability estimates of different traits for some of African goat breeds are summarized in Table 4.

2.4.2. Genetic and phenotypic correlations

Correlation is the measure of association between two characteristics or traits. Both genetic and phenotypic correlations are of particular interest to animal breeders. They are an integral part of breeding program design and analysis. The phenotypic correlation is an estimate of the association between two visible characteristics in the current flock. The genetic correlation is the correlation between breeding values. It is an estimate of the way in which selection of parents for one trait will cause a change in a second trait in the progeny. Observations of traits on related animals are used to estimate genetic correlations. Genetic correlations are an indication of the proportion of genes that affect both traits in the direction of the sign (positive or negative (Simm, 1998). Genetic and phenotypic correlation estimates of some of important traits of Ethiopian and other tropical goat breeds are summarized in Table 5.

Table 4. Heritability estimates for important traits of some of tropical goat population

Trait	Breed	h^2	Country	Source
AFK	Arsi-Bale	0.25±0.19	Ethiopia	Kebede *et al*. (2012a)
KI	Arsi-Bale	0.06±0.08	Ethiopia	Kebede *et al*. (2012a)
LSB	Arsi-Bale	0.07±0.05	Ethiopia	Kebede *et al*. (2012a)
LSW	Arsi-Bale	0.01±0.05	Ethiopia	Kebede *et al*. (2012a)
AFK	Saanen	0.25±0.04	South Africa	Muller (2005)
LSB	Zaraibi	0.08±0.01	Egypt	Hamed *et al*.(2009)
LSW	Zaraibi	0.05±0.01	Egypt	Hamed *et al*.(2009)
LSB	WAD	0.32±0.07	Nigeria	Odubate (1996)
KI	WAD	0.03±0.01	Nigeria	Odubate (1996)
LSB	Sahle	0.39±0.09	Nigeria	Alade *et al*. (2010)
BW	Arsi-Bale	0.09±0.08	Ethiopia	Bedhane *et al*. (2013)
WW	Arsi-Bale	0.03±0.08	Ethiopia	Bedhane *et al*. (2013)
SMW	Arsi-Bale	0.04±0.08	Ethiopia	Bedhane *et al*. (2013)
YW	Arsi-Bale	0.02±0.10	Ethiopia	Bedhane *et al*. (2013)
BW	Draa	0.16±0.07	Morocco	Boujenane and Hazzab (2012)
WW	Draa	0.11±0.06	Morocco	Boujenane and Hazzab (2012)
SMW	Draa	0.01±0.08	Morocco	Boujenane and Hazzab (2012)
BW	WAD	0.50±0.05	Gambia	Bosso *et al*. (2007)
WWT	WAD	0.43±0.07	Gambia	Bosso *et al*. (2007)
YW	WAD	0.30±0.07	Gambia	Bosso *et al*. (2007)
BW	Nubian	0.54±0.05	Sudan	Ballal *et al*. (2008)
WW	Nubian	0.16±0.12	Sudan	Ballal *et al*. (2008)
LL	Arsi-Bale	0.03±0.15	Ethiopia	Bedhane *et al*. (2012)
LMY	Arsi-Bale	0.22±0.12	Ethiopia	Bedhane *et al*. (2012)
DMY	Arsi-Bale	0.26±0.12	Ethiopia	Bedhane *et al*. (2012)
DMY	Saanen	0.31±0.04	South Africa	Muller (2005)

Note: AFK=Age at first kidding; KI=Kidding interval; LSB=Litter size at birth; LSW=Litter size at Weaning BW= Birth weight; WW=Weaning weight; SMW=Six months weight; YW=Yearling weight; LL=lactation length LMY=Lactation milk yield; DMY=Daily milk yield

Table 5. Genetic and phenotypic correlation estimates between traits of some of African goat population

Traits	Breed	Genetic correlation	Phenotypic correlation	Source
AFK with KI	Arsi-Bale	-0.43±0.01	0.05	Kebede *et al*. (2012a)
AFK with LSB	Arsi-Bale	0.61±0.21	0.11	Kebede *et al*. (2012a)
AFK with LSW	Arsi-Bale	0.34±0.14	0.05	Kebede *et al*. (2012a)
KI with LSB	Arsi-Bale	0.69±0.18	-0.06	Kebede *et al*. (2012a)
KI with LSW	Arsi-Bale	0.59±0.02	-0.07	Kebede *et al*. (2012a)
LSB with LSW	Arsi-Bale	0.81±0.21	0.21	Kebede *et al*. (2012a)
LSB with LSW	Zaraibi	0.91	0.63	Hamed *et al*.(2009)
LSB with BW	Sahel	-0.25	-0.29	Alade *et al*. (2010)
LS with WW	Sahel	-0.15	-0.12	Alade *et al*. (2010)
BW with WW	Arsi-Bale	0.70±0.55	0.17	Bedhane *et al*. (2013)
BW with SMW	Arsi-Bale	0.64±0.47	0.19	Bedhane *et al*. (2013)
BW with YW	Arsi-Bale	0.10±0.35	0.12	Bedhane *et al*. (2013)
WW with SMW	Arsi-Bale	0.94±0.33	0.72	Bedhane *et al*. (2013)
WW with YWT	Arsi-Bale	0.52±0.50	0.56	Bedhane *et al*. (2013)
SMW with YWT	Arsi-Bale	0.57±0.43	0.65	Bedhane *et al*. (2013)
BW with WW	Draa	0.58	0.27	Boujenane and Hazzab (2012)
BW with SMW	Draa	0.28	0.15	Boujenane and Hazzab (2012)
WW with SMW	Draa	0.43	0.51	Boujenane and Hazzab (2012)
BW with WW	WAD	0.74±0.08	0.30	Bosso *et al*. (2007)
BW with YW	WAD	0.73±0.14	0.19	Bosso *et al*. (2007)
LL with LMY	Arsi-Bale	0.43	0.15	Bedhane *et al*. (2012)
LL with DMY	Arsi-Bale	-0.01	-0.19	Bedhane *et al*. (2012)
LMY with DMY	Arsi-Bale	0.31	0.49	Bedhane *et al*. (2012)

Note: AFK=Age at first kidding; KI=Kidding interval; LSB=Litter size at birth; LSW=Litter size at Weaning BW= Birth weight; WW=Weaning weight; SMW=Six months weight; YW=Yearling weight; LL=lactation length LMY=Lactation milk yield; DMY=Daily milk yield

2.5. Breed characterization

A good understanding of breed characteristics is the base for decision making in livestock development and breeding programs (FAO, 2007). Breed characterization includes all activities related with the description of the origin, development, structure, population, quantitative and qualitative characteristics of the breeds in defined management and climatic conditions (Ayalew, 2004; Rege, *et al*., 2006; Gizaw et al., 2011). Breeds can be characterized by morphological (phenotypic) and molecular tools.

2.5.1. Morphological or phenotypic characterization

According to FAO (2012) phenotypic characterization is defined as the process of identifying distinct breed populations and describing their external and production characteristics in a given environment and under given management, taking into consideration the social and economic factors that affect them. Phenotypic characterization is description of breeds in terms of external characteristics (such as coat color, ear type and shape, horn shape and type), linear body measurements (such as height at wither, heart girth, body length, ear length), production traits (body weight, milk yield) and reproductive traits (such as age at first kidding, litter size) (FAO, 1986; Tesfaye, 2004; FAO, 2012). Phenotypic characterization is a comparatively easy and cheap tool of breed characterization but phenotypic characters are highly influenced by environmental effects and by sometimes strong genetic and environmental correlations and interaction. Therefore, it should be supported by molecular characterization (FAO, 2011; Gizaw *et al*., 2011).

2.5.2. Molecular characterization

Molecular characterization involves describing and classifying of livestock breeds and species at molecular level by measuring frequencies of genotypes and alleles, degrees of polymorphism, allelic diversity (observed and expected hetrozygosity) and genetic distances (Toro *et al*., 2009; Gizaw *et al*., 2011). Tools for molecular analysis are biochemical (protein) polymorphisms and molecular DNA. Protein (Allozymes) polymorphisms were the first markers used for genetic studies in livestock. However, the number of polymorphic loci that can be assayed, and the level of polymorphisms observed at the loci are often low, which greatly limits their application in genetic diversity studies (Toro *et al*., 2009). With the development of new technologies, Molecular polymorphisms (nuclear DNA) have become the markers of choice for molecular-based surveys of genetic variation. Different types of markers are now available to detect polymorphisms in nuclear DNA. Randomly amplified polymorphic DNA (RAPD), amplified fragment length polymorphisms (AFLP), restriction fragment length polymorphisms (RFLP), microsatellites and single nucleotide polymorphisms (SNPs) have been developed and utilized in genetic diversity analysis (Baumung *et al*., 2004: FAO, 2011). However, microsatellites and SNPs are the currently most used and recommended (FAO, 2011).

2.5.2.1. Microsatellites

Microsatellites are simple tandem nucleotide repeats, interspersed throughout the genome and usually found in non-coding part of the genome (FAO, 2011). Because of their high polymorphism, high abundance, co-dominant inheritance, simplicity to analyze and ease of scorine, microsatellites have been the markers of choice until very recent and have been used for genetic diversity studies of many livestock species (Arif and Khan, 2009; Baumang *et al*., 2004). They have been successfully utilized for genetic analysis of different breeds of goats worldwide (Agha *et al.,* 2008; Fatima *et al*., 2008; Li *et al*., 2008; Missehou *et al*., 2011; Hassen *et al*., 2012). Microsatellites have some limitations in genetic diversity study such as null alleles, interpretation difficulty of allele calling and size homoplasy (Pariset *et al*., 2009)

2.5.2.2. Single nucleotide polymorphisms (SNPs)

A SNP is a DNA sequence variation that occurs through the substitution of one nucleotide by another at a single location within the genome of a species or breed (Beuzen *et al*., 2000; Vignal *et al*., 2002; FAO, 2011). SNPs occur about once every 1 kb, within the coding and non-coding regions. For a variation to be considered a SNP, it must occur in at least 1% of the population (Vignal *et al*., 2002; Mburu and Hanotte, 2005). SNP markers have promising advantages over microsatellite markers such as being prevalent and providing potential markers near or in any locus of interest. Some SNPs are located in coding regions and directly affect protein function. SNPs have lower mutation rates than microsatellites, making them more suited as long term selection markers and SNPs are more suitable for different genotyping techniques and have strong potential for automation (Beuzen *et al*., 2000; Vignal *et al*., 2002; Herraz *et al*., 2005; Nigrini *et al*., 2008). However, as SNPs have bi-allelic nature, the information content per SNP marker is lower than that of microsatellite markers. Around 5-6 SNPs markers are equivally informartive as one microsatellite marker (Beuzen *et al*., 2000; Toro et al., 2009). Therefore, large numbers of SNPs are required for genetic diversity analysis to get the accurate results. Due to the growing availability of mapped SNPs of different species, SNP markers are now beinig used for molecular breed characterization of different species in different areas such as cattle (Mckay *et al*., 2008; Nigrini *et al*., 2008; Edea *et al*., 2013), sheep (Kijas *et al*., 2009), goat (Pariset *et al*., 2009; Kijas *et al*., 2012; Hykai *et al*., 2013) and horses (Petersen *et al*., 2013). Molecular diversity studies based on SNPs for African goat are not available.

2.6. Genetic improvement strategies

The main objective of animal breeding is to genetically improve population of livestock which is achieved through selecting the best individuals of the current generation and using them as parents of the next generation. Genetic improvement aimed to exploit the present within and between breed variations (ILCA, 1994). Any genetic improvement programs falls under the three major genetic improvement pathways: 1.within breed selection; 2. Selection between breeds (breed substitution) and 3 crossbreeding. To be successful in genetic improvement of livestock, appropriate breeding programs need to be planned, implemented and maintained. Breeding program is defined as the organized structure that is set up in order to realize the desired genetic improvement of the population. Small ruminant breeding programs in tropical country are less organized and largely fragmented. Many of the programs were based on the upgrading of the indigenous animal to exotic breeds. The crossbred animals were often good in terms of growth and some other production traits under on station evaluation. Yet, the performance of the crossbred animals at smallholder level is frequently low (Hassen *et al.,* 2002 ; Ayalew *et al*., 2003; Kosgey *et al*., 2006). In general most of the crossbreeding activities were not successful and sustainable due to incompatibility of the breeding objectives and the management approaches of the existing production system of the area (Ayalew et al., 2003; Kosgey *et al*., 2006; Wollny, 2003). Furthermore, Haile *et al*. (2009) in review work summarized the main problems of upgrading tropical breeds with exotic breeds as follows:

- Lack of clearly defined breeding policy
- No owner participation
- Too complicated in terms of logistics, technology and infrastructure
- Indiscriminate crossbreeding
- Lack of analysis of the different socio-economic and cultural roles that livestock play

Therefore, in tropical countries, it is very useful to understand the level of performance and the potential of genetic improvement through selection within the indigenous breeds before implementing any breeding strategy (Philipsson *et al*., 2011). Pure breeding and other breeding programs involve the description of and decisions about a series of interacting components. Among them the most important components to be considered in breeding program design are: description of production environment and production system, characterization of the available genotype, definition of breeding objectives, identification of traits to be selected, decision about breeding methods and breeding population and understanding people, structure and organization (Iñiguez, 1998; Sölkner *et al*., 1998; FAO, 2010).

According to Kosgey *et al*. (2006) review work, the small flock size, single sire mating, lack of performance and pedigree recording, low level of literacy, and lack of organizational structure hinders within breed selection in tropics. To solve these problems, nucleus (open and closed) breeding schemes are the most used and recommended tools for small ruminant genetic improvement programs in tropical countries (Wolly, 2003; Tibbo *et al*., 2006; Muller, 2006). Community based breeding program is a recently advocated option for tropical traditional low input livestock production systems (Sölkner *et al*., 1998; Kahi *et al*., 2005; Gizaw *et al*., 2009; Haile *et al*., 2011; Wurzinger et al., 2011).

2.6.1. Nucleus breeding schemes

The principle of nucleus breeding program is bring the best breeding males and females from the participants (population) to a central place to create elite breeding animals and to make strong selection there. The selected animals (mostly male animals) will be distributed to participating farmers to disseminate the genetic superiority obtained at the nucleus to the whole population. Open nucleus breeding scheme allow the flow of animals in both directions from the nucleus to the population and vice versa while the closed scheme allows only the flow of animal from the nucleus to the population (Tibbo, *et al*., 2006; Philipsson, *et al*. 2011). Nucleus breeding program have the following advantages in tropical countries where performance recording at farm level is not practiced; they allow having accurate recording and processing by which achieving efficient selection and high genetic gain. However, to run such a program in a sustainable way it needs high infrastructure and technical input (Kosgey *et al*., 2006). Yapi-Gnoare (2000) in Ivory Coast for Djallonke sheep breeds, Von Wielligh (2001) in Namibia for Damera sheep and Ramsay et al. (2000) in South Africa for Boer goat and Dorper sheep reported successful nucleus programs where the program had strong support from the government and other sources as well as strong community participation. However many nucleus breeding programs in tropics failed due to the lack of sustainable support and inadequate involvement of the community at the beginning of the program (Iniguez, 1998; Wollny, 2003; Kosgey *et al*., 2006; Kosgey and Okeyo, 2007).

2.6. 2. Community (village) based breeding schemes

Community based breeding programs are a new approach of genetic improvement program proposed for the low input traditional smallholder farming system (Sölkner *et al*., 1998; Kahi *et al*., 2005; Haile *et al*., 2011; Wurzinger et al., 2011). Sölkner *et al*. (1998) defined community based breeding programs operating in the following conditions: ‘‘Village breeding programs are carried out by communities of smallholder farmers (villagers), often at subsistence level. The availability of feed for the animals is far from optimal with large seasonal variations and variations between years (e.g., droughts and floods in the tropics, summer and winter in extreme mountain regions of Asia). The pressure from diseases may be high (tropical regions). The level of organization is low, hierarchical structures with good flow of information between levels of the hierarchy cannot always be assumed to work. Data recording in the sense used by animal breeders in the developed countries will often be missing''. According to (Haile *et al*., 2009) community is defined as the group of people having social, cultural and economic relation based on common interest, goal, problems or practices shared interest and living in a well defined area. Different from the conventional top down approach, community based breeding programs takes in account the indigenous knowledge of the communities on breeding practices and breeding objectives (Gizaw *et al*., 2013). The community-based breeding strategies also consider the production system holistically and involve the local community at every stage, from planning to operation of the breeding program (Baker and Gray, 2004). The breeding structure of such a program is commonly single-tiered with no distinction between the breeding and production units, i.e., the farmers and pastoralists are both breeders and producers (Gizaw *et al*., 2013). The basic steps in community based breeding program are selection of the target community and breeds, description of the production system, definition of breeding goals in participatory manner, assessment of alternative schemes and implementation of feasible schemes (Haile, *et al*., 2011) The following summarized reasons have been identified as an advantage of the community-based breeding programs for sustainable genetic improvement in tropical regions (Wollny, 2003; Kahi *et al*., 2005):

- The breeding flocks are located within the production environment and potential genotype-environment interactions are therefore minimized
- Direct farmer participation is possible
- The farmers are owners of the initiative and benefit from it
- The farmers have a sense of responsibility for the targeted breed, since it is a part of the traditional culture and contributes to their identity and self respect
- Keeping of the targeted breed is economically important
- Utilization of available feed resources
- Maintenance is labor-intensive and not capital intensive
- The initiative is self-administered by the community, but is supported by government and other organizations. The community therefore knows where to obtain information and technical advice.

- The community has the capacity to run the initiative through relevant training and visits to other initiatives in other areas.

2.7. Breeding goal definition

Breeding goal definition is the first step to be made in designing of breeding program. A clear understanding of production objective and breeding goal of the farmers (Beneficiaries) is an important component of planning of breeding programs. The breeding goal identifies the animal traits that farmers would like to be improved. Breeding objectives must to be set at national (macro), regional or local level by stakeholders (and not by outsiders) to truly reflect the real needs of the area; farmers must support the direction of change (Ahuya *et al.,* 2005; Kosgey *et al*., 2006; FAO, 2010). The ultimate goals of a breed at the macro-level should be expressed by the agricultural development policy, market, production system of the country, region or locality (FAO, 2010). At the micro level the definition of breeding objectives means that for the given production environment the relative importance of improvement of different traits of the breed must be identified (Phillpson, 2011). Breeding objectives are affected by many factors and have to consider the needs and priorities of the animal owners or producers, the consumers of animal products, the food industry, and increasingly also the general public. In smallholder and pastoral communities, breeding goals are multi-functional than and include many aspects other than high productivity (Taye, 2006). Thus the breeding goal definition in subsistence system needs to take account the diversity of traits (Muller, 2006). Therefore, the breeding objective and the selection criteria (traits), on which the livestock keepers wish to improve and base their selection should be identified through the full participation of pastoralist and smallholder farmers. Lack of participation of farmers in defining the breeding objective was the main reason for failure of many livestock improvement programs in tropics (Kahi *et al*., 2005; Wurzinger *et al*., 2011). Duguma *et al.* (2010) and Haile *et al*. (2011) recommended five participatory tools (Personal interviews, workshops, choice cards, and two types pf ranking experiments with live animals) to identify the breeding objectives and the breeding objective traits in pastoral and smallholder subsistence system. Their advantages and short-comings of these tools are summarized in Table 6.

Table 6. Advantages and disadvantages of the five breeding objective identification methods

Properties	Personal interviews	Workshops	Choice cards	Ranking of live animals	
				Own animals	Unknown for farmers
Advantages	-A large number of persons can be interviewed - Possible to verify the consistency of the responses -Additional information can be gathered at the same time	-Information from different persons collected at once - Differences can be directly discussed	-Large sample size -Enumerator introduced bias likely to be lower than in interviews -Price can be included as a characteristic	-Relatively easy to handle -Closer to reality than choice cards: Seeing a live animal is better than a picture -Information from different family members can be considered	-Easily done by farmers -Closer to reality than choice cards: seeing a live animal is better than a picture
Disadvantages	-Language barrier -Enumerator introduced bias may be high -Important traits may not be mentioned	-Some people (e.g. with higher social status) might dominate the discussion	-Limited number of animal profile choices can be made per person -Visual illustration of some traits can be complicated or impossible	-There may not be enough animals of the same category available in small herds	-Large 'pool' of animals often no readily available -Hypothetical life history provided with a given animal may not be compatible with the visual appearance according to farmers' experience

Adopted from Haile *et al*. (2011)

2.8. Methods of optimizing alternative breeding programs

Breeding planning includes all steps for developing and optimizing breeding programs (Herold *et al*., 2012). Optimizing the different scenarios of the breeding program is useful procedure to look the quality of breeding schemes through predicting selection response for the breeding goal traits and the economic return of the given scenario. Two methodological approaches, stochastic and deterministic are available for simulating the different alternatives of breeding schemes. A stochastic simulation generates breeding and phenotypic values for each simulated individual while deterministic simulation uses a whole population model. Stochastic simulation is relatively simple, but requires repeated running of a simulated breeding program. Deterministic methods are widely used in livestock breeding planning because of its short computational time requirement and giving more insight into the genetic gain and inbreeding of the breeding programs. It requires formulas to adjust for things such as the Bulmer effect of reduced diversity due to inbreeding, reduced selection intensities small populations, correlations between EBVs, prediction of inbreeding etc. It is therefore more complicated and possibly more approximate.

ZPLAN and SelAction are the most commonly used computer programs that use deterministic method. The first version of ZPLAN was developed by Karras (1984), Using the gene flow methods and selection index procedures, the program enables to simulate different breeding plans in any livestock species and it can be applied for plans with several sub-populations, for populations used in cross breeding schemes and considers several units in the scheme such as nucleus, multipliers, and production levels (Willam *et al*., 2008). The important output parameters of the program are annual monitoring genetic gain for the aggregate genotype, annual genetic gain for individual trait, discounted return and discounted profit for a given investment period (William *et al*., 2008). The ZPLAN program is not user friendly. The user is expected to have basic FORTRAN programming knowledge. A new web based user friendly version of the software (ZPLAN+) was developed by Täubert *et al*. (2010) and is available for commercial purpose.

SelAction (Rutten *et al*., 2002) predict response to selection within the selection group and rate of inbreeding of livestock improvement programs using deterministic simulation methods. However it does not give the option to evaluate the breeding programs in terms of discounted returns and profits (Herold *et al*., 2012).

3. Materials and Methods

3.1. The study areas

The study was conducted in Metema and Abergelle districts of the Amhara National Regional State of Ethiopia (Figure 1). Metema and Abergelle districts were purposively selected for this study to address goat production in two different agro-ecological zones, farming systems and goat breeds. Metema district is located in a wet Lowland agro-ecological zone and in the North Western part of the country, 860 km from the capital Addis Ababa. The altitude ranges from 550 to 1608 m and the latitude of 12°40’ N to 13°14’ N. The rainfall pattern is unimodal with a mean annual range from 850 to 1100 mm, occurring from June to September (IPMS, 2005). Temperature ranges from a minimum of 22°C to the maximum of 43°C (IPMS, 2005). The production system is a mixed crop-livestock system with dominance of crop production as there is a high potential for biomass production. The dominant goat breed is Western Lowland (Gumuz). The second study area, Abergelle district is in the dry/sub-moist highland agro-ecological zone of the Northern part of the country, 780 km from Addis Ababa. The altitude ranges from 1150 to 2500 m with the latitude of 12°18’N to 13°06’N. The mean annual rainfall ranges from 250 to 750 mm, falling mainly from July to September (DOARD, 2010). The rainfall pattern is very erratic and uneven. Due to this erratic nature of rainfall, frequent crop failure and drought are common phenomena in the area. The production system is a mixed crop-livestock system with a focus on livestock, mainly Abergelle goat production.

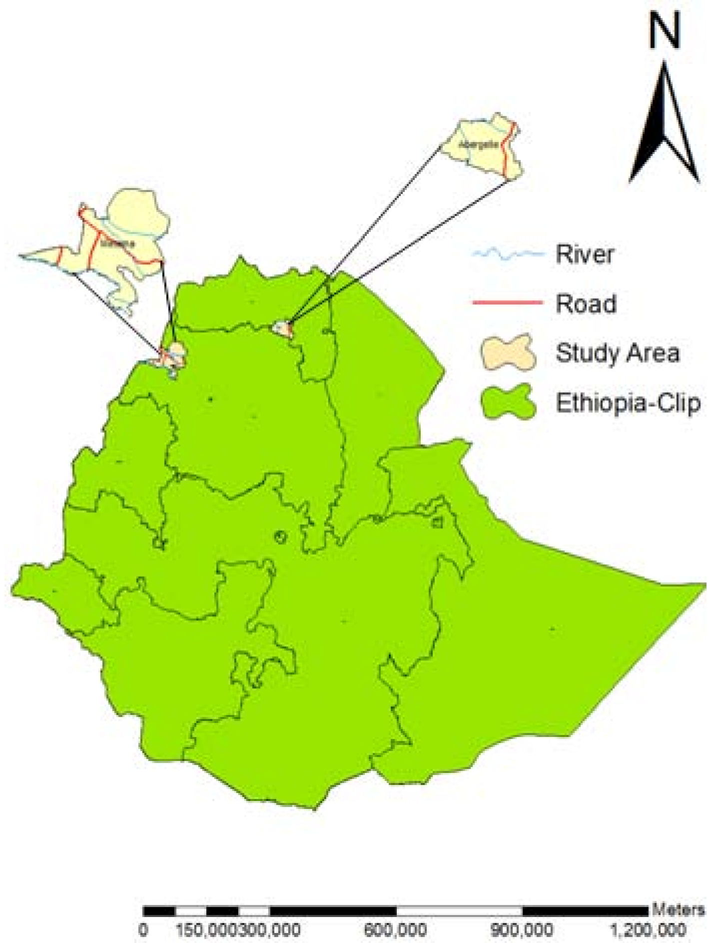

Figure 1-Maps of the study areas

3.2. Data collection

3.2.1. Description of production systems

Two villages, one from each district, were selected as the study sites based on goat production potential and willingness of the farmers to participate in a community based goat improvement program. A total of 120 goat keepers (60 from each district) were selected and interviewed. For the interviews structured questionnaires were used that covered the following topics: general household characteristics, purpose of keeping goats, livestock ownership, flock structure, performance of goats, management and breeding practices and goat production constraints. Before the survey was conducted, enumerators were trained and the questionnaire was pretested. General information and environmental conditions of the study areas were obtained through secondary data, field observation, informal interviews with farmers and the reports of District Office of Agriculture and Rural Development.

3.2.2. Morphological characterization

A total of 476 Western Lowland and 534 Abergelle goats with different dentition classes were used for the morphological characterization. They were classified into six age groups based on their dentition; kids (less than six months), young (between 6 and 12 months), 1Pair of Permanent Incisors (PPI) (1year), 2 PPI (2 years), 3 PPI (3 years) and 4 PPI (4 years and above) (FAO, 1994). The kids and the young were differentiated by asking the age of animals from the owners. Qualitative characteristics (coat color and pattern, presence or absence of wattles and ruff and hair type) and linear measurements (body weight, body length, chest girth and height at withers) were recorded and measured by using the standard format adapted from the FAO (1986) breed descriptor list (Appendix 2). Body weight (kg) was determined using suspended spring scales and other body measurements were taken using a flexible metal tape after restraining and holding the animals in natural position. 726 female animals were available for body weight and other body measurements. Pregnant animals were excluded from the measurement to avoid over estimation.

3.2.3. Molecular diversity study using SNPs marker

Understanding of the within and between breed diversity are very helpful for future breed improvement and conservation planning. Molecular genetic diversity and homozygous segments of both breeds were studied using 47K genome wide SNPs markers.

3.2. 3. 1. Sample collection and genotyping

A tissue sample of 54 and 41 animals were collected from Abergelle and Western Lowland goat (Gumuz) breeds, respectively. To avoid sampling of closely related animals, the samples were collected from different households with a maximum number of three unrelated animals per households. The tissue samples of individual animals were taken from the ear by tissue puncher tubes using Alflex tissue applicator (http://www.allflexusa.com) (Appendix 11). Genomic DNA was extracted from the tissue samples following the standard manufacturers procedure of Qiagen Puregene tissue extraction method (http://www.qiagen.com/gentra-puregene-tissue-kit).The genomic DNA was genotyped using Illumina 47K SNPs bead chip technology (Illumina, 2013). Additional data sets of (47K SNPs and 25 animals from each breed) three Nigerian goat population (West African Dwarf, Red Sokoto and Sahel goat) were provided by USDA-ARS for comparison purpose.

3.2.3. 2. Quality control and data management

Animals with greater than 10% missing genotype, SNPs with greater than 10% missing genotype and SNPs assigned for X chromosome were excluded from the data set using PLINK software (Purcell *et al*., 2007). After the above quality control measures 46,885 autosomal SNPs and 53, 41, 23, 22 and 22 animals for Abergelle, Western Lowland, West African Dwarf, Red Sokoto and Sahel goats were available for genetic diversity analysis, respectively. For runs of homozygosity (ROH) analysis, 44,721 SNPs were available after further pruned for MAF (<0.05) and for Hardy Weinberg Equilibrium (HWE=p<0.0001). 16,127 randomly selected SNPs were used for model-based clustering analysis using STRUCTURE software. According to (Frkonja *et al*., 2012) in a cattle admixture study, a small number of sub set SNPs (4000 SNPs from the 50K SNP chip) were sufficient to study breed composition. PLINK (Purcell *et al*., 2007) and R (http://cran.r-project.org) programs were used to arrange the SNP data. PGDSpider 2.0.1.4 (Lischer and Excoffier, 2012) software was used to convert the data files into different programs formats.

3.2.4. Participatory identification of breeding objectives traits

Identification of the breeding objectives traits in participatory manner are a recommended approach for the sustainable breed improvement programs in tropics (Sölkner *et al*., 1998; Gizaw *et al*., 2010b; Wurzinger *et al*., 2011). In the present study, participatory own flock ranking and group ranking methods adapted from (Mirkena, 2011) were applied.

3.2.4.1. Own flock ranking methods

In own flock ranking experiment, sixty and thirty households, respectively, from Metema and Abergelle areas were visited. The household members were asked to choose their first best, second best, third best and the most inferior does among the breeding does in their flocks. The reasons of ranking and life history of the ranked animals (age, number of kidding, number of kids born per kidding, number of kids weaned) were inquired and recorded. The live body weight and some linear body measurement of the ranked animals were also taken.

3.2.4.2 Group animal ranking

Twelve breeding does and twelve breeding bucks from western Lowland goats and fifteen does and fifteen bucks from Abergelle goats were randomly selected. Similar to the own flock ranking experiment, the life history of does and the life history of bucks (age, birth type, libido and temperament) were inquired from the owners. The live weight of the selected animals was also measured. The selected animals were brought to the central place and randomly assigned into groups. The selected animals were grouped into four in western Lowland goats and five in Abergelle goats for each sex with three animals per group. Fifteen farmers for Western Lowland goats and 10 farmers for Abergelle goats who have not known the selected animals before were invited to rank the animals. Each farmer was asked to rank the animals in each group and the reasons of ranking. After a first round of ranking, farmers were provided with the life histories attached to individual animals and asked whether they would consider re-ranking the animals. This procedure was continued until all groups covered.

3.2.5. Designing and optimizing of alternative breeding programs

3.2.5.1. Population structure and Selection pathways

The community based one tier selection scheme was considered for both breeds as the optimal breeding program for both of the study areas. The community based breeding program is believed to be a more convenient breeding program for such type of production systems which are characterized as low-input system with poorly developed infrastructures (Sölkner *et al.*, 1998; Kahi et al., 2005; Gizaw et al., 2009). The flocks from 30 households with the average of 26 breeding does per household were considered as one breeding unit for Abergelle goat, While the flocks from 60 households with the average of 5 breeding does per household was considered as one breeding unit for Western Lowland goats.

Four selection groups were defined to indicate the selection pathways. A selection group is defined by both, type of parents (one sex) passing genes and type of offspring receiving their genes. The selection groups were Bucks to produce Bucks (B>B), Bucks to produce Does (B>D), Does to produce Bucks (D>B) and Does to produce Does (D>D). Strong selection of male animals was assumed. The assumption was that the genetic gain obtained through selection would be disseminated by the selected bucks. The female animals would be selected only for the replacement. The young bucks at the age of six months would be selected based on their own performance of growth and the information from their dams for others traits. Breeding bucks were assumed to be in use for two time units (two years). Early age of selection (six months weight) was assumed to be more appropriate for the existing production systems of the study areas where negative selection is very common. Farmers tend to sale the fast growing animal at early age to get attractive market price.

The important input parameters of the two breeds for modeling (running ZPLAN) are shown in table 7. The information for the input parameters were derived from the production system, morphological characterization and own flock ranking results of this study and published report of on-farm monitoring studies (Derbie, 2008; Tsegaye, 2009; Derbie and Taye, 2013). The number of proven (candidate) animals in each time unit (year) were projected using the reproductive parameters and survival rate of the breeds. For instance the numbers of proven male animals for Western Lowland goat were calculated as follows: Assuming that sixty participant farmers with the average of 5 breeding does and the total of 300 breeding does in the village selection scheme. Only 85% of them have kidding within one time unit (year), 0.6 year kidding interval, 1.5 liters per kidding, 1.67 kidding per year (time unit), 80% of survival rate and 50 % sex ratio. It gives 255 male selection candidates (300*.85*1.5*1.67*.8*.5=255).

In this study, only the costs of additional activities to the normal management practices were considered as the cost parameters. Those were the cost of performance recording (Enumerator salary, cost of items for animal identification and cost of stationary materials) and cost of drugs. Those costs were calculated per individual breeding does per year. For instance the costs at Western Lowland goat were estimated as follow:

a) Labor cost for recording: One enumerator for 300 does: Enumerator salary 24.59 €/month=295.08€/year; 295.08€/300 does; 0.98€/doe/year

b) Identification cost: 2 tags/animal/year (a doe and her 2.5 kids/year) 0.2€/tag = 2*3.4*0.2 =1.36 €/does/year

C) Drugs: 0.4 €/animal/year = 3.4 (a doe plus 1.13 kids/year)*0.4 =1.36€/does/year

Table 7. Input parameters for modeling alternative breeding programs

Parameters	Abergelle	Western Lowland
Population parameters		
Population size(Does)	780	300
Number of proven males/years	300	255
Proportion of bucks selected	10%	10 %
Biological parameters		
Breeding does in use(year)	5	5
Breeding bucks in use (year)	2	2
Mean age of bucks at birth of first offspring (years)	1.5	1.2
Mean age of does at birth of first offspring (years)	1.3	1.1
Kidding rate	.85	.85
Mean time period b/n subsequent kidding (years)	1	.6
Mean number of kids per litter (litter size)	1.13	1.5
Number of kidding/doe/year	1	1.67
Kid survival to six months (%)	80%	80 %
Cost parameters		
Animal identification doe/year(€)	.86	1.36
drug /doe/year(€)	.86	1.36
Enumerator salary(€)	.98	.98
Stationary materials for recording(€)	.20	.20
Interest rate return (%)	0.05	0.05
Interest rate cost (%)	0.08	0.08
Investment period /year	15	15

3.2.5.2. Alternatives breeding programs

Four different alternatives for each breed were proposed for evaluating optimal breeding program (Table 8). The alternatives were based on the variation of the number of the traits in the selection index (recording) while keeping all traits in aggregate breeding goal. The important considerations of the alternatives were to see the effect of the variation of the number of traits in the recording scheme (selection criteria) on the genetic gains of the individual traits as well as the aggregate response. Since the selection program will operate at village level, inclusion of all traits in recording scheme might not be feasible in technical and economical terms.

Table 8. Alternative breeding schemes for Abergelle and Western Lowland goats

Alternatives	Breed	
	Abergelle	Western Lowland
1	All traits in the selection index(SMW+DMY+PKW)	All traits in the selection index(SMW+NKB+PKW)
2	SMW+DMY in the selection index	SMW+NKB in the selection index
3	SMW+PKW in the selection index	SMW+PKW in the selection index
4	Only SMW in the selection index	Only SMW in the selection index

Note: SMW=Six months weight, DMY=Daily milk yield, PKW=Proportion of Kid weaned, NKB=Number of kids born

3.2.5.3. Genetic and phenotypic parameters

The genetic and phenotypic parameters are presented in Table 9. Due to the population parameters of the study breeds lacking, the weighted heritability estimates of the traits from published reports of other local and exotic goats were used (Odubate *et al*., 1996; Bosso *et al*., 2007; Valencia *et al*., 2007; Rashidi *et al*., 2008; Chun-yan Zhang *et al*., 2009; Alade *et al*., 2010; Faruque *et al*., 2010; Mantaldo *et al*., 2010; Kebede *et al*., 2012a). The genetic and phenotypic correlations of the traits were obtained from published reports on sheep (Abegaz, 2002; Matika *et al*., 2003; Gizaw *et al*., 2007; Afolayan *et al*., 2009).

Table 9. Phenotypic correlation (above the diagonal), genotypic correlation (below the diagonal) and heritability of the traits (along diagonal)

Traits	Abergelle			Western Lowland		
	SMW	DMY	PKW	SMW	NKB	PKW
SMW	0.28	0.1	0.1	0.28	0	0.1
DMY/NKB	0.2	0.32	0.14	0	0.10	0.15
PKW	0.3	0.53	.05	0.3	-0.20	0.05

Note: SMW=Six months weight, DMY=Daily milk yield, PKW=Proportion of Kids weaned, NKB=Number of kids born

3.3. Statistical analysis

3.3.1. Questionnaire data

The SAS (2009) program was used to describe the survey data. Chi-square or t-test was employed when required to test the independence of categories or to assess the statistical significance. Indices were calculated for ranked variables (reasons of goat keeping, selection criteria and production constraints). Indices were computed as: sum of (3x for rank 1 + 2x for rank 2 + 1x for rank 3) given for a given reason divided by the sum of (3x for rank 1 + 2x for rank 2 + 1x for rank 3) for overall reasons.

3.3.2. Morphological data

Qualitative characteristics of the breeds from morphological characterization data were analyzed by frequency procedures SAS (2009). A general linear model (GLM) procedure SAS (2009) was used to analyze body weight and other linear body measurements. The male animals were excluded in the model in analysis of body weight and other body measurements because only a few male animals were available at older age/dentition classes. Homogeneity of variance test for body weight in natural scale and log transfer scale at different age classes were also done to see within breed variability.

The statistical model used was;

$Y_{ijk} = \mu + A_i + B_j + (A \times B)_{ij} + e_{ijk}$

Where:

Y_{ijk} = the observation on body weight, chest girth, body length and height at withers

μ = the overall mean;

A_i = the fixed effect of age (i = ≤ 6 months, 6–12 months, 1PPI, 2PPI, 3PPI, 4PPI)

B_j = the fixed effect of breed (j =Western Lowland, Abergelle)

$(A \times B)_{ij}$ =the interaction effect of age with breed

e_{ijk} = the effect of random error.

3.3.3. SNP data

3.3.3.1. Within-breed diversity

Allelic frequencies, number of polymorphic loci (MAF>0.05), observed heterozygosities (Ho), and expected heterozygosities (He) were obtained using Arlequin version 3.1 (Excoffier *et al*., 2005). The same package was used to test deviation from Hardy-Weinberg equilibrium using a Markov chain of steps100 batches, 5,000 iterations per batch, and 10,000 dememorization step.

3.3.3.2. Population differentiation and cluster analysis

Analysis of molecular variance (AMOVA) was calculated using the Arlequin version 3.1 software (Excoffier *et al*., 2005). Population differentiation was measured using F-statistics by calculating F_{IS} (inbreeding within the population), F_{ST} (the degree of gene differentiation among population) and F_{IT} (inbreeding in a group of populations). F statistics (F_{IS}, F_{ST} and F_{IT}) known as fixation index were calculated according to the methods of Weir and Cockerham (1984) using GENEPOP package version 4.2.1 (Rousset, 2008). The significance of pair wise population differentiation and significance of fixation index was tested using permutation test (10000 permutations). Reynolds standard population pair-wise genetic distance matrix (Reynolds *et al*., 1983) was computed as implemented by Arlequin version 3.1 software (Excoffier *et al*., 2005). Neighborhood-joining dendrogram was constructed based on the Reynolds genetic distance using Unweighted Pair Group Method Arithmetic Averages (UPGMA). MEGA software version 5.2 was used to construct the tree (Tamura *et al*., 2008). Principal components analysis (PCA) was performed by GENABEL package in R (http://cran.r-project.org) and the principal components were calculated from all allele frequencies for each population. The population structure and admixture was evaluated based on a Bayesian clustering analysis by employing the STRUCTURE program (Pritchard *et al*., 2000). The samples were clustered with number of genetic clusters, *K* ranging from 2 to 5, applying 5 independent runs for each of the different values of K, with burn-in period of 5000 iterations and run length of 10,000 iterations.

3.3.3.3 Runs of homozygosity (ROH)

ROH are contiguous lengths of homozygous genotypes that are present in animal due to both parents transmitting identical haplotypes to their offspring (Purfield *et al*., 2012). The degree and frequency of these may inform on the ancestry of an individual and its population. The longer ROH segments are generated by inbreeding to a recent ancestor while the shorter ROH segments may also inform on the presence of remote ancestral inbreeding. (Purfield *et al*., 2012; Ferencakovic *et al*., 2013a). In this study, ROH was detected by using CgaTOH (Zhang *et al*., 2013) software by applying the following ROH definition; the minimum number of SNPs needed to define a segment as ROH, 20; number of missing calls allowed, 5; number of heterozygous call allowed, 1; maximum gap between consecutive homozygous SNPs, 1 Mb; minimum length of ROH set for >1, >2, >4, >6, > 8, >10, and >16 MB to see inbreeding at different ancestral generations. A genomic inbreeding (F_{ROH}) was derived as the ratio of the length of genome present in ROH at specific run length to the total length of autozygous genome covered by the consensus map of SNPs (2402.62MB). The SAS (2009) software was used to describe the ROH results.

3.3.4. Participatory identification of breeding objectives traits

The statistical software SAS (2009) was used to analyzed the data from the own flock ranking and group ranking experiments. The proportion of traits preferred by the farmers in own flock ranking and group ranking experiment were analyzed by the frequency procedure. The body measurements and other traits from the life history were analyzed by glm procedure fitting the rank as fixed effects in the model.

3.3.5. Optimizing alternative breeding programs

Alternative breeding schemes were designed and evaluated using the computer program ZPLAN (Willam, *et al*., 2008). Using the gene flow method and selection index procedures, the program enables to simulate different breeding plans by deterministic approach. The program calculates genetic gain for the aggregate breeding value, the annual response for each trait and discounted return and discounted profit for a given investment periods. ZPLAN cannot consider reduced genetic variance due to selection (Bulmer effect) and inbreeding. Rate of inbreeding per generation (ΔF) were calculated using a formula relating effective population size to use number of male (N_m) and number of female (N_f) breeding animals (Falconer and Mackay 1996); $\Delta F = (1/8\ N_m) + (1/8\ N_f)$

4. Results and Discussion

4.1. Production system study

4.1.1. General household characteristics

The majority (91.7 %) of the respondents in both study areas were male. The mean (±standard deviation) age of the respondents was 42.50±12.01 and 42.00±12.29 years for Western Lowland and Abergelle goat keepers, respectively. The mean family size was 5.40±1.85 and 6.30±2.34 for Western Lowland and Abergelle, respectively. This was higher than the national average of 4.80 (CSA, 2010b). In Western Lowland goat keepers the majority of respondents (56.6%) are able to read and write, whereas in Abergelle only 18 out of 60 farmers were literate. The relatively higher proportion of literate household heads for Western Lowland goat owners would be a good opportunity to implement a goat improvement program as it might be easier for them to record performance and pedigree information. The average land holding (5.03±2.78 ha) of Western Lowland goat owners was significantly higher ($P<0.05$) than land holding of Abergelle goat owners (1.00±1.47 ha). These figures include only privately owned land for crop production. For grazing, communal grazing areas are used.

4.1.2. Purpose of keeping goats

Table 10 shows the purpose of keeping goats and their respective rank by study areas. Better understanding of the purposes of keeping goats is a prerequisite for defining breeding goals (Jaitner *et al*., 2001). The purpose of goat keeping identified in this study is in line with previous studies from Ethiopia and other African countries (Harpe and Abebe, 2008; Kosgey *et al*., 2008; Legesse *et al*., 2008; Assen and Aklilu, 2012). The role of goat as source of cash income was found to be the primary reason of keeping goats in both study areas with index values of 0.5 and 0.4 for Western Lowland goat keepers and Abergelle, respectively. Milk production was ranked as the second most important role in Abergelle, while consumption of goat milk was considered as a cultural taboo in Western Lowland goat breeders. The value of manure was ranked third in Abergelle, whereas for Western Lowland goat breeders it was ranked fourth.

Table 10. Ranks of purpose for keeping goats

Purpose	Study communities							
	Western Lowland goat owners				Abergelle goat owners			
	Rank				Rank			
	1st	2nd	3rd	Index	1st	2nd	3rd	Index
Income	52	8	-	0.500	38	13	7	0.410
Manure	-	1	3	0.014	8	14	21	0.205
Meat	3	31	25	0.270	1	4	13	0.067
Milk	-	-	-	-	12	28	15	0.300
Saving	5	20	25	0.220	-	-	3	0.010
Skin	-	-	4	0.010	-	-	-	-

The highest index value means the highest importance

Western Lowland goat breeders gave higher priority to meat production (rank 2) and savings (rank 3) compared with Abergelle goat keepers. These results clearly show that goat rearing is seen as an option to generate income through sale of slaughter animals, but also contributes to the household consumption through meat and milk production. Based on the above, the conclusion is made that the main breeding goal of Western Lowland goat breeders is to increase meat production for marketing and consumption whereas Abergelle goat breeders wish to increase meat as well as milk production.

4.1.3. Livestock holding and flock structure

This study revealed that farmers keep mixed livestock species. The average ± SD ownership per household of cattle, goats, sheep and donkeys for Western Lowland goat owners were 10.1±7.8, 10.8±7.2, 0.3±1.5 and 1.0±0.3, respectively. The corresponding values for Abergelle were 7.6±6.8, 48.5±52.2, 6.4±11.6 and 1.3±1.4 respectively (Table 11). Goats were found to be an important species owned by respondents in both study areas, particularly in Abergelle. The average flock size of goats in Metema was significantly ($P<0.05$) lower than the average flock size in Abergelle. FARM Africa (1996) reported 11 goats per household for Western Lowland flocks and 20 goats per household for Abergelle flocks. The relatively higher flock size of Abergelle goats indicates the importance of goat production and a strong scope for breeding activities in the community.

Table 11. Age structure of goats in flocks of the different study communities

Age class	Study communities							
	Western Lowland goat owners (N=60)				Abergelle goat owners (N=60)			
	Mean (number of goats)	SD	Range	%	Mean	SD	Range	%
Doe	4.2	2.32	1-10	44.79	25.9	36.29	2-240	51.80
Buck	0.6	0.92	0-4	4.14	2.8	2.94	0-15	6.65
Castrated	0.4	0.80	0-4	2.27	0.6	2.07	0-13	0.56
Young Buck	1.0	1.42	0-5	7.21	4.6	5.38	0-30	9.60
Young Doe	1.6	1.81	0-8	12.80	6.6	7.33	0-35	12.89
Kid	3.1	2.58	0-10	28.75	9.5	14.29	0-90	18.40

N= Number of households SD= Standard deviation

The proportion of goats at different sex and age classes in both study areas follow similar trends, where breeding does represent the largest class, followed by kids (Table 11). These findings are in line with results of Deribe (2008) and Tsegaye (2009) who reported 48.1% breeding does for Metema and 56.6% breeding does for Abergelle region, respectively In Western Lowland goat, breeding does made up to 44.8% of the flock followed by kids (28.75%), young does (did not give birth) (12.8%), young bucks (not sexually active) (7.21 %), bucks (4.14%) and castrates (2.27%). A similar pattern was also observed in Abergelle with 51.8% breeding does, 18.4% kids, 12.89% young does, 9.60 young bucks, 6.65% bucks and 0.56% of castrates. The lower the proportions of the kids in the Abergelle area were due to seasonal kidding there. As the area is drought prone area, most of kidding was happened between November and December following the active mating at the wet season (June and July).

The ratio of breeding buck to breeding does was 1:7 for Western Lowland goat and 1:12 for Abergelle, which was higher than the recommended ratio of 1:25 for tropical traditional production system (Wilson and Durkin, 1988).

4.1.4. Selection criteria and breeding practice

Selection criteria for breeding does and bucks are summarized in Table 12. For Western Lowland goat owners, the most important selection criteria for breeding does were multiple births, body conformation, mothering ability and kid growth with index values of 0.34, 0.16, 0.15 and 0.11, respectively. Coat color, fertility traits (kidding interval and age at 1st kidding) were also mentioned as selection criteria but with lower ranking. The probable reason of high emphasis for multiple births as the preferred trait by Western Lowland goat keeper could be due to the high availability of the feed throughout the year and the breed potential. Around 1.6 litters per kidding were reported by Western Lowland goat breeders. For Abergelle goat owners, milk yield, body conformation and multiple births were ranked as first, second and third important selection criteria with index values of 0.32, 0.21 and 0.12, respectively. Drought resistance, coat colour, kidding interval, kid growth, mothering ability and pedigree information were also described as selection criteria. Body conformation followed by coat color were found as the most important selection criteria of breeding bucks in both study communities with the index values of 0.33 and 0.22 for Western Lowland goat keepers and 0 .31 and 0.25 for Abergelle, respectively. The preferred colors in Western Lowland goat breeders were white, red and patchy of those colors. The preferred colors for Abergelle goat breeders were red brown and red. Plain black was the less preferred color in both communities. Due to the relatively large flock sizes per household in Abergelle goat, farmers gave a high emphasis on sexual activity of breeding bucks. In general, goat owners in both study sites preferred size and other performance traits. The improvement of traits related with growth performance can be achieved easily through village level selection as the traits are easy to measure and have high heritability.

Table 12. Selection criteria for breeding does and bucks

Selection criteria	Western Lowland goat owners				Abergelle goat owners			
	Rank				Rank			
	1st	2nd	3rd	Index	1st	2nd	3rd	Index
Breeding does								
Body conformation(size)	4	15	13	.156	14	13	5	.211
Twinning	32	9	7	.340	6	10	5	.124
Milk yield	2	-	1	.019	20	20	10	.317
Mothering ability	7	12	8	.151	2	3	10	.063
Kidding interval	4	7	3	.082	7	3	3	.086
Kid growth	2	12	9	.110	3	4	8	.072
Color	2	4	12	.074	1	3	11	.057
Age of 1st kidding	-	-	1	.003	-	-	-	-
Drought resistance	-	-	-	-	5	1	2	.055
Pedigree (Ancestor performance)	6	-	2	.056	-	1	2	.011
Breeding bucks								
Body conformation(Size)	20	25	5	.330	20	18	12	.310
Color	11	11	16	.225	9	24	16	.254
Libido	2	3	4	.045	20	5	13	.232
Growth rate	13	1	15	.216	3	8	8	.092
Pedigree	8	3	11	.116	7	1	4	.075
Horn	-	-	4	.017	-	2	4	.022
Drought resistance	-	1	2	.011	1	2	1	.030
Age at 1st mating	-	15	1	.003	-	-	-	-

In both study areas, mating was uncontrolled and random, since bucks were mixed with the does throughout the year. Most of the goat keeper respondents (91.67%) in Western Lowland practiced mixing of their flock during grazing period on average with 5 other flocks. However, in Abergelle only 15 percent of the respondents allowed their flocks to mix with other flocks during grazing. As explained by Kosgey *et al.* (2006) uncontrolled mating together with small flock size would increase the level of inbreeding. On the other hand, practice of mixing flocks would minimize the problem of inbreeding by increasing the chance of mating of unrelated animals (Jaitner *et al*., 2001). The implication of these results is that cooperative village level breeding scheme would be appropriate for Western Lowland goat breeders, while selection within individual flocks could be possible in Abergelle goat given the individual flock grazing practice and the large flock size. There is a significant (X^2, $P<0.05$) difference in buck ownership between the two communities. Only 40% of the respondents of Western Lowland goat keepers had their own buck, however higher proportions of (86.67 %) Abergelle goat keepers had their own buck. The farmers, who had no buck, used bucks from their neighbors and grazing lands. Regardless of the communities, farmers kept bucks mainly for mating and later fattening and slaughter.

Castration of bucks after mating/service was common practice in both study areas. Fattening was the most important reason of castration (77.5% for Western Lowland goat keepers and 82.32% in Abergelle). Castration to control mating and temperament were reported by a few respondents. The average age (2.10± 0.68 years) of castration for Western Lowland goat was significantly ($P<0.001$) lower than that of Abergelle (4.40 ± 1.05 years). Keeping of intact male in the flock for a prolonged period would increase the hazard of inbreeding through increasing the chance of mating of bucks with their daughters. The practice of castration reported in both communities would be good for implementing village level selection through avoiding of mating of unwanted bucks and it would also increase the value of culled bucks.

4.1.5. Reproductive performance

The average reproductive performances of goats as reported by the respondents are given in Table 13. There was a significant ($P<0.001$) difference between the two breeds for all aspects of reproductive performance considered. The better performance of Western Lowland goats may be due to the genetic superiority of the breed and/or better feed situation of the area. Age at first kidding reported in female Western Lowland goat (12.4 months) and Abergelle (15.5 months) goat were comparable to the report of 13.6 months for Metema area (Tsegaye, 2009) and 14.9

months for Abergelle (Deribe, 2008). The kidding interval, 6.29 months for Western Lowland and 8.28 months in Abergelle, observed in this survey was lower than given in earlier reports of 8.4 months for Western Lowland goat (Tsegaye, 2009) and 11.31 months for Abergelle goat (Deribe, 2008).

Table 13. Reproductive performance of goats as reported by respondents in the surveyed area

Trait	Breed								Test
	Western Lowland				Abergelle				
	N	Mean	SD	Range	N	Mean	SD	Range	P value
Age at 1st mating of male (months)	60	7.4	2.01	4-12	60	12.3	4.48	6-24	.0001
Age at 1st kidding (months)	60	12.4	1.39	9-18	59	15.5	5.48	10-18	.0001
Kidding interval (months)	59	6.3	0.64	6-9	57	8.3	3.37	6-24	.0001
Longevity of female goats (Year)	57	6.6	1.47	3-10	59	8.0	2.20	4-15	.0001
Life time number of kids	54	17.3	5.98	6-30	54	12.2	5.98	5-25	.0001

N= Number of respondents SD= Standard deviation

4.1.6. Production constraints

A good understanding of the existing production constraints in the study regions is essential for planning appropriate interventions. In both study areas high prevalence of disease and parasites were mentioned by the goat owners as the most limiting factor for goat production. All respondents complained about the low efficiency of veterinary service provided by the government. Feed shortage and recurrent droughts were also identified as important constraints for Abergelle goat owners. Goat keepers moved their goats to other areas where enough feed was available as a possible mitigation strategy. Feed shortage was mentioned by only a few goat owners of Western Lowland. This is because the area receives good rain and there is a relatively large area of communal grazing land. Predators, input (mostly veterinary service), lack of improved genotypes, labour and capital, theft, lack of market and lacking extension service were also reported as limiting factors of goat production in both study areas. This result is in line with goat production constraints reported for Southern Ethiopia (Tibbo, 2000; Legesse *et al.,* 2008) and Northern Ethiopia (Tsegaye, 2009; Assen and Aklilu, 2012).

4.2. Morphological characteristics

3.2.1. Qualitative characteristics

Qualitative characters observed for female and male goats of the two breeds are presented in Tables 14 and 15. The study revealed that the two breeds have a wide range of coat colors. Most of (54%) Abergelle goats have a plain coat pattern, while most (60%) of Western Lowland goats show a mixture of different colors with patchy and spotted patterns. Red brown, brown and the combination of these colors with other colors are the predominant coat colors observed in Abergelle goat (Figures 2 and 3). White and the combination of white with other colors were the major coat colors of Western Lowland goat (Figure 4 and 5). Irrespective of breeds and sex groups, all observed goats had short and smooth hair. There is a very small number (3.36%) of animals of the Western Lowland goat breed, which have a long and coarse hair type. Wattles were found in Western Lowland goats (24.53%) and Abergelle goats (10.11%). A variation in the existence of ruff was observed between breeds and sex groups. Only 8.0% of males of Abergelle goats have a ruff and 42.28 and 5.11 % of males and females of Western Lowland goats have a ruff, respectively. Almost all males and females of Abergelle goats had horns and around 5% of Western Lowland goats were polled. Most of the qualitative characters of both breeds obtained in this study were in agreement with the results of FARM-Africa (1996).

Table 14. Qualitative characteristics of Abergelle goat

Characters		Male		Female		Total	
		N	%	N	%	N	%
Color	Red brown	33	21.85	92	24.66	125	23.85
	White and brown	26	17.22	56	15.01	82	15.65
	Brown	36	23.84	67	17.96	100	19.66
	Red brown and white	17	11.75	50	13.4	67	12.79
	Brown and white	7	4.64	28	7.51	35	6.68
	Others	32	21.18	92	24.66	124	5.34
Coat pattern	Plain	81	64.8	203	54.42	284	54.2
	Patchy and spotted	70	35.2	170	45.58	240	45.8
Hair type	Short and smooth	151	100	373	100	524	100
Wattle	Present	12	7.95	41	10.99	53	10.11
	Absent	139	92.05	332	89.99	472	89.89
Ruff	Present	42	27.81	-	-	42	8.02
	Absent	109	72.19	373	100	492	91.98

N= Number of goats observed

Table 15. Qualitative characteristics of Western Lowland goat

Characters		Male		Female		Total	
		N	%	N	%	N	%
Color	White	37	30.08	60	17	97	20.38
	Brown and White	20	16.26	67	18.98	87	18.28
	Brown and Red brown	12	9.76	29	8.22	41	8.61
	Red brown and White	17	13.81	77	21.81	94	19.75
	Red black and white	12	9.76	35	9.92	47	9.87
	Others	25	20.32	84	25.63	109	23.1
Coat pattern	Plain	55	44.72	126	35.59	181	37.95
	Patchy and spotted	68	55.29	228	64.4	296	62.05
Hair type	Short and smooth	116	95.08	344	97.18	460	96.64
	Long and course	6	4.92	10	2.82	16	3.36
Wattle	Present	36	29.27	81	22.88	117	24.53
	Absent	87	70.73	273	77.12	360	75.47
Ruff	Present	52	42.28	18	5.11	70	14.74
	Absent	71	57.72	334	94.89	405	85.26

N= Number of goats observed

Figure 2-Adult male of Abergelle goat

Figure 4-Young male of Western Lowland goat

Figure 3-Adult female of Abergelle goat

Figure 5--Adult female of Western Lowland goat

4.2.2. Quantitative characteristics

The male animals were excluded from the model due to only a small number available at older age. However, the sexual dimorphism was observed at lower age group (not shown in the paper). Male goats showed higher values for all measurements than their female counterparts. The least squares means and standard error of body weight, chest girth, body length and height at withers of female Abergelle goats were 24.00±0.19kg, 65.27±0.23cm, 54.8±0.21cm and 62.60±0.22cm, respectively. The corresponding value for Abergelle goats were 18.34±0.22kg, 61.03±0.27cm, 51.00±0.24cm and 58.99±0.25cm, respectively (Table 16).

Breed had significant effect on all body measurements. The Western Lowland goat had the highest values for all measurements. Age strongly influenced ($P<0.001$) body weight and other linear body measurements. Except for age classes 1PPI and 2PPI, there was a significant increase in weight from the lower dentition class to the higher. A similar trend was observed for chest girth, body length and height at withers. This situation is expected since the size and the shape of animals' changes as the age increased.

The interaction effect of breed with age affected body weight ($P<0.01$) and chest girth ($P<0.05$). But, there was no significant ($P>0.05$) age by breed interaction effect on body length and height at withers. Western Lowland goats at dentition group 3PPI and 4PPI were significantly heavier than other categories. Western Lowland and Abergelle goats at older age (3PPI and 3PPI) had highest chest girth compared with other age breed interaction groups. The weight of 32.62 kg for Western Lowland and 25.64 kg for Abergelle goat obtained for mature females were slightly lower than the mature weight of 33.9 kg of Western Lowland and 28.4 kg of Abergelle goat reported by FARM Africa (1996). This deviation could be indication of the decrease of performance through time because of the change in environment and production systems such as drought and shrinkage of grazing land. The average weight at young age of 14.11 kg of Abergelle goat was similar to the report of Deribe and Taye (2013) for the same breed, who reported 13.5kg of weight at yearling age.

Table 16. Least squares means and standard error of body weight, body length and height at withers at different breed and age groups

Level	Body weight(kg)		Chest girth (cm)		Body length(cm)		Height at Wither (CM)		
	LSM	SE	LSM	SE	LSM	SE	LSM	SE	N
Breed	***		***		***		***		
WL	24.00	0.19	65.27	0.23	54.80	0.21	62.60	0.22	340
Abergelle	18.34	0.22	61.03	0.27	51.00	0.24	58.99	0.25	368
Dentition	***		***		***		***		
kids	10.35^{a}	0.42	48.84^{a}	0.51	41.26^{a}	0.46	49.50^{a}	0.49	95
young	17.08^{b}	0.28	58.98^{b}	0.33	49.55^{b}	0.30	58.27^{b}	0.32	157
1PPI	21.91^{c}	0.41	64.62^{c}	0.50	54.36^{c}	0.45	62.43^{c}	0.47	66
2PPI	23.07^{c}	0.41	66.36^{c}	0.49	55.28^{c}	0.44	63.42^{cd}	0.47	72
3PPI	25.50^{d}	0.38	68.92^{d}	0.45	57.49^{d}	0.41	65.12^{de}	0.43	79
4PPI	29.13^{e}	0.22	71.19^{e}	0.26	59.44^{e}	0.24	66.02^{e}	0.25	239
Age*Breed	**		*		NS		NS		
Kid*WL	12.25^{b}	0.38	50.64^{b}	0.45	43.00	0.41	50.95	0.43	76
Kid*Abergelle	8.46^{a}	0.76	47.05^{a}	0.91	39.52	0.82	48.05	0-87	19
Young*WL	20.04^{d}	0.45	62.13^{d}	0.55	51.85	0.50	60.22	0.53	52
Young*Abergelle	14.11^{c}	0.32	55.82^{c}	0.39	47.24	0.35	56.32	0.37	105
1PPI*WL	24.73^{fg}	0.63	66.36^{e}	0.77	56.37	0.69	64.59	0.73	27
1PPI*Abergelle	19.10^{d}	0.53	62.89^{d}	0.64	52.35	0.57	60.28	0.61	39
2PPI*WL	25.38^{g}	0.48	68.12^{f}	0.58	56.81	0.52	65.06	0.55	47
2PPI*Abergelle	20.76^{de}	0.66	64.60^{de}	0.80	53.76	0.72	61.78	0.76	25
3PPI*WL	29.01^{h}	0.48	71.35^{gh}	0.58	59.58	0.52	66.89	0.55	47
3PPI*Abergelle	21.99^{ef}	0.58	66.50^{ef}	0.70	55.40	0.63	63.35	0.67	32
4PPI*WL	32.62i	0.34	73.02^{h}	0.41	61.18	0.37	67.88	0.40	91
4PPI*Abergelle	25.64^{g}	0.27	69.35^{fg}	0.32	57.70	0.29	64.16	0.31	148

Column means within each sub-class with different superscript letter are statistically differ. NS=Non significant, *=P≤0.05, **=P≤0.01, ***≤0.001 PPI=Pair of permanent incisors. SE=Standard error WL=Western Lowland

There was a significantly higher within breed variation of body weight of Western Lowland goats compared to the Abergelle goats in natural scale for most of age categories. However there was no significant difference for many of the age categories except for age group 3PPI after transformation to the log scale (Table 17). The relatively higher variation observed in Western

Lowland goat could be a larger scope for genetic improvement of Western Lowland goats through selection compared to the Abergelle goats.

Table 17. Variability of the body weight at different age groups

Age classes	WL		Abergelle		P Value	WL	Abergelle	P Value
	N	SD	N	SD		CV	CV	
Kid	76	2.61	19	1.55	0.0198	0.21	0.18	0.2642
Young	52	3.20	106	2.59	0.0748	0.16	0.18	0.7201
1PPI	27	3.10	39	2.09	0.0342	0.12	0.10	0.3807
2PPI	47	3.63	25	3.05	0.3198	0.18	0.14	0.8935
3PPI	47	4.73	32	2.45	0.0028	0.16	0.11	0.0383
4PPI	94	4.61	148	3.12	<0.0001	0.14	0.12	0.1127

WL=Western Lowland goat; N=Number of animals; SD=Standard deviation CV=Coefficient of variation

4.3. Molecular diversity

4. 3. 1. SNP polymorphism and genetic diversity within breeds

The proportion of polymorphic loci, number of loci deviate from HWE and genetic variability (i.e observed and expected heterozygosities) are presented in Table 18. All populations showed high levels of polymorphism. The level of SNP polymorphism found in this study is in agreement with the previous report for four goat populations based on 50k SNP analysis (Kijas *et al*., 2012). However, Kijas *et al*. (2009) reported lower levels of polymorphism for ovine breeds. Similarly Edea *et al*. (2013) found less than 86 % level of polymorphism for Ethiopian cattle population based on the analysis of 8K SNPs. The higher level polymorphic SNPs found for goat population than other livestock species could be explained that goats have higher diversity than others (Kijas *et al*., 2012). Alternatively, different choices for the selection of SNPs during quality control might strongly impact these results.

Table 18. Proportion of polymorphic SNPs, observed heterozygosity(Ho), expected heterozygosity (He), population level loss of heterozygosity (F_{IS}) of five goats population

Breed	N	% of polymorphic loci	Ho	He	F_{IS}
Abergelle	53	97.5	0.379±0.137	0.382±0.127	0.0046
Western Lowland	41	98.5	0.384±0.138	0.387±0.123	0.0052
Red Sokoto	22	97.8	0.375±0.151	0.389±0.125	0.0302
West African Dwarf	23	95.7	0.355±0.160	0.367±0.139	0.0300
Sahel	22	98.3	0.387±0.151	0.392±0.123	0.0098

In all studied populations, the average expected heterozygosity values were slightly higher than the observed heterozygosity. The average heterozygosity observed was 0.379, 0.384, 0.375, 0.355 and 0.378 for Abergelle, Western Lowland, Red Sokoto, West African Dwarf and Shale, respectively. Shale, the Nigerian goat and Western Lowland the Ethiopian goats showed higher diversity with the highest observed (0.387 and 0.384) and expected (0.392 and 0.384) heterozygosity levels, respectively. The lowest genetic diversity (Ho= 0.355 and He=0.300) was observed in West African Dwarf goat population. Differently from the present findings, higher hetrozygosity values were reported in various molecular diversity studies of goat population in tropics and elsewhere based on microsatellite markers (*Hassen et al*, 2012; Missohou *et al*., 2011; Agha *et al*., 2008; Fatima *et al*., 2008; Li *et al*., 2008). This variation is due to the difference in the nature of the markers used. Microsatellite markers have much higher numbers of alleles than SNPs. However, the heterozygosities values found in this study are comparable with what found in SNPs based studies on Asian native goat by Lin *et al*. (2013), on four goat populations by Kijas *et al*. (2012) and on sixteen European goat breeds by Pariset *et al*. (2009).

The majority of the SNP markers were at Hardy Weinberg Equilibrium. A 3.2, 3.3, 3.6, 3.0 and 3.4 percent of SNPs markers in Abergelle, Western Lowland, Red Sokoto, Sahel and West African Dwarf goats were found significantly ($P \leq 0.05$) deviated from HWE, respectively. The measure of loss of heterozygosities (F_{IS}) value revealed that low inbreeding coefficients within population. Ethiopian goats had lower inbreeding coefficients (Abergelle=0.0046, Western Lowland=0.0052) than the three Nigerian goat populations. The inbreeding coefficient (F_{IS}) value observed in Ethiopian goat populations in this study was lower than that reported for Ethiopian goats in study using microsatellite markers (*Hassen et al*., 2012). This deviation could be because of the difference in markers and sampling frame. However, the F_{IS} values obtained for Nigerian goat are in the range of previously reported values for goats in the same region (Traore *et al*., 2009; Missohou *et al*., 2011).

4.3. 2. Breed differentiation

The analysis of molecular variance (AMOVA) revealed as a low but significant ($p<0.05$) overall F_{ST} 0.063. That is, a high proportion of the variation (93.7 %) is derived from within population and only 6.3 % variation comes from across populations. The overall within population inbreeding coefficient (F_{IS}=0.012) was found insignificant ($P>0.05$) while significant ($P<0.001$) global level loss of heterozygosity (F_{IT}=0.075) was found.

Table 19. Pair-wise genetic differentiation (FST) values between the five African goat (below diagonal) and Reynolds' genetic distance (above the diagonal)

Population	Abergelle	Western Lowland	Red Sokoto	West African Dwarf	Sahel
Abergelle	-	0.017	0.083	0.131	0.066
Western Lowland	0.018	-	0.071	0.118	0.058
Red Sokoto	0.079	0.068	-	0.035	0.007
West African Dwarf	0.123	0.112	0.035	-	0.049
Sahel	0.067	0.056	0.001	0.048	-

Tables 19 show the pair-wise genetic differentiation (F_{ST}) and Reynolds' distance between the five goat breeds. As expected, the pair-wise genetic differentiation (F_{ST}) values were very low within Ethiopian goats and Nigerian goats. The highest F_{ST} values of 0.123 and 0.112 were observe between West African Dwarf and Abergelle and between West African Dwarf and Western Lowland goats, respectively, whereas the lowest values were obtained between Saheland Red Sokoto (0.001) and between Abergelle and Western Lowland (0.018) goats. Similar F_{ST} values with the range of 0.025 to 0.098 in five Nigerian goats were reported by Missohou *et al*. (2011), 0.024 to 0.09 in Burkina Faso goats by Traore *et al*. (2009) and the overall F_{ST} value of 0.05 was also reported for five goat breeds in northern Ethiopia (*Hassen et al*., 2012). The small differentiation between the breeds within the same region might be explained by less selective breeding, uncontrolled matting and transfer of genetic material due to animal movement.

4.3.3. Population structure and clustering

The Neighbor-joining dendogram (Figure 6) cluster analysis based on Reynolds' standard genetic distance was consistent with the geographical location of the breeds. Two clear clusters were observed: The first cluster consisted the two Ethiopian goats breed (Abergelle and Western Lowland) and the second group consisted the three Nigerian goats (West African Dwarf, Red Sokoto and Sahel). Furthermore, the Red Sokoto goats were more close to Sahel goats. According to DAGRIS (2007) Red Sokoto and Sahel goats are grouped under the some breed groups of short-eared twisted and subgroup of West African twisted horn.

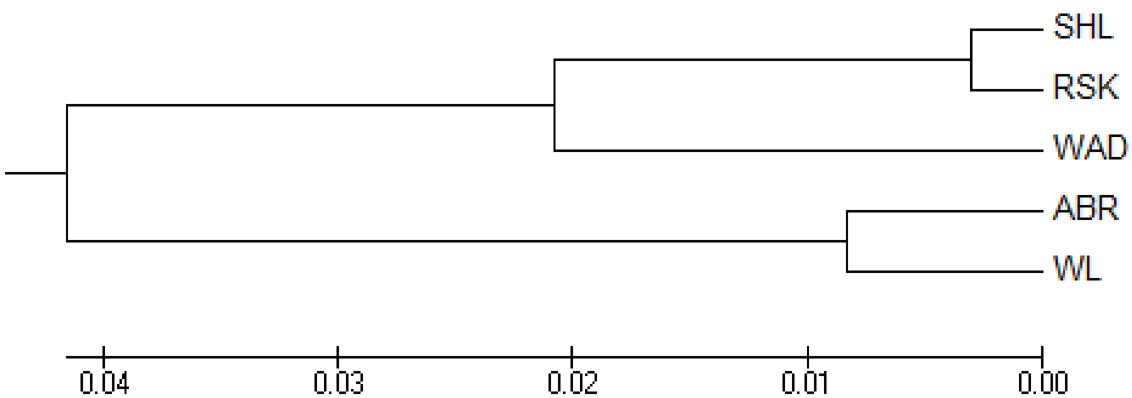

Figure 6-UPGMA neighbor-joining tree based on Reynolds' distance of 5 African goat breeds

The principal component analysis was performed based on allele frequencies to see the population cluster of the five goat population (Figure 7). Except for a few outliers, the membership of each cluster coincided with their geographical origin. The first axis explains 11% of the total variation and separated the Nigerian goat population from Ethiopian goat population. The second axis contributed 2.2% of total variation. It separated the goat populations within the same geographical location.

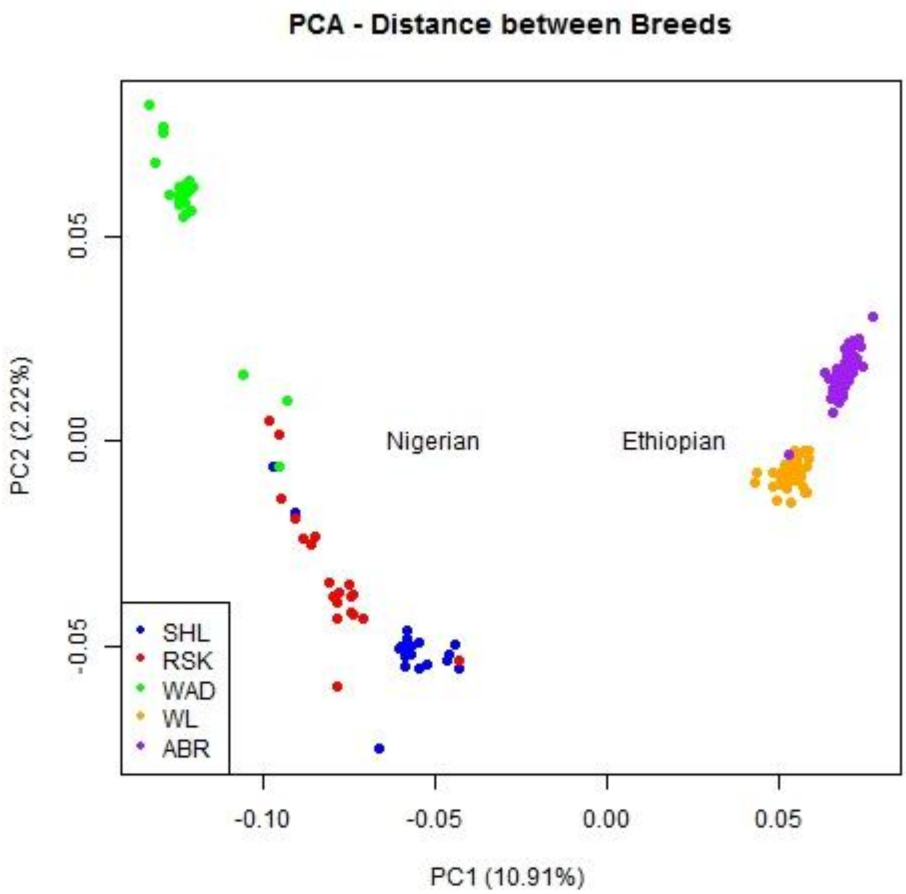

Figure 7-Principal component analysis of five African goat populations

Figure 8 shows the graphical representation of genetic structure analyzed by STRUCTURE software. Four independent runs for the given K (K=2-5) were done to determine the optimum K–value. The most likely number of clusters was 3. In K=3 across runs, the average ln p(X/K) was maximum and the mean variance in lnp(X/K) was minimum. The Ethiopian goats, Abergelle and Western Lowland, weren not differentiated from each other. Except for a few admixture levels in Western Lowland goat, they clustered together as one group. The Nigerian goats tended to be clustered into two groups. That is, West African Dwarf goats as one separate cluster and admix population of Red Sokoto and Sahel goat as another group. The proportion membership of each predefined population in each of the 3 most likely inferred clusters is shown in Table 20. 99 % and 88 % of the two Ethiopian goat populations Abergelle and Western Lowland were included in the same cluster, respectively. The West African Dwarf goat was grouped in its own cluster with an estimated membership of 80%. The Red Sokoto and Sahel goats were grouped in the same cluster but with the high level of admixture; 67 % and 70

% of estimated membership, respectively. In general, the cluster analysis result from PCA, Neighborhood joined tree and STRUCTURE program reveled that the studied goat population were less differentiated according to their type and morphological classification. They were more differentiated based on their geographical location. This finding is supported by previous studies report (Chenyambuga et al., 2004; Missohu et al., 2006).

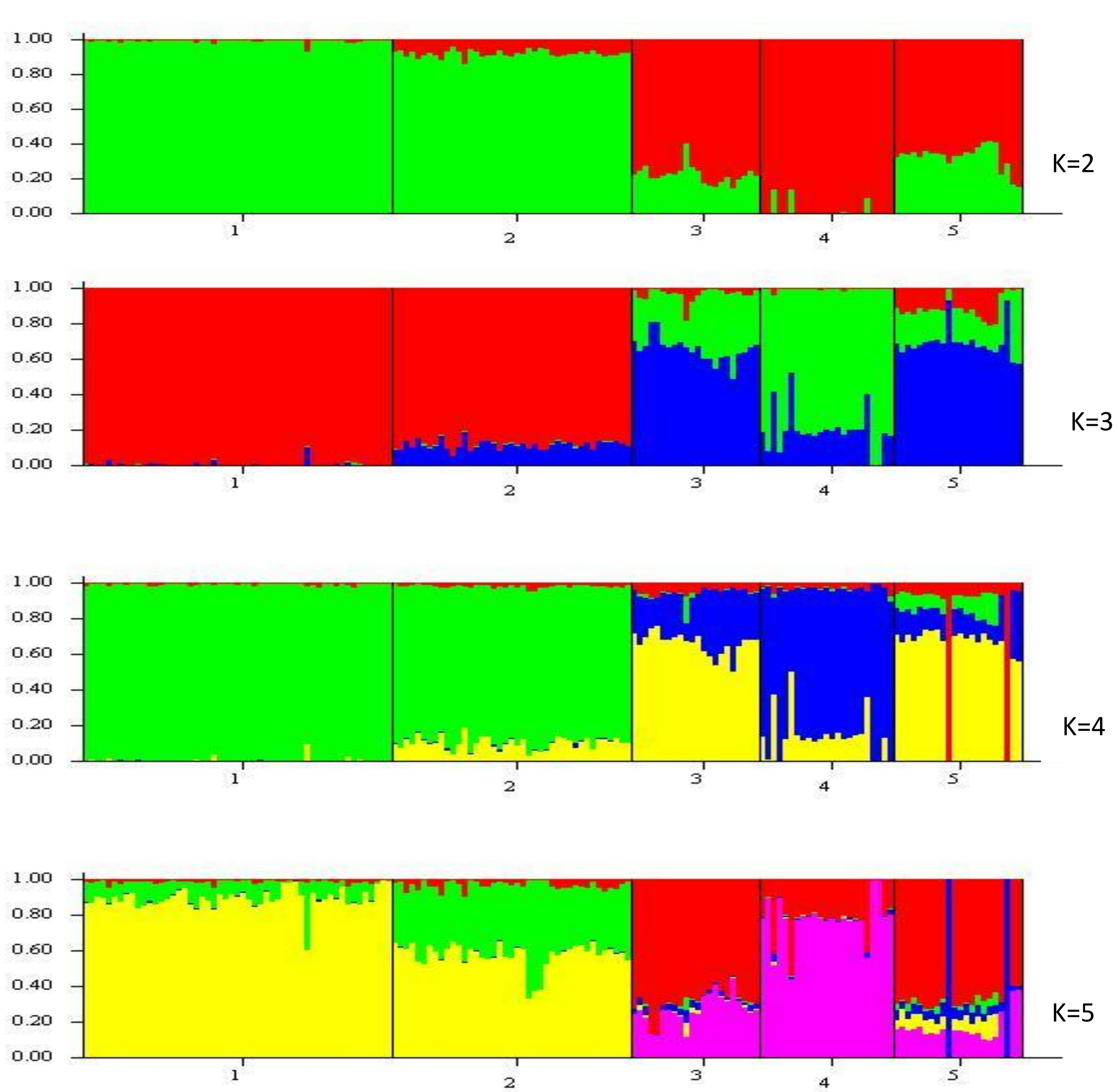

Figure 8-Population partitioning suggested by STRUCTURE program

Each individual animal is represented by a single vertical line divided into K color, where K is the number of clusters assumed and length of the colored segments the individual's ancestry proportion of membership to a particular cluster estimate. Breed groups which are separated by vertical black line (1=Abergelle: 2=Western Lowland: 3=RSK: 4=WAD: 5=SHL)

Table 20. Proportion of analyzed goat populations in each of the three clusters (K=3)

	Inferred cluster		
Population	1	2	3
Abergelle	0.005	0.989	0.007
Western Lowland	0.012	0.876	0.112
Red Sokoto	0.312	0.023	0.665
West African Dwarf	0.800	0.003	0.197
Sahel	0.197	0.099	0.704

4.3.4. Runs of homozygosity (ROH)

A ROH is a long continuous homozygote segment at diploid state. Detecting autozygous segments is the most common tool for association study of disease in human genomics. And it is also useful in farm animals to calculate the inbreeding coefficients at different ancestral population especially when pedigree information is lacking (Ferencakovic *et al*., 2013a). Moderat to high correlations were reported between pedigree inbreeding coefficients and genomic inbreeding in different studies of cattle populations (Ferencakovic *et al*., 2011; Ferencakovic *et al*., 2013a). ROH at different length categories (>1MB, >2MB, >4MB, >6MB, >8MB, >10MB and >16MB) were analysed for all breeds to detect autozygous segments over the whole genome. The proportions of animals with ROHs at a given length are given in Figure 9. At ROH length >1MB all animals in all five population showed ROHs segments. As the ROH run length increased, the proportion of animals with ROH segments substantially decreased. For instance, at run length of >16 MB the proportion of animals with ROHs for Abergelle, Western Lowland, Red Sokoto, Sahel and West African Dwarf were 9.4%, 7.3%, 31.8%, 30.4% and 9.1 %, respectively. The descriptive statistics of the number of ROH segments >1MB and total length of ROH of the five goat populations are presented in Table 21 and the relationship between number ROH segments and total ROH length of individual animals is depicted in Figure 10 . At the ROH >1Mb West African Dwarf goats had the highest average number of segments (42.48±42.48) and it also cover the longest ROH segments as well (120.17MB) while Shale goat had the lowest number of ROH segments (20.5±10.01) and the shortest ROH length (61.68 MB).

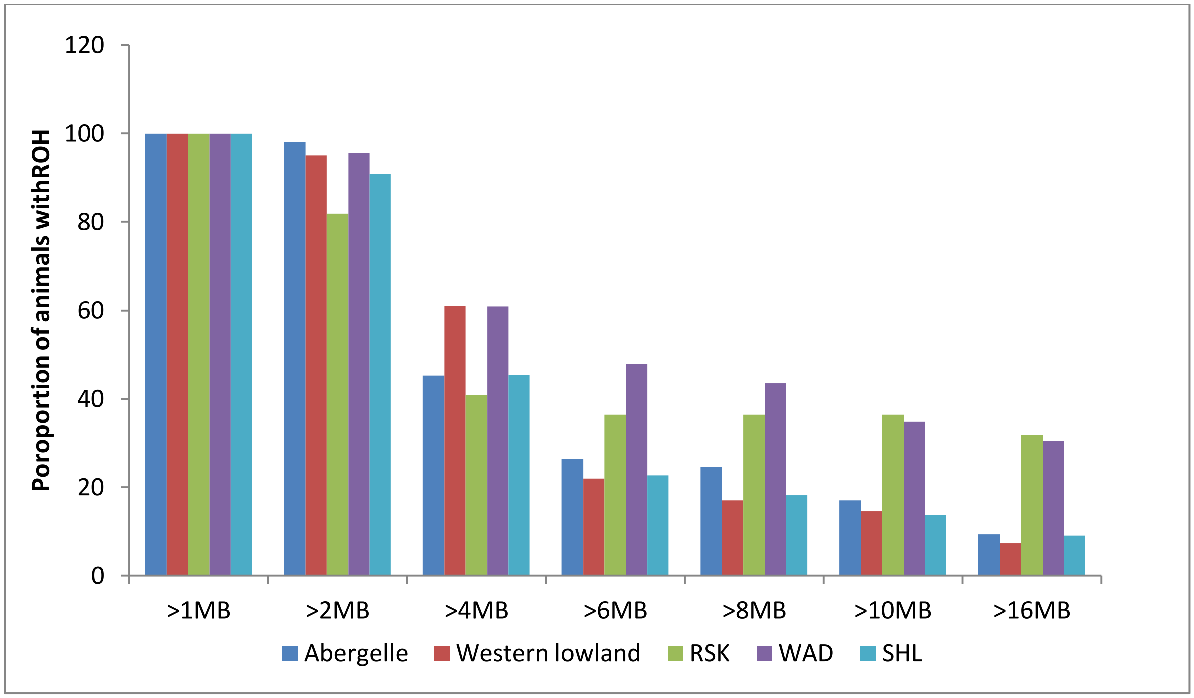

Figure 9-Proportion of the number of animals with ROH segments at different runs

Figure 11 described the average length of ROH at different length categories. All population had the highest value at the categories 1-2MB and >16MB. The West African Dwarf goat population had the highest average length of ROH at the length categories of 1-2MB and >16MB with the value greater than 45 MB. Red Sokoto (RSK) had the highest value of average length of ROH (55MB) at category length >16MB. The highest value of average total length of ROH for Red Sokoto and West African Dwarf goats at category length >16 MB were associated with the presence of a few outliers highly inbreed animals.

The genomic inbreeding coefficients of individual animals at different run lengths were calculated as the ratio of total ROH segments of individual animals to the total genome length. The average genomic inbreeding coefficients were very low for all breeds at all run lengths, ranging from 0.6 % to 5% (Table 22). For all breeds, as the length of run increased the genomic inbreeding decreased. The F_{ROH} at 8 MB and 10 MB for all studied population were very close to the values of loss of heterozygosity (F_{IS}) obtained from F statistics analysis. According to Ferencakovic *et al*. (2013b) the F_{ROH} estimate in the runs less than 4MB from low density SNPs (50K) are not very accurate because of capturing short segments that are not truly homozygous when analyzed at higher SNP density.

Table 21. Descriptive statistics of number of ROH segments and total length of ROH of the studied goat population

Breed		Number of ROH	Total length of ROH
Abergelle	Mean	33.24	69.11
	Median	32	46.3
	SD	8.39	89.15
	Range	18-61	25.93-611.57
Western Lowland	Mean	29.35	63.86
	Median	28.0	44.57
	SD	7.701	78.98
	Range	15-55	21.45-501.64
Red Sokoto	Mean	28.49	115.02
	Median	28	35.30
	SD	13.33	189.17
	Range	14-65	17.106-817.58
West African Dwarf	Mean	42.48	120.17
	Median	45	79.79
	SD	42.48	148.66
	Range	12-54	15.39-733.16
Sahel	Mean	21.86	61.68
	Median	20.5	29.84
	SD	10.01	122.69
	Range	12-60	17.05-598.31

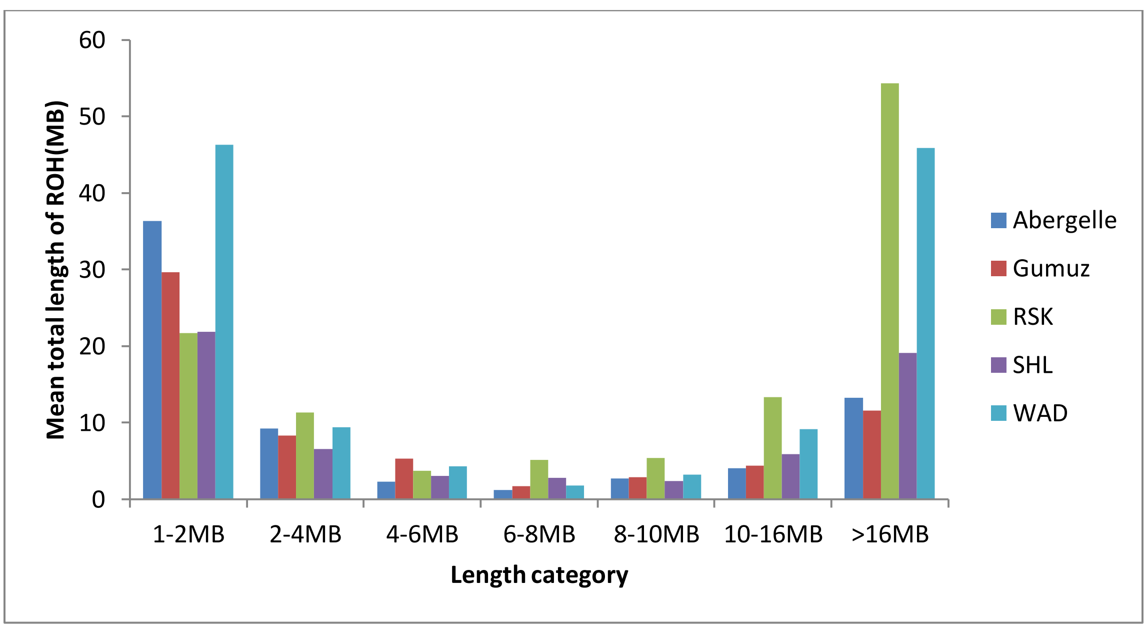

Figure 10-The average total length of ROH at different length of categories

Among the studied breeds the Nigerian goats WAD and RSK had relatively highest genomic inbreeding coefficient compared to other breeds at all runs lengths. The small number of ROH segments and low F_{ROH} at long runs found in this study indicated that the populations had no the recent inbreeding problems. Even though the F_{ROH} estimates at shortest runs are less reliable, all studied populations had relatively higher ancestral generation inbreeding coefficients than recent generation inbreeding. The ROH length found in this study is much lower than what was reported for different cattle breeds. (Ferencakovic *et al*., 2013a; Ferencakovic *et al*., 2011; Purfield *et al*., 2012). This could be because of the differences in the procedure of data collection and the species and population differences. In the present study, the samples were purposely collected from distantly related animals to avoid biased results in genetic diversity study.

Table 22. Genomic inbreeding coefficients of five goat population at different runs length

Breed	F_{ROH1}	F_{ROH2}	F_{ROH4}	F_{ROH6}	F_{ROH8}	F_{ROH10}	F_{ROH16}
Abergelle	0.0288	0.0136	0.0098	0.0088	0.0083	0.0072	0.0055
Western Lowland	0.0266	0.0142	0.0108	0.0085	0.0078	0.0067	0.0048
Red Sokoto	0.0479	0.0388	0.0341	0.0326	0.0304	0.0282	0.0226
West African Dwarf	0.0500	0.0307	0.0268	0.0250	0.0242	0.0229	0.0191
Sahel	0.0257	0.0166	0.0138	0.0126	0.0114	0.0104	0.0080

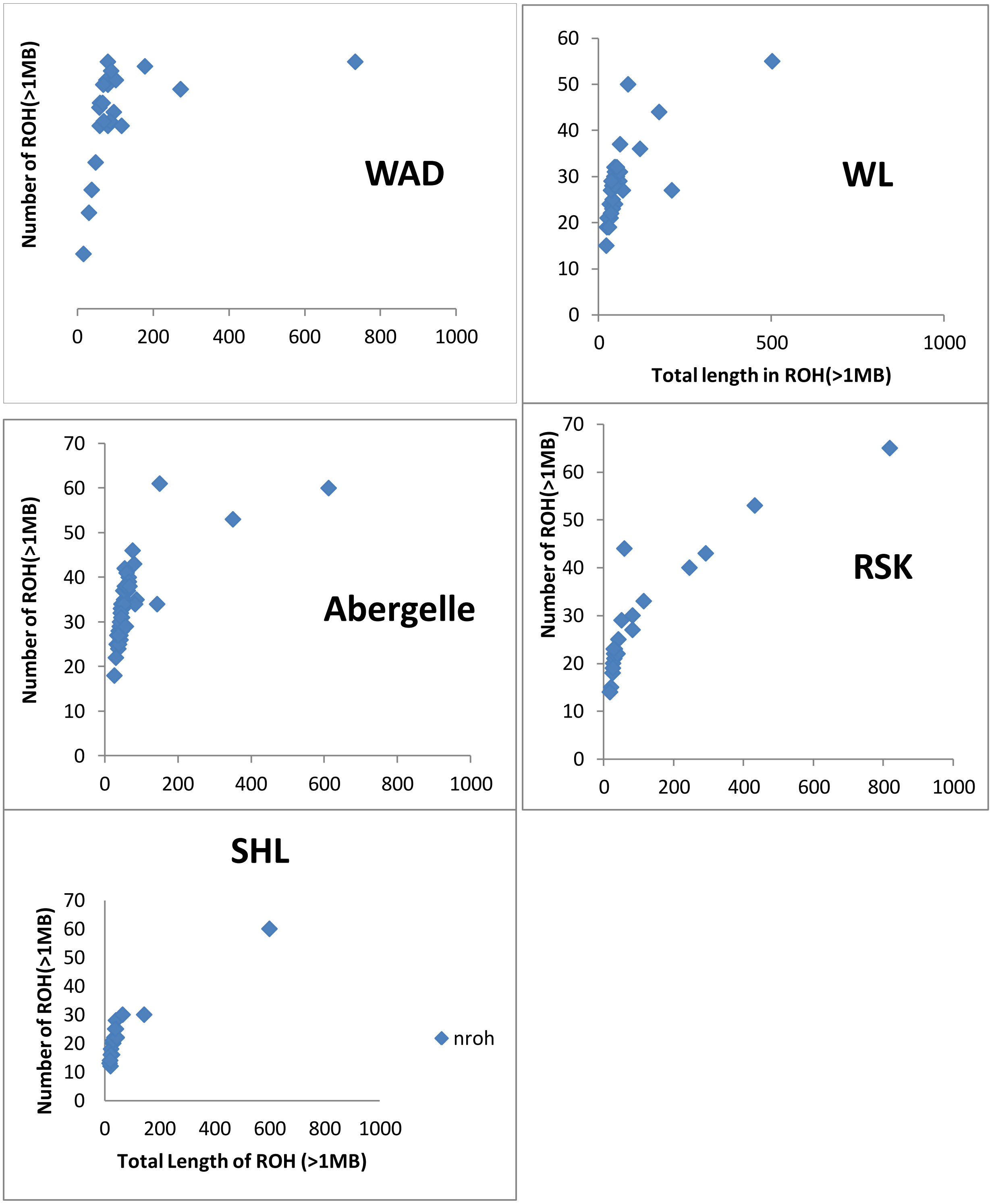

Figure 11-The relationship of number of ROH segments to the total length in ROH of individual animals

4.4. Participatory identification of breeding objectives traits

4.4. 1. Does traits in own-flock ranking experiments

The list of preferred does traits by farmers from own flock ranking experiments are described in Table 23. Various traits were mentioned by the farmers as preferred traits of breeding does. The diverse traits as the selection criteria for breeding female animals for tropical countries are also well documented in many research reports (Jaitner *et al*., 2001; Bett et al., 2009; Alexandre *et al*., 2009; Duguma *et al*., 2011; Mirkena, 2011; Berhanu *et al*., 2012; Gebreyesus *et al*., 2013). The traits of preference by the farmers reflect the multi-functional role of goat. Milk yield, drought resistance, body size, kid growth and twinning rate were frequently mentioned as the preferred traits of breeding does by Abergelle goat owners. Twinning rate (multiple birth), kids growth, body size, mothering ability and kidding interval were reported as important traits of preferences for breeding does by Western Lowland goat owners.

Table 23. List of traits of does from own flock ranking methods

Traits	Abergelle		Western Lowland	
	Freq	%	Freq	%
Milk yield	26	20.47	-	-
Body size	18	14.17	35	15.42
Drought resistance	19	14.96	-	-
Kid growth	15	11.81	42	18.50
Twining	13	10.24	46	20.26
Sex of kid	1	0.79	1	0.44
Kidding interval	12	9.45	32	14.10
Mothering ability	10	7.87	35	15.42
Weight of kid at birth	8	6.30	7	3.08
Temperament	2	1.57	-	-
Beauty	3	2.36	2	0.80
Body length	-	-	8	3.52
Color	-	-	3	1.32
Ear length	-	-	5	2.20
Tail shape	-	-	1	0.44
Tail length	-	-	6	2.64
Udder size			4	1.76

Although there was similarity of the trait preference between the two systems, there was a big difference in preferences for some traits. For instance, Milk yield (20.47 %) and drought resistance (14.96 %) were mentioned as important traits by Abergelle goat owners but these traits were not mentioned at all by Western Lowland goat keepers. This result clearly associated with the breeding objectives and the agro ecology of the study area where milk from goat is an important human food and where moisture stress is prevalent and feed is scarce for most parts of the year. Similar finding for goats and sheep in comparable environment have been reported (Duguma *et al*., 2011; Mirkena, 2011; Gebreyesus et al., 2013).

The preference of big body size and fast kid growth as the preferred attributes in both study areas are expected when the main purpose of keeping goat is for cash source. The animals with big size are highly demanded in market and fetch good local market prices. Higher preference values of body size for breeding animals were reported by similar studies in Ethiopia and elsewhere in the tropics (Berhanu *et al*., 2012; Mbuku *et al*., 2006; Kebede *et al*., 2012b; Duguma *et al*., 2011; Jaitner *et al*., 2001). Relatively higher twinning rate (20.26 %) as the preferred traits for Western low land goat might be the availability of enough feed throughout the year that support many animals compared with the dry highland of Abergelle area.

Since the western Lowland goat breeder do not use goat milk, in this area does with high milk are considered as good mothers for their kids. Thus mothering ability (like; nursing behavior and good attachment with their offspring) has relatively higher proportion (15.42%) as ranking criteria for Western Lowland goat than for Abergelle goat owners. Reproductive performance such as kidding interval was also mentioned as important traits 9.45 % and 14.10% for Abergelle and Western Lowland, respectively. Shorter kidding interval will increase flock productivity by providing many animals for marketing and replacement. It would be also helpful for genetic improvement program by increasing selection intensity. However, the improvement of kidding interval through selection may be slow because of the low heritability of the trait and very seasonal kidding, particularly in the Abergelle area.

Table 24 describes mean ± SE values for some reproduction and production traits and age of the ranked does. Age of the does, doe weight, number of kidding, number of kids born, number of kids weaned and twinning rate significantly ($P<0.001$) influenced the ranking decision of the farmers in both study areas. Milk yield also significantly ($P<0.001$) influenced the ranking decision of Abergelle goat owners. This result revealed that the farmers' decisions for ranking of breeding does were highly correlated with the performance of the given animals. In both areas, there was a logical trend in the mean values of the traits between 1st best, 2nd best, 3rd best and inferior does. For instance in Abergelle goats, the magnitude difference between the 1st best and inferior does in live weight, number of kids weaned and milk yield were 6.76kg, 5.10, and 0.42l /day, respectively. In Western Lowland goats, the differences between the two groups were 9.14 kg of live weight, 8.17 numbers of kids weaned; and 0.31 litter sizes. Appreciations and using of farmers knowledge for selecting the best animals is possible option to start the breeding program where performance recording totally lacking.

Table 24. Means ± SE of body weight and traits from the life history of the ranked animals

Breed	Traits	p	Rank			
			1	2	3	Inferior
Western Lowland	Age	***	5.47±0.19[a]	3.88±0.18[b]	2.90±0.18[c]	2.61±0.18[c]
	BW	***	34.04±0.65[a]	31.02±0.64[b]	27.17±0.64[c]	24.90±0.64[c]
	NK	***	5.83±0.22[a]	3.73±0.22[b]	2.78±0.22[c]	2.18±0.22[c]
	NKB	***	10.71±0.43[a]	6.15±0.43[b]	4.06±0.44[c]	2.81±0.43[c]
	NKW	***	9.78±0.41[a]	5.16±0.41[b]	3.13±0.41[c]	1.61±0.41[d]
	Twinning	***	1.83±0.04[a]	1.61±0.04[b]	1.37±0.05[c]	1.19±0.04[c]
Abergelle	Age	***	6.33±0.29[a]	4.93±0.29[cb]	5.89±0.30[ab]	4.73±0.29[c]
	BW	***	32.26±0.59[a]	30.14±.59[b]	30.40±0.61[b]	25.50±0.61[b]
	NK	***	5.36±0.25[a]	3.76±0.25[cb]	4.41±0.26[b]	3.06±0.25[c]
	NKB	***	6.76±0.39[a]	4.33±0.39[b]	4.58±0.40[b]	3.10±0.39[c]
	NKW	***	6.40±0.36[a]	3.90±0.36[b]	3.96±0.37[b]	1.30±0.36[c]
	Twinning	***	1.24±0.04[a]	1.14±0.04[a]	1.03±0.04[b]	0.96±0.04[b]
	Milk yield	***	0.58±0.03[a]	0.48±0.03[ba]	0.40±0.03[b]	0.16±0.03[c]

BW=Body weight; NK=Number of kidding; NKB=Number of kids born; the means in the same row with different superscripts are significantly different from each other

4.4.2. Doe traits identified in group-animal ranking experiments

Table 25 describes the list of preferred traits of breeding does in the group ranking experiment. The most important traits identified in Western Lowland goats were body size, body conformation, coat color, twinning and udder size, which were accounted 21.71%, 15.43, 10.86% and 6.86%, respectively. The farmers in Abergelle mentioned body conformation (19.31 %), color (17.24%), mothering ability (17.24 %) and body size (13.79 %) as the most important preferred traits of the breeding does.

Table 25. List of does traits in group ranking experiment

	WL		Abergelle	
Traits	Freq.	%	Freq	%
Body conformation	27	15.43	28	19.31
Body length	9	5.14	11	7.59
Body size	38	21.71	20	13.79
Color	22	12.57	25	17.24
Beauty	2	1.14	2	1.38
Height	8	4.57	12	8.28
Ear length	3	1.71	-	-
Horn shape	-	-	5	3.45
Horn length	2	1.14	2	1.38
Tail shape	1	0.57	-	-
Tail length	7	4	1	0.69
Mothering ability	6	3.43	25	17.24
Milk yield	-	-	13	8.97
Kidding interval	7	4	1	.69
Twinning	19	10.86	-	-
Udder size	12	6.86	-	-
Age	9	5.14	-	-

WL=Western Lowland goat

4.4.3. Buck traits identified in group ranking experiment

Table 26 shows the list of traits mentioned by farmers for ranking of breeding bucks and does in group ranking experiment of Western Lowland goats. The important attributes listed in group ranking of bucks for Western Lowland goat owners were coat color, body size, body conformation and height with the magnitude of 23.86%, 21.02%, 10.23% and 9.09%, respectively. Similarly coat color (31.88%), body conformation (17.39 %) and body size (14.29%) were mentioned as important traits for ranking of bucks in Abergelle area. In both site, coat color has got higher value for buck selection than for does. This is in agreement with previous breeding objective traits identification studies where color and beauty related traits were considered as important traits of preference for male breeding animals than female animals (Wurzinger *et al.*, 2006; Duguma; 2011; Kassie *et al.*, 2009; Berhanu *et al.*, 2012).

Table 26. List of bucks traits in group ranking experiment

	WL		Abergelle	
Traits	Freq.	%	Freq	%
Body conformation	24	17.39	18	10.23
Body length	16	11.59	2	1.14
Body size	19	14.29	37	21.02
Color	43	31.88	42	23.86
Activeness	5	3.62	4	2.27
Ear length	-	-	4	2.27
Fast growth	2	1.45	14	7.95
Horn shape	2	1.45	-	-
Horn length	7	5.07	5	2.84
Height	11	8.62	16	9.09
Leg length	4	2.90	4	2.27
Beauty	-	-	8	4.55
Libido	-	-	1	0.57
Tail shape	-	-	4	2.27
Tail length	-	-	11	6.25
Temperament	-	-	1	0.57

WL=Western Lowland goat

4.4.4. Comparisons objective traits ranking before and after the provision of life history

Table 27 summarizes the proportion of rank altered after the provision of the life history of the ranked animals. Lower rank alterations were observed in male animals. In Western Lowland goat: 91.66%, 91.66% and 90% bucks were kept their rank as 1st, 2nd and 3rd, respectively. The corresponding proportion in Abergelle bucks were 98%, 90% and 98%. More substantial rank changes based on life history information were observed in female animals. In Western Lowland does, 16.66% and 6.66% change their ranks from 1st to 2nd and 1st to 3rd, respectively. The corresponding values in Abergelle goats were 10 % and 40%. The probable reason for this is that apart from physical observation (body size, color and body conformation) farmers tend to select female animals based on their reproductive performance and mothering ability. This revealed that the attached performance of individual animals highly influenced rank alteration breeding does compared to breeding bucks. Similar finding were reported in identification of breeding objective traits studies through phenotypic group ranking methods for sheep breeds in Ethiopia (Mirkena, 2011) and for Ankole cattle in Uganda (Ndumu *et al*., 2008).

Table 27. Rank proportion before and after provision of additional information in group ranking

Breed	Rank[1]	Rank[2] Buck			Rank[2] Does		
		1	2	3	1	2	3
Western lowlan	1	**55(91.66%)**	2(3.33%)	3(5%)	**46(76.66%)**	10(16.66%)	4(6.66%)
	2	1(1.6%)	**55(91.66%)**	4(6.6%)	0(0)	**46(76.66%)**	14(23.33%)
	3	3(5%)	3(5%)	**54(90%)**	4(6.6%)	11(18.33%)	**45(75%)**
Abergelle	1	**49(98%)**	1(2%)	0(0%)	**25(50%)**	5(10%)	20(40%)
	2	5(10%)	**45(90%)**	0(%)	14(28%)	**33(66%)**	3(6%)
	3	1(2%)	0(0%)	**49(98%)**	13(26%)	12(24%)	**25(50%)**

[1]= Rank before additional information given [2]=Rank after provision of additional information

In general, in group ranking experiment farmers tend to select the animal based on physical appearance such as color, size and conformation and they overlook the other performance whereas in own flock ranking farmer give more emphasis on performance of the animals such as reproductive performance, mothering ability and milk yield. For tropical small ruminant production systems, identification of the traits related with both subjective and objective criteria are equally important to establish sustainable breeding programs. Thus it could be advisable to use both methods for identification of breeding objectives traits in similar production systems.

4.5. Optimization of alternative breeding programs

4.5.1. Breeding objectives and selection criteria

The primary step in the evaluation of the efficiency of alternative breeding systems is definition of the breeding objective. As the breeding program would be implemented at community level, for each breed, only three traits with high preference by farmers and easy to measure were considered. A breeding goal with many traits and traits with no reliable data for heritability and phenotypic and genetic correlation seems unrealistic to implement at community based selection schemes (Wurzinger *et al*., 2008). In this study, the breeding objectives were derived from the preferred traits by the community from the production system study, own flock ranking and group ranking experiments (Table 28). Some of the traits such as drought resistance, kidding interval and color which had higher preference by farmers were intentionally excluded to avoid the complexity during implementation. The identified breeding objective traits from those studies were scaled to hundred percent (unity) and weighted for the ranking. The breeding objectives identified for Abergelle goat owners were: Body size, milk yield and mothering ability (kids survival), while the breeding objectives for Western Lowland goat owners were body size, twinning rate and mothering ability (kids survival). Two selection indexes, one for each breed were constructed. Index 1, to reflect the breeding objective of Abergelle goat breeders, included six months weight (for body size), daily milk yield (for milk yield) and proportion of kids weaned (for kid survival). Index 2 to reflect the breeding objective of western Lowland goat six months weight, number of kid born per does per year and proportion of kids weaned per does per year.

Table 28. List of traits for breeding does from own flock ranking, group ranking and production system study

Traits	Abergelle				Western Lowland			
	OWFR	PS	GR	WR	OWFR	PS	GR	WR
Milk yield	20.47 (2)	.317(1)	8.97(3)	1.5 (2)	-			
Body size	32.28 (1)	.283(2)	48.97(1)	1.25(1)	40.52(1)	.307(2)	47.42(1)	1.5 (1)
Drought resistance	14.96 (3)	.055(6)		4.5(4)	-	-	-	-
Twining	10.24 (4)	.124(3)		3.5 (3)	20.26(2)	.340(1)	10.86(3)	1.25(2)
Kidding interval	9.45(5)	.086(4)		4.5 (4)	14.10(4)	.082(5)	4.00(4)	4.5
Mothering ability	7.87(6)	.063(5)	17.24(2)	5.5	15.42(3)	.151(3)		3(4)
Temperament	1.57				-			
Beauty	2.36				0.8			
Color	-				1.32		12.57(2)	2(3)
Ear length	-				2.2			
Tail shape	-				0.44			
Tail length	-				2.64			
Udder size					1.76			

Note: OWFR= Own flock ranking, PS= Production system, GR=Group ranking, WR=Weighted ranking

4.5.2. Economic values

The relative economic weights based of the preference of the community were derived. Thus the relative economic weight were set for the selected breeding objectives trait using the result from production system (PS), own flock ranking (OFR) and group ranking (GR) studies results of the breeding does. The proportion of the selected breeding objective traits of does from different study (production system study, own flock ranking and group ranking) were scaled to one hundred percent (unity) and weighted for ranking ((%Ps+%OFR+%GR)/3) (Table 29).The weighted proportion of the given traits were used as the relative economic weights. The phenotypic standard deviation of the traits were estimated from the result of morphological characterization and enumeration of own flock ranking experiment of this study. The genetic standard deviations of the traits were also estimated by the ratio of phenotypic standard deviation to the heritability of a trait.

Table 29. Economic weight and variance component of the selection criteria (traits)

Breeding objective traits	Selection criteria	Unit	REW	σ_a	σ_p
Abergelle					
Body size	Six month weight	Kg	54%	1.45	2.74
Milk yield	Milk yield	kg	30 %	0.13	0.23
Kid survival (mothering ability)	Proportion of kids weaned/does/year	%	16%	0.089	0.40
Western Lowland					
Body size	Six months weight	Kg	55%	1.99	3.76
Twinning	Number of kid born /doe/year		31%	0.14	0.45
Kid survival (mothering ability)	proportion of kids weaned /does/year	%	14%	0.13	0.60

RW- Relative economic weight; σ_a – Additive genetic standard deviation; σ_p – phenotypic standard deviation

4.5. 3. Annual genetic gain in individual traits

Optimization of the community based breeding program by looking at different alternative schemes to predict the genetic gain and the economic return is very helpful during implementation. It gives the chance to adjust the technical, infrastructural and socio economical issues ahead of the implementation. The predicted annual genetic gains (ΔG) of individual breeding objectives traits from different alternative schemes of the two breeds are presented in Table 30. Those parameters were different among the different alternatives and breeds. For all traits considered, higher genetic gains were predicted for Western Lowland goats than the Abergelle goats. These variations were due to higher phenotypic variation of the traits, lower generation interval and better performance (such as high twinning rate) of Western Lowland goats. The highest genetic gain of 0.3676 kg per year for six month's weight was predicted for Abergelle goats in growth only scheme (alternative 4) while the lowest 0.3599 was obtained in the alternative 2. As expected the highest gain was simulated for six month weight from growth only alternative where only the information of growth was included in the selection index. The highest value 0.8724 kg annual genetic gain of the six months weight was simulated for Western Lowland goats from alternative 3 (growth and survival information in the selection index) whereas the lowest value of 0.8702 kg was simulated from alternative 2 (growth and twinning information in the selection index). The highest gain of six month weight from alternative 3 was due to relatively higher positive genetic and phenotypic correlation between the two traits. The lowest genetic gain of six months weight from growth and twinning alternative was associated with the lower phenotypic and the negative genetic correlation of the two traits attached in the model. The genetic gain of six months weight predicted in this study is in the range of the predicted annual genetic gain of six months weight in similar study of Kenyan cross breed goats (Bett *et al*., 2012).

Table 30. Genetic gain per year for the breeding objective traits in different alternatives

Breed	Alternativies	Traits			
		SMW(kg)	DMY(kg)	PKW (%)	NKB
Abergelle	1 SMW+DMY+PKW	0.3600	0.0114	0.0085	_
	2 SMW+DMY	0.3599	0.0110	0.0083	_
	3 SMW+PKW	0.3669	0.0069	0.0072	_
	4 SMW	0.3675	0.0066	0.0068	_
Western Lowland	1 SMW+NKB+PKW	0.8710	-	0.0192	0.0006
	2 SMW+NKB	0.8702	-	0.0184	0.0006
	3 SMW+PKW	0.8724	-	0.0195	-0.0001
	4 SMW	0.8718	-	0.0186	0

SMW= Six months weight, DMY= Daily milk yield, NKB=Number of kids born, PKW=Proportion of kids weaned,

Relatively lower genetic gains of 6.60 g and 6.97 g milk yield were predicted from alternatives 4 and 3 for Abergelle goats, respectively. Higher values of 11.43 and 11.37 g of milk yield were predicted from alternatives 1 and 2, respectively. In these alternatives the information of milk yield was included in the selection index. Differently from this result higher genetic gain 0,261-0.809 kg milk yield were predicted in different alternatives of Kenyan dairy goat (Bett *et al*., 2012). However, a very close result with the range of 0.018 -0.020 kg of genetic gain of milk yield was predicted for different alternatives in a study on Ethiopian Afar sheep (Mirkena *et al*., 2012). There was a difference of 4.77g in genetic gain of milk yield between the alternative with highest gain and the alternative with the lowest gain in the present study. This result indicates that including milk record in the selection index would result the positive genetic gain but the profit will be minimal. Milk recording at village level is operationally difficult and routine milk recording even at monthly intervals is costly. It may be more appropriate to rely on indirect selection of milk yield through associated traits in this situation.

The genetic gains of kid survival at different scenarios ranged between 0.006764% to 0.008517% for Abergelle goat, while it ranged from 0.018389% to 0.019227% for Western

Lowland goats. In both breeds, the differences of annual genetic gain of kid survival between different alternatives were very small. This is because of the low heritability of the trait and low correlation with other traits. Comparable results with the range of 0.00-0.007% were predicted from different alternatives for Kenyan dairy goat breeds (Bett *et al*., 2012) and the range of 0.009- 0.01% for Ethiopian Afar sheep breed (Mirkena *et al*., 2012).

Very low genetic gains of twining rate were predicted from all alternatives for Western Lowland goats. Even negative gain was predicted from the alternative 3 and 4 where the twinning information was not included in the recording scheme. This is due to the low heritability the trait and low phenotypic and genetic correlation with other traits. In addition to this, selection intensity was mostly derived from the male path of selection thus the twinning rate performance information was obtained only from the dams of young bucks. Since recording of the twinning rate is very simple, it would be worthwhile to include the information of twinning rate in the recording and give more weight in breeding goal to avoid the loss of genetic gain of twinning rates which was reported as the most preferred traits in Western Lowland goat keepers.

4.5.4. Evaluation criteria

Table 31 depicts the important evaluation criteria simulated by ZPLAN program. The selection accuracies of obtained from different alternatives for both breeds were in the acceptable range 0.481 to 0.512. Relatively higher accuracy of selection 0.504 and 0.512 were obtained from Alternative 1 (all traits in selection index) for Abergelle goats and Western Lowland goats, respectively. This reflects as the information source increased in the selection criteria the accuracy also increased. The annual monetary genetic gains ranged between 16.42 to 17.57 Euro were predicted for Abergelle goats from the different alternatives whereas 25.96 to 26.06 were predicted for western Lowland goats. As the difference between the schemes was only by varying the information source in the selection index, there was no difference between the different alternatives in selection intensity and generation interval within the same breed. The differences of those parameters between the two breeds were connected with the difference of population size of the breeding does and the difference in reproductive performance of the breeds in input parameters. A selection accuracy of 1.99 and a generation interval of 2.88 years were predicted for Abergelle goats while the corresponding values for Western Lowland goats were 2.25 and 2.14 years. The discounted profit found in all alternatives and in both breeds was very high. It might not be appropriate to compare the alternatives in this study based on the discounted profit because the economic value attached to each trait is not in the real monitoring term and only additional cost to the normal practice were considered as the cost. The relative economic weights based on farmers' preference were assigned as the economic weight. The rate of inbreeding per generation 0.4% and 1.3% were calculated for Abergelle and Western Lowland goats respectively. The higher inbreeding rate for Western Lowland goats could be explained by the small flock size per household. During the implementation period, increasing the participant farmers with in the village or implementing across village selection for Western Lowland goat breeds would be advisable to avoid the problem of inbreeding.

Table 31. Important evaluation criteria simulated from different alternative in Abergelle and Western Lowland goats

Alternative	Criteria	Abergelle	Western Lowland
1	Accuracy of selection	0.503	0.512
	AMGG	17.57	26.06
	Discounted profit/doe	138.85	213.29
2	Accuracy of selection	0.504	0.511
	AMGG	17.51	26.05
	Discounted profit/doe	138.48	212.83
3	Accuracy of selection	0.484	0.511
	AMGG	16.58	26.01
	Discounted profit/doe	133.24	212.99
4	Accuracy of selection	0.481	0.510
	AMGG	16.42	25.93
	Discounted profit/doe	132.32	212.41

4.5.5. Practical implementation

The community level alternative schemes were designed and predicted for smallholder goat farmer conditions. Community based breeding program is the breeding program implemented at the smallholder levels where the infrastructure is poor and low input production system prevails. Therefore, the organizational structure should be simple and the traits in the recording should also small in number to avoid complexity during implementation (Sölkner *et al*., 1998; Wurzinger *et al*., 2008; Gizaw *et al*., 2009). This study was aimed that to see how much genetic gain and economic return loss in aggregate breeding goals (breeding objectives traits) by varying the number of traits at selection criteria. Even though, relatively higher gain from the alternatives with more traits in the selection criteria, the magnitude of the loss in genetic gains and economic returns from the alternatives with single versus more traits in the selection index were very small. For instance, the difference in annual monitoring genetic gain between all traits and one trait alternative for Abergelle goats were 1.154%. This result indicates that it might be good to start the community based breeding by using a few traits in the recording schemes with minimum loss of genetic gain of other traits in the breeding goal.

The present prediction study gave an acceptable range of genetic improvement for breeding objectives traits from different alternatives in both breeds at the community level. However implementation of community based breeding program need some organizational set up at the community level and strong participation of the community members (Wurzinger *et al*., 2011).The alternative schemes should be presented to the farmers to choose the appropriate options and the farmers have to be aware of advantage of genetically improved goats. The willing farmers need to be organized in form of a breed association. Some rules and regulation should be set to run the program smoothly. The rule may include how to manage and use the selected bucks. Giving some incentive like treatment of sick animal will also help for the successful implementation by creating motivation on the farmers. As the response of selection is slow, integration of other livestock improvement technologies such as feed technologies and disease control strategies would be also appropriate. The analysis of similar running projects such as the community based sheep breeding programs in Ethiopia and taking the lesson from them will help for successful implementation(Haile *et al*., 2011; Gizaw *et al*., 2013). The strong technical and financial back up from the public service like research institutes and agricultural extension system is very important especially at the beginning. One of the reasons for unsustainability of the breeding programs in the tropical countries is the interruption of the program immediately after the funding stopped (Kosgey *et al*., 2006). Therefore, the program should be designed in the way that it can be run by the community.

5. Conclusions

This study provides the basic insights into production system, breed characteristics, breeding objectives and selection criteria of Abergelle and Western Lowland goats in Ethiopia which are basic elements for community based breeding program planning. From this study it is possible to conclude that goat farming is an important component of the farming activity in the study areas by providing multifunctional roles to their owners. The high economic importance of goat with high flock size in Abergelle area and high potential of biomass production in Metema area would suggest the scope of goat improvements in both study areas. However, poor breeding practice like uncontrolled mating, mixing flock and negative selection of young bucks and high disease prevalence in both study areas and feed shortage in Abergelle area should be addressed. Thus, implementation of holistic community level development approach that considers the multifunctional roles of goats and existing goat production constraints is important.

Phenotypic characterization of this study indicated high variation within and between the studied breeds in qualitative and quantitative traits. Western Lowland goats are on an average not only bigger than Abergelle goats but also show considerably higher variation in body size. This indicates a large scope of genetic improvement by selecting best young males. Molecular diversity analysis from the SNPs markers revealed that substantial amount of the variation of the studied goat populations are explained by within breed variation. The existing higher variability within indigenous goat breeds would be useful for future genetic improvement through selection and breed conservation. In order to have sustainable breed improvements and breed conservation, it would be worthwhile to develop effective breeding methods that reduce the gene flow between breeds.

Participatory identification of the breeding objective traits is a central idea of community based breeding programs. In our approach, live animal ranking, the wide range of traits and with magnitude difference between the study areas were identified as breeding objective traits which are the reflection of multifunctional roles of goats and the differences in relative importance of goats in the study areas. In own flock ranking method farmers tend to prefer the animals based on production and reproduction traits like body size, multiple births, milk yield, litter size and kidding interval whereas in group ranking methods farmers give more emphasis on observable characters such as body size, body conformation and coat color. Therefore, both methods can be used for identification of breeding objective traits in low input system where performance records of the traits are not available. However, it is advisable to use the combination of methods for identification of breeding objective traits at smallholder level. However, breeding for a minimal number of traits should be performed in community based breeding programs to avoid complex and intractable schemes. The simulation results from different scenarios gave an acceptable range of genetic gains for breeding objective traits with small differences between alternative with more traits in selection index and a few traits in selection index. This indicates that it is possible to start a feasible community based breeding with growth only or very few traits in selection criteria with little loss of genetic gain in breeding goal traits.

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Appendix

Appendix 1. Questionnaire for production system description of Western Lowland and Abergelle goats

Notice for enumerators

Before starting your work, you should introduce yourself, your organization and the objective of the work for farmers.

A. <u>General information about the area</u>

1. Name of head of the family____________________________

2. Sex

   1. Male ☐ 2. Female ☐

3. Age_____

4. Education back ground

   1. Literate ☐ 2. Illiterate ☐ 3. Read and write ☐

5. If your answer is literate, what is your grade? ________

6. Marital status

   1. Married ☐ 2. Single ☐ 3. Divorced ☐ 4. Widow ☐

7. How many family members do you have? Total_________ Male_____ Female_______

8. What is your family livelihood (source of income)?

   1. Agriculture ☐ 2. Trade ☐ 3. Employee ☐ 4. other(specify)_________________

9. What is your major farming activity?

   1. Crop ☐ 2. Livestock ☐ 3. Both ☐

10. What is your family total area of land? Local measurement________= _______ha

    Crop land________________ Local measurement = ________ha

    Fallow land_______________ Local measurement= ________ha

    Grazing land______________ Local measurement= ________ha

    Other specify_____________ Local measurement= ________ha

11. Please tell us species of livestock you have and their numbers?

Species	Number
Cattle	
Goat	
Sheep	
Donkey	
Mule	
Horse	
Camel	
Poultry	
Bee hive	

12. Please tell us the number of goats you have at different age?

Class	Number
Does (> 1 years)	
Buck (> 1 years)	
Young Female (< 1 years)	
Young Buck (< 1 years)	
Kid (< 6 months)	
Castrated	

13. What are the major objectives of goat production in your family? (Give rank in their importance)

Use	Tick	Rank (Top three)
Income		
Home consumption (Meat)		
Home consumption (Milk)		
Saving		
Wealth status		
Manure		
Skin		
Other (specify)		

14. Household Income contribution of different farming activities (in ranking order)

Farming activities	Rank
Goat production	
Cattle production	
Field crop production	
Sheep production	
Apiculture	
Vegetable production	

15. Which species of livestock are more important for your livelihoods (in ranking order)?

Species	Rank
Cattle	
Goat	
Sheep	
Equine	
Poultry	
Bee	

B. Reproductive performance (Specific to Gumuz and Abergelle goats)

1. What is the average age of 1st mating of female goat? _____________

2. What is the average age of 1st mating of male goat? _______________

3. What is the average age of 1st kidding? ____________________

4. Do you fix age at first mating for the females?

1. Yes ☐ 2. N o ☐

5. Do you fix age at first mating for the males?

1. Yes ☐ 2. No ☐

6. What is the average kidding interval? ______________________________

7. What is the frequent type of birth?

1. Single ☐ 2. Twin ☐ 3. Triple ☐

8. How long the average reproductive age of the does? _______________Year

9. How many kids are born in the life time of one doe? ____________

10. Please tell us the months where frequent kidding is happening.

Month	Tick	Rank (Top three)
September		
October		
November		
December		
January		
February		
March		
April		
May		
June		
July		
August		

C. Mating and breeding management

1. Do you have your own buck?

1. Yes ☐ 2.No ☐

2. If your answer is no, where do you get buck?

1. From neighbors ☐ 2. By rent ☐ 3. Other (specify) ___________

3. If yes, how many buck do you have?________

4. If you have more than one, why do you need to keep more than one?___________

5. How your buck give mating service?

1. For my flock only ☐ 2. For my flock and neighbors ☐ 3. Rent out ☐

4. Not fixed ☐

6. Is their any special management for breeding buck? 1. Yes ☐ 2. No ☐

7. If yes, specify type of management? ___________________________

8. What is your purpose of keeping Buck?

1. Mating ☐ 2. Socio-cultural ☐ 3. Fattening ☐ 4. Other Specify ☐ ___________________________

9. How long the same buck give service in flock? _________

10. How mating is practice in your goat flock?

1. Mixing of buck with ewes ☐ 2. Introduction of buck with fixed time ☐

3. Other (specify)_________________

11. Do you practice control mating?

1. Yes ☐ 2. No ☐

12. If you answer is yes, how?

1. Introduction of buck at fixed time (Buck isolation) ☐

2. Castrate unwanted buc ☐ 3. Others (Specify)__________

13. If your answer is no, why?

1. Goat grazes together ☐ 2. Lack of buck ☐ 3. Lack of awareness ☐ 4. Other specify ( ) ____________

14. Where do you get replacement buck?

1. From young kids of my own flock ☐ 2. From young kids of other flock ☐

3. Purchased from market ☐ 4. Others (specify) ___________________

15. Do you select best female goat as parent of the next generation with in your goats?

1. Yes ☐ 2. No ☐

16. If your answer is yes, what are your selection criteria for female goat (does)?

Criteria	Tick as mentioned	Rank (Top three)
Size/ appearance		
Color		
Kid growth		
Kid Survival		
Lambing frequency		
Twining ability		
Mothering ability		
Milk yield		
Age at first maturity		

17. Do you select best male goat as parent of the next generation with in your goats?
   1. Yes☐ 2. No☐

18. If your answer is yes, at what age?_______

19. If your answer is yes, what are your selection criteria for male goat (Buck)?

Criteria	Tick as mentioned	Rank (Top three)
Appearance/conformation		
Colour		
Horns		
Character		
Growth		
Libido		
Ability to walk long distance		
Age at first maturity		
Pedigree		
Adaptability		

20. Do you allow a buck to mate his

	Yes	No	Reason
1. Mother	☐	☐	______________________________
2. Daughter	☐	☐	______________________________
3. Sister	☐	☐	______________________________

21. Do you allow your buck to serve does other than yours?

Reason

1. Yes☐ ______________________________

2. No ☐ ______________________________

22. Do you allow your doe to be served by anyone else buck?

Reason

1. Yes ☐ ______________________________

2. No ☐ ______________________________

23. Do you practice goat castration?

1. Yes☐ 2. No ☐

24. If your answer is yes what are the reasons?

1. Control mating ☐ 2. Fattening ☐ 3. Better Temperament☐ 4. Others (specify)____

25. At what age do you castrate your goat? ☐ _________

26. At what season do you castrate your goat?

1. Wet season ☐ 2.Dry season ☐ 3. Anytime☐

27. Do you provide special feed for castrated goat?

1. Yes☐ 2. No☐

28. If your answer is yes, what type of feed you provide and how long?

Type of feed	length of time
1. ____________________________	______________________
2. ____________________________	______________________
3. ____________________________	______________________

29. What type of method you use for goat castration? ☐

1. Traditional ☐(specify) ____

2. Modern ☐ (specify)____

D. Culling

1. Do you practice culling of female goat?

1. Yes☐ 2. No ☐

2. If your answer is yes, what is the reason?

1. Disease☐ 2. Old age☐ 3. Sterility☐ 4. Poor physical condition ☐
5. Low milk yield ☐ 6. Poor mothering ability Other☐
(specify)____

3. Do you practice culling of male goat? 1. Yes ☐ 2. No ☐

4. If your answer is yes, what is the reason?

1. Disease ☐ 2. old age ☐ 3. Poor physical condition ☐ 4. Bad color ☐ 5. Poor libido ☐ 6. Poor horn☐

5. At what age does and buck culled?

1. Does_________ year 2. Buck _______year

6. What is the use of culled animals?

1. Sold ☐ 2. Slaughtered ☐ 3. Exchange☐ 4. Others (specify)____________________________

E. Market

1. What is average market age of male goat? _____________

2. What is average market age of female goat?____________

2. Which class of goat do you sell first in case of cash needed?

Class	Rank
Male kid (<6 month)	
Female kid (<6 month)	
Male (6 to 12 months)	
Female (6 to 12 months)	
Breeding doe	
Breeding buck	
Old doe	
Castrated	

3. Does your family sell milk and milk products from goats?

1. Yes☐ 2. No☐

4. If sold, how much was the average prices (in the last 12 months) in Birr/kg?

1. Row milk_______ 2. Yogurt _______ 3. Cheese _______ 4. Butter______

F. Feeds and Feeding

1. What are the major goats feed resource in your area?

	Feed Resource	Dry season	Rank(Tope 3)	Wet season	Rank (Tope 3)
1	Communal grazing land				
2	Private grazing land				
3	Grazing after math				
4	Grazing fallow land				
5	Crop residue				
6	Cut grass and browses				
7	Improved forage				
8	Concentrate				
9.	Hay				
10	*Enbaz*				
11	*Atella*				
12	Other (specify)				

2. What are the grazing methods in your area in different seasons?

Grazing Methods	Wet season	Dry season
Free grazing		
Herded		
Cut and carry		
Tethering		

3. Do you provide concentrate for your goats?

1. Yes☐ 2. No☐

4. If your answer is yes, what type of concentrate and for which type of goats?

Type of concentrate	Class of goat				Name	Rank
	Kids	Doe	Buck	Castrate		
Home made grain						
Bran						
Oil seed cake						
Embaz						
Atella (local brewery by product)						

5. When do you provide concentrate for your goat?

1. Dry season ☐ 2. Wet seaso☐ 3. Both☐ 4. Other

6. If you don't provide concentrate feed, what are the reasons?

1. Expensive☐ 2. Not Available☐ 3. Not want to offer ☐ 4. Others (specify)________________

G. Housing

1. What type of shelter do you have for your goat?

1. No shelter ☐ 2. Separate house for goat ☐ 3. Shelter constructed in side main house☐ 4. Shelter constructed expansion of the main houses. ☐5. Open barn ☐6. Other

2. Are kids housed together with adult goats?

1. Yes ☐ 2. No☐

3. Are goats housed together with other animals?

1. Yes ☐ 2. No ☐

4. If your answer is yes which type of animals housed together with goats?

1. Sheep☐ 2. Cattle☐ 3. Equine ☐

4. All species ☐

H. HERDING AND OTHER MANAGEMENT ACTIVITIES

1. How are your goats herded during grazing time?

1. With other species ☐

2. Separately☐

3. No control☐

2. If they are herded separately; in which season and the reason?

Season	**Reason**
1.___________________	___________________________
2.___________________	___________________________

3. If they are graze together with other species, with what species, when and reason?

Type of species	**Season**	**Reason**
1. Cattle ☐	__________________	_________________
2. Sheep ☐	__________________	_________________
3. Equines ☐	__________________	_________________
4. All species ☐	__________________	_________________

4. Who do the different tasks and decides on benefits obtained from goats?

Type of work					
	Husband	Wife	Girls	Boy	Hired labor
Flock herding					
Care for kid					
Animal and product sealing					
Watering					
Milking					
Cleaning					
Product processing					
Castration					
Cut and carry grasses					

5. Do you practice mixing of your goat flock with other flocks?

1. Yes ☐ 2. No ☐

6. If your answer is yes, how many household mix their goat together? _______

I. Health

1. Please specify (describe) the major goat disease, their symptoms, season of occurrences, and cultural treatment (please include the predator)

Local name of disease	symptoms	Season of occurrences	Reason of occurrences	Is it contagious	Which age group mostly affected	Local treatment	Service provide by govern ment

Service: 1.Vaccination 2. Diagnosis 3. Treatment 4. Others (Specify)

2. Do you get vaccination service for your goat?

1. Yes☐ 2. No ☐

3. If your answer is yes, when the service is given?

1. When disease out brake occur ☐ 2. Any time in a year ☐ 3. Before disease out break☐ 4. Others (specify) _________________________

4. Where you get medicine and vaccination?

1. Agricultural office ☐ 2. NGO ☐ 3.Private veterinary house ☐ 4. Others (specify) ________________________________

5. How many goats are died in the last year (Previous 12 months) in your flock?

Category	Number of death	Reason of death				
		Disease	Predator	Mechanical		Others (specify)
Doe						
Buck						
Young Doe						
Young Buck						
Kids						
Castrate						

L. Product utilization

1. Do you slaughter goat for household consumption?

1. Yes ☐ 2. No ☐

2. If your answer is yes how frequent?

1. For festivals ☐ 2.Whenever slaughter age animals available 3.Wedding ☐ 4.Births in family ☐ 5.For guests ☐ 6.circumcise ☐ At funeral ☐ 8.Others, ☐ specify_______________

3. Which sex you usually slaughter?

1. Intact Male ☐ 2. Female ☐ 3. Castrate ☐

4. What is the average age of slaughter? Male _______ Female________

5. Do you use goat milk for consumption?

1. Yes ☐ 2. No ☐

6. Do you process milk into other product?

1. Yes ☐ 2. No ☐

7. If your answer is yes, what are the products?

1. Yogurt ☐ 2. Cheese ☐ 3. Butter ☐ 4. Other specify ☐

8. What is the milk production per day per doe (in liters)?

Maximum ________ Minimum _____ Average ________

9. What is the lactation length (in months)?

Maximum ________ Minimum _____ Average ______

10. Frequency of milking

1. Once a day ☐ 2. Twice a day ☐ 3.Three times a day ☐

11. Do you practice weaning? 1. Yes ☐ 2. No ☐

12. Average weaning age of kids?

1. < 3 months ☐
2. 3–4 months ☐
3. 5–6 months ☐
4. > 6 months ☐

13. Milk feeding up to weaning

1. Unrestricted suckling ☐
2. Restricted suckling ☐
3. Bucket feeding ☐
4. Others (Specify)________________________________

M. Production constraint

1. What are the major problems of goat production in your area? (Rank according to their severity)?

Constraint	Tick as mentioned	Rank (Top three)
Disease		
Feed shortage		
Water Shortage		
Labor shortage		
Market problem		
Predator		
Genotype		
Lack of input		
Lack of extension service		
Drought		

Thank you very much!

Appendix 2. Recording format for body measurements and physical description

ID number	Flock number	Sex	Breed	Castration	Body weight	Body condition	Coat		Hair type	Head profile	Wattle	Ruff	Tail length	Dentition	Age	Horn			Ear		Body length	Chest girth	Height at wither
							color	Pattern								Shape	Orientati	Length	formatio	length			

Appendix 3. Codes for body measurement and physical description

Character	Level	Code	Character	Level	Code
Breed	Gumuz	1	Horn shape	Straight	1
	Abergelle	2		curved	2
Sex	Male	1		Scurs	3
	Female	2		Polled	4
Dentitions	0 pair of PI lost	0		Spiral or corkscrew	5
	1 pair of PI lost	1	Horn orientation	Obliquely upward	1
	2 pair of PI lost	2		Front	2
	3 pair of PI lost	3		Backward	3
	4 pair of PI lost	4		Lateral	4
	5 broken teeth	5	Castration	Yes	1
Head profile	Straight/flat	1		No	2
	Concave	2	Hair type	Short and smooth	1
	Markedly convex	3		Long and course	2
	Slightly convex	4		Short and course	3
Wattle	With wattle	1	Coat color pattern	Plain	1
	Without wattle	2		Patchy	2
Ruff	With ruff	1		Spotted	3
	Without ruff	2	Coat color	White	1
Ear formation	Rudimentary	1		Brown	2
	Short ear	2		Black	3
	Long ear	3		Gray	4
	Erect	4		When mixed list all colors (dominant)	5
	Pendulous	5			
	Semi-pendulous	6			

Appendix 4. Format for Phenotypic ranking of goat by owners (Does)

Farmers Name_________________ Location______________ Flock size_______
doe________ Bucks_________ Female kids_____ Male Kids_____ castrated_____ young doe_____ Young buck________

No	Traits	1st best	2nd best	3rd best	Worst	Remark
1	Body length					
2	Wither height					
3	Chest girth					
4	Tail length					
5	Body weight					
6	Body condition					
7	Dentition					
8	Ear length					
9	Color type					
10	Color pattern					
11	Number of kidding					
12	Twining					
13	No. kid born					
14	No.kid weaned					
Reasons for ranking						

Appendix 5. Recording format for buck life history (as recalled by owner)

Owner name__________ Animal ID__________

Location______________ Site _____________

No	Traits	Description
1	Age	
2	Birth type	
3	Live weight	
4	Libido	
5	Temperament	

Appendix 6. Recording format for life history of does (as recalled by owner)

Owner name__________ Animal ID__________

Location______________ Site _____________

Traits	Description
Age	
Birth type	
Live weight	
Number of kidding	
Number of kid born	
Number of kids weaned	
Growth of Kids	
Milk yield	

Appendix 7. Recording format for ranking before getting life history information on individual buck/doe in group ranking

Pen 1		Pen 2		Pen 3		Pen 4		Pen 5	
ID	Rank	ID	Rank	ID	Rank	ID	Rank	ID	Rank

Reasons

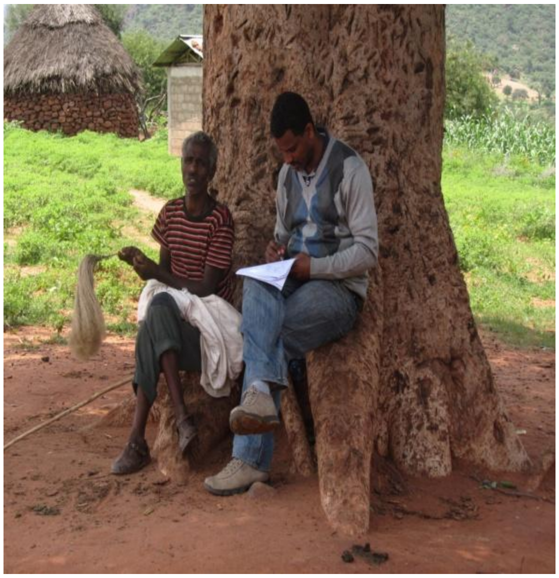
____
____
____
____
____
____
____
____

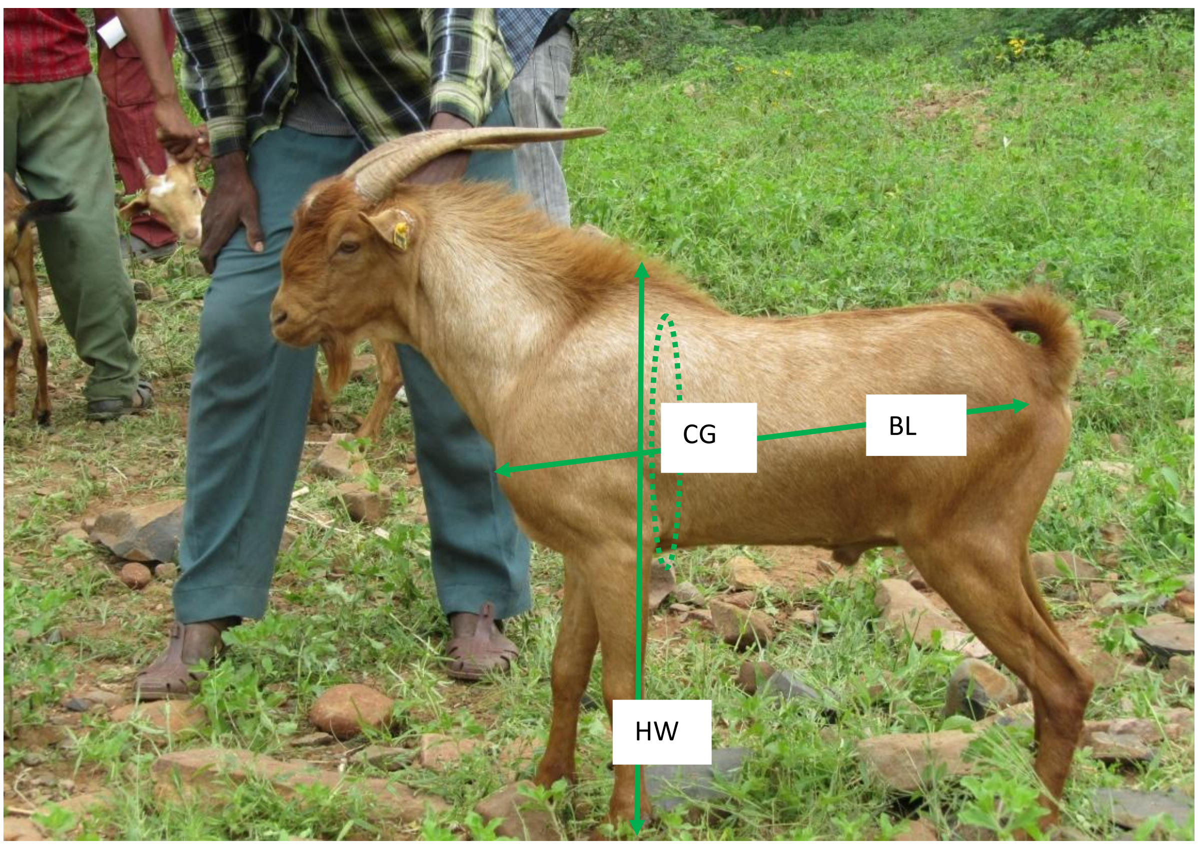
Appendix 8. Recording format for ranking after getting information on individual buck/does in group ranking

Pen 1		Pen 2		Pen 3		Pen 4		Pen 5	
ID	Rank	ID	Rank	ID	Rank	ID	Rank	ID	Rank

Reasons

Appendix 9. Pictures during household interview





Appendix 10. illustration of body measurements

Appendix 11. Picture of Alflex tissue applicator and tissue sample tube

Appendix 12. Pictures during animal measurements

Appendix 13. Pictures during live animal ranking