GENETIC PARAMETERS, PRODUCTIVITY INDICES AND BREEDING PLANS FOR DESIGNING COMMUNITY-BASED GOAT BREEDING PROGRAMS IN ETHIOPIA

PHD DISSERTATION

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Genetic parameters, productivity indices and breeding plans for designing community-based goat breeding programs in Ethiopia

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I hereby certify that I have read and evaluated this Dissertation titled ***"Genetic parameters, productivity indices and breeding plans for designing community-based goat breeding programs in Ethiopia"*** prepared under my guidance by Temesgen Jembere. I recommend that it be submitted as fulfilling the dissertation requirement.

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DEDICATION

This work is dedicated to my most beloved wife Kidist Desalegn Gabisa and to our children Moa, Nanati and Denea Temesgen.

STATEMENT OF THE AUTHOR

I hereby declare that this Dissertation is my bonafide work and that all sources of materials used for this Dissertation have been duly acknowledged. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis and completion of this Dissertation. All scholarly matter that is included in the Dissertation has been given recognition through citation. Every serious effort has been made to avoid any plagiarism in the preparation of this Dissertation. This Dissertation has been submitted in partial fulfilment of the requirements for PhD degree in Animal Genetics and Breeding at Haramaya University and is deposited at that University Library to be made available to borrowers under the rules of the library. I solemnly declare that this Dissertation has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate. Brief quotations from this Dissertation may be used without special permission provided that accurate and complete acknowledgement of the source is made. Requests for permission for extended quotations from, or reproduction of this Dissertation in whole or in part may be granted by the Head of the School or Department or the Dean/director of the postgraduate Program Directorate when in his or her judgment the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author of the Dissertation.

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BIOGRAPHICAL SKETCH

The author, Mr. Temesgen was born from his father Jembere Bakara and his mother Hinsene Ejeta on November 6, 1980 in Jimma Gannati Distrct, Horro Guduru Wollega Administrative Zone of Oromia. He attended his elementary education in Gaba Robi Elementary School from 1988 to 1993 and his junior and high school education at Harato Junior and Senior Secondary School from 1994 to 1999.

Then after he joined the then Awassa College of Agriculture (now Hawassa University) in 2000 and was awarded a B.Sc. degree in Animal Production and Rangeland Management in 2003. After his graduation, he was employed by Ministry of Agriculture as a junior instructor to serve Gode Agricultural and Technical Educational Training College located in Somali region.

After working for Ministry of Agriculture for eight months, he joined Oromia Agricultural Research Institute (OARI) in June 2004 and served at Bako Agricultural Research Center as a researcher in animal feeds and nutrition research division.

He joined the School of Graduate Studies of the Haramaya University in 2008 and awarded a Master of Science degree in Agriculture majoring in Animal Genetics and Breeding in 2010. He was working as animal breeder in Bako Agricultural Research Center until he joined the Haramaya University, School of animal and range sciences, in October 2012 to study PhD in animal genetics and breeding.

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"Be thou exalted, O God, above the heavens: and thy glory above all the earth;" Psalm 108:5.

LIST OF ABBREVIATION

11mw	11 Months Weight
12mw	12 Months Weight
150MY	150 days milk yield
16mw	16 Months Weight
18mw	18 Months Weight
1mw	One Month Weight
1st KI	First Kidding Interval
1^{st}LMY	First Lactation Milk Yield
20d	20 Days Weight
270MY	270 Days Milk Yield
2mw	Two Months Weight
3mw	Three Months Weight
4mw	Four Months Weight
5mw	Five Months Weight
6mw	Six Months Weight
70d	70 Days Weight
7mw	Seven Months Weight
8mw	Eight Months Weight
90DMY	90 Days Milk Yield
9mw	Nine Months Weight
AB	Abergelle Goat Breed
ADG1	Average Daily Gain from birth to three months
ADG2	Average Daily Gain from three to six months
ADG3	Average Daily Gain from six to 12 months
ADM	Average Daily Milk Yield
AFK	Age at First Kidding
bwt	Birth Weight
c^2	Ratio of Common Environmental Effect

CH	Central Highland Goat Breed
COMB P&F	Combined Protein and Fat
F%	Fat Percentage
FATY	Fat Yield
GL	Gestation Length
h_a^2	Direct heritability
h_m^2	Maternal heritability
ICARDA	Intonations Center for Agricultural Research in Dry Areas
ILRI	International Livestock Research Institute
KI	Kidding Interval
LL	Lactation Length
LMY	Lactation Milk Yield
LSB	Litter Size at Birth
LSW	Litter Size at Weaning
LWB	Litter Weight at Birth
m.a.s.l	Meters Above Sea Level.
P%	Protein Percentage
PAGG	Predicted Annual Genetic Gain
PAGGs	Predicted Annual Genetic Gain
PPW	Post Partum Weight
PROTY	Protein Yield
R	Repeatability
Ratio P:F	Ratio of Protein to Fat
r_g	Genetic Correlation
r_p	Phenotypic Correlation
SN	Scenario
SN	Scenario
SURV	Survival to Six Months
WG	Woyto-Guji goat breed

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Genetic parameters, productivity indices and breeding plans for designing community based goat breeding programs in Ethiopia

GENERAL ABSTRACT

The overall objectives of this dissertation were to improve access to improved/selected bucks by farmers of the research sites and to contribute to their food security and income improvements. The specific objectives were: 1) to present reliable genetic parameter estimates based on meta-analysis of literature reports; 2) to evaluate production and productivity of three indigenous goat breeds in Ethiopia namely Abergelle (AB), Central Highland (CH) and Woyto-Guji (WG) and have bench mark production and productivity estimates for the ongoing Community Based Breeding Programs (CBBPs) in Ethiopia; 3) to evaluate alternative breeding scenarios in the CBBP of the three goat breeds including dam-side selection, genomic selection and two-tier breeding programs; and 4) to assess the need for recording birth weight in CBBP of small ruminants. This dissertation was based on four articles/manuscripts. Accordingly, in article 1, unweighted and weighted average genetic parameters including direct heritability (h_a^2), maternal heritability (h_m^2), ratio of common environmental variances (c^2), repeatability (R), phenotypic (r_p) and genetic (r_g) correlations for growth, reproduction and milk production traits in goats were presented. Unweighted averages across publications were obtained directly. For the calculation of weighted average h_a^2, h_m^2, c^2 and R, the inverse of their variances were used. Weighted average r_p and r_g were transformed to an approximate normal scale using Fisher's Z transformation and then transformed back to correlations. Weighted average h_a^2 for growth, reproduction and milk production traits ranged from 0.03 to 0.45, 0.00 to 0.17 and 0.15 to 0.22, respectively. Weighted averages r_p and r_g correlations among growth traits ranged from -0.06 to 0.84 and 0.01 to 0.98, respectively. It seemed that weighted average h_a^2, h_m^2, c^2, R, and r_g are more reliable for two reasons: weighted estimates were more conservative than values based on relatively higher number of records and the absence of significant effects of the tested fixed factors on some parameter estimates. Papers II-VI were based on data generated from the three indigenous goat breeds, in two villages for each. Production parameters including three months weight (3mw, kg), kidding interval (KI, days) and litter size at birth (LSB); and productivity indices including live weight production per parturition (kg) (index I), index I per postpartum weight (ppw) (Index II) and overall productivity (index III) were analyzed in manuscript II. Fixed effects of villages, year, season, type, sex, and parity of kids' birth, flock size and ppw were investigated on the parameters, except for index III. The overall means of 3mw (kg) were 7.44, 10.96 and 9.38 for AB, CH and WG goat breeds, respectively. The overall means of KI were 362, 268 and 309 days for AB, CH and WG goat breeds, respectively. The overall means of LSB for AB, CH and WG goat breeds were 1.03, 1.40 and 1.09, respectively. Overall means of index I and index II were 16.66 kg and 0.50, respectively.

*Index III ranged from 0.27 to 0.53. In general, CH goat breed was found to be the most productive using the three indices. In manuscript III, application of dam-side (SN2) and genomic selection (SN3) onto the current breeding practice, where only male side selection is practiced, (SN1) and expansion of SN1 to a two tiers programs (SN4) were evaluated for three indigenous goat breeds to determine the optimal scenario(s). Due to significant distances between CH Gonder site and CH Ambo site, separate breeding plans were optimized for the CH goat breeds. The predicted annual genetic gain (PAGG) in six month weight (6mw, kg) ranged from 0.308 to 0.467 (CH Gonder site), 0.209 to 0.311(CH Ambo site), 0.188 to 0.270 (WG) and 0.174 to 0.249 (AB). The PAGGs in KI for WG goats ranged from 0.167 to 0.419 from all the scenarios. The PAGG in average daily milk yield (ml) and survival to six months (SURV) (%) for AB ranged from 0.617 to 0.970 and 0.008 to 0.013, respectively. The PAGGs in LSB and litter size at weaning (LSW) for CH were found to be small (0.001 to 0.002). The discounted profit from SN3 was negative for all breeds. Based on the PAGGs and discounted profitability, SN2 was recommended. In article IV, the Pearson correlation "r" between birth weight (BWT) & six month weight (6MW), BWT & nine month weight (9MW), three month weight (3MW) & 6MW & 3MW & 9MW; and regression coefficients ("**b**") of 6MW & 9MW on BWT, 6MW & 9MW on 3MW were investigated. The "r" BWT & 6MW, BWT & 9MW, 3MW & 6MW & 3MW & 9MW ranged from 0.099 to 0.176, 0.051 to 0.163, 0.598 to 0.706 & 0.370 to 0.546, respectively. The "**b**" of 6MW on BWT, 9MW on BWT, 6MW on 3MW & 9MW on 3MW ranged from 0.494 to 0.999, 0.311 to 0.996, 0.706 to 0.927 and 0.415 to 0.669, respectively. In general, BWT had weak "r" with 6MW & 9MW in three indigenous goat breeds of Ethiopia. However, it seems that recording BWT in the CBBP is compulsory. Hence, it was concluded that keeping BWT records under the CBBP of small ruminants has little or no significance. In summary, reliable genetic parameter estimates are presented for genetic improvements in goats. Production parameters and productivity indices presented here could be used as reliable benchmark for the anticipated CBBPs. The productivity indices could also be used to compare productivity efficiencies among different goat breeds. Planning dam-side selection could be considered together with sire side selection. Recording of BWT could be avoided in CBBPs to contribute to reduced breeding costs.*

Key words: *Birth weight; Genetic gain; Genetic parameters; Goat; Productivity*

APPENDICES (ARTICLES/MANUSCRIPTS)

The Dissertation is based on the following four articles/ manuscripts.

1. Meta-analysis of average estimates of genetic parameters for growth, reproduction and milk production traits in goats (**Accepted in journal of small ruminant research**).

2. Production parameters and productivity assessment in goat breeds of Ethiopia (**Prepared for submission**)

3. Dam-side and genomic selection scenarios enhance genetic gains in community based goat breeding program in Ethiopia (**under review in journal of livestock sciences**).

4. Recording birth weight has no significance in village based genetic improvement programs of small ruminants (**Published in Livestock Research for Rural Development. Volume 28, Article #135).**

1. GENERAL INTRODUCTION

Ethiopia has the largest livestock population in Africa (CSA, 2014). According to this source, the country's goat population was more than 28 million heads. The goat population in Ethiopia showed an increasing trend from year to year (FAO, 2014). Increasing population pressure, land scarcity and diminishing production resources are among promoters of goat production in the tropics (Bett *et al*., 2009). Being relatively tolerant to drought, goats can survive on woody browse and infrequent watering and their fast reproduction rate enables their owners to recover quickly, following a drought (Peacock, 2005).

In developing countries, indigenous goats make valuable contributions, especially to the poor in the rural areas. They are important sources of meat, milk, manure, fibers & skins, and satisfy various cultural and religious functions (Tesfaye, 2004; Kosgey and Okeyo, 2007; Kanani, 2009; Aziz, 2010; Devendra, 2012). The importance of this valuable genetic resource is, however, underestimated and contribution to the livelihood of the poor is inadequately understood (Kosgey *et al*., 2006; Kanani, 2009; Aziz, 2010). The productivity of these indigenous goats is also low as a result of many interrelated factors including genetic potential of the indigenous stock.

Most of the goats are reared in extensive small holder systems in developing countries (Rashidi *et al*., 2011), where their breeding programs in these environments have been limited, amongst other factors, by lack of pedigree and the lack of performance records for traits of economic importance. In Ethiopia, goat research was hotchpotch and not organized. Research reports not geared with long term improvements are available (Kebede *et al*., 2012; Badhane *et al*., 2013).

Estimates of genetic and environmental parameters of breeding goal traits are needed to develop a proper selection program (Mohamed *et al*., 2012). The potential of genetic improvement of a trait of interest is largely dependent on its heritability value and genetic relationship with other traits of economic importance (Faruque *et al*., 2010). However, reliable data set are not always available especially in developing countries (Koots *et al*., 1994a, b). In

such cases, average estimates from literature could be used (Koots *et al*., 1994 a, b; Lobo *et al*., 2000; Safari *et al*., 2005). The literature averages could be used as an input in optimization of alternative breeding scenarios.

In Haile *et al*. (2011) the procedures for optimizing breeding schemes for small ruminants is illustrated. It should begin with characterization of a production system. In order to put interactions between livestock and the environment in a system, livestock production systems must be defined, described and put in a geographic context (FAO, 1995). Mode of livestock production in Ethiopia are majorly classified as pastoral, agro pastoral and crop-livestock mixed production systems. There are also less dominant and underdeveloped systems including urban/peri-urban dairying and fattening and the large scale commercial livestock production systems (Solomon *et al*., 2010).

The production systems study should be followed by appropriate definition of breeding objective traits. Four methods could be used to define breeding objective traits. These include semi-structured questioner, choice card experimentation, group discussion and ranking of live animals (Duguma, 2010; Mirkena, 2010; Haile *et al*., 2011). While the first three were often used, the last method was brought forth by Mirkena (2010). Ranking of live animals has two forms: ranking of animals with known history and ranking of animals with unknown history. One can use combination of the methods to determine the breeding objective for a given breed. Details on the methods is documented in Haile *et al*. (2011).

Optimization of alternative scenarios is critical before implementing a given breeding program. For instance, various alternative breeding plans were optimized for sheep (Gizaw *et al*., 2014a, b; Mirkena *et al*., 2012; Haile *et al*., 2011). The process requires preparation of different input parameters including, population, biological, cost and genetic and phenotypic.

Alternative breeding scenarios could be compared based on genetic gain per time unit and discounted profit. If reliable inputs parameters are used in the optimization of breeding scenarios, nearly realistic realized genetic gain and discounted profit could be calculated.

With the help of SIDA (Swedish) funded project, named Biosciences for eastern and central Africa, International Livestock Research Institute (BecA-ILRI), a community-based breeding programs (CBBPs) for specified indigenous goats in Ethiopia were initiated in six villages in 2013. The breeds included Abergelle (AB), Central Highland (CH) and Woyto-Guji (WG). The breeds were reared in arid, crop-livestock and semi-arid production systems, respectively (Tatek *et al*., 2016).

The present work was part of the Beca-ILRI goat project initiated in these villages and on the three breeds which is a follow-up of the production systems characterization by Alubel (2015) and Zergaw *et al*. (2016), and definition of the breeding objective traits by Tatek *et al*. (2016).

The overall goal of the present study was designing alternative breeding plans for the three indigenous goats (AB, CH and WG). This dissertation was based on four articles/manuscripts. Paper I and II were associated with preparation of input parameters. The utility of the first paper is rather global. Paper III was about optimization of breeding plans as an alternative to the currently operating community-based breeding program of goats. Paper IV dealt with ways of breeding cost minimization by reducing the number of traits recorded in CBBP, which is also associated with the optimization of the alternative breeding scenarios.

General Objectives

- ✓ The overall objectives were to improve access to improved/selected bucks by farmers of the research sites and to contribute to their food security and income improvement.

Specific objectives:

- ✓ To present reliable genetic parameter estimates based on meta-analysis of literature reports.
- ✓ To evaluate productivity of three indigenous goats (Abergelle, Central Highland and Woyto-Guji) of Ethiopia and have bench mark production and productivity parameter estimate for the ongoing CBBPs in Ethiopia

- ✓ To evaluate alternative breeding plans in the CBBP of goats including dam-side selection, genomic selection and two-tier breeding programs
- ✓ To assess the need for recording birth weight in CBBP of small ruminants.

2. GENERAL BACKGROUND

2.1. Goat Breeds

According to FAO (2015) there are 662 goat breeds (local and trans-boundary) worldwide. Of these, about 17% are found in Africa. Ethiopia is a home for about thirteen local goat breeds, based on phenotypic classification, including Abergelle, Afar, Arsi- Bale, Central Highland, Hararghe Highland, Keffa, Long eared Somali, Nubian, Short-eared Somali, Western Highland, Western Lowland and Woyto-Guji (Kasahun and Solomon, 2009). However, according to molecular characterization of Tesfaye (2004) there are only eight distinct breeds. Recently, the Getinet (2016) regrouped the existing Ethiopian goat breeds, on molecular basis, into seven.

2.2. Genetic Parameters to Plan Breeding Programs

Genetic parameters including genetic correlations and heritabilities are required to plan breeding strategies and genetic evaluation programs in livestock (Willam *et al*., 2008). However, sufficient time and suitable data limit the genetic parameter estimations available for specific populations (Koots *et al*., 1994a, b), especially in developing countries. Even when parameter estimates are available, according to these authors, precision is generally low.

In quantitative genetics it is commonly believed that the genetic parameters refer to the population in which they are estimated. Koots and Gibson (1996), however, indicated that referring estimates of genetic parameters to the population in which they are estimated should not be a universally accepted principle. That means values estimated elsewhere could be used for populations with no parameter estimates. Little or no differences in parameter estimates between populations or breeds (Koots and Gibson, 1996) encouraged the use of parameters estimated elsewhere. Hence, the genetic parameters might be more accurately estimated by pooling results from literature and combined them with specific population (where available) estimates (Koots *et al*., 1994a, b; Koots and Gibson, 1996; Lobo *et al*., 2000).

There are different ways to pool and present genetic parameter estimated from literature. For instance, Cammack *et al*. (2009) summarized in the form of ranges; Utrera and Vleck (2004) presented in the unweighted form; Safari *et al*. (2005) presented in the weighted form; Koots *et al*. (1994a, b) and Lobo *et al*. (2000) presented both unweighted and weighted forms. While literature estimates of genetic parameters are available for cattle (Koots *et al*., 1994a; Koots *et al*., 1994b; Lobo *et al*., 2000; Utrera and Vleck, 2004; Cammack *et al*., 2009) and sheep (Safari *et al*., 2005), such reports are lacking for goat traits globally.

2.3. Goat Production Systems in Ethiopia

In order to put interactions between livestock and the environment in a system, livestock production systems must be defined, described and put in a geographic context (FAO, 1995). Different authors classified livestock/small ruminant production systems using different criteria. Bases for identification of livestock production systems could be contribution of the livestock sector to the total household revenue (income and food), type and level of crop agriculture practiced, types of livestock species kept, and mobility and duration of movement (Solomon *et al.*, 2010).

Solomon *et al.* (2010) presented three major and two less dominant livestock productions systems in Ethiopia. The three major livestock production systems included pastoral, agro pastoral and crop-livestock mixed production systems whereas the two less dominant and underdeveloped included urban/peri-urban dairying and fattening and the large scale commercial livestock production systems.

In agreement with Solomon *et al*. (2010) report Dereje *et al.* (2015) said that almost all goats in Ethiopia are produced in mixed crop-livestock and pastoral and agro-pastoral systems. According to According to Tembely (1998) and EARO (2000), goats are reared under two broad production systems: 1) crop-livestock farming systems and 2) pastoral and agro-pastoral production systems. Getahun (2008) reported four small ruminant production system categories in Ethiopia, basing the prevalent agricultural activity: 1) small ruminant in annual crop-based systems, 2) small ruminant in perennial crop-based systems, 3) small ruminant in

cattle-based systems and 4) small ruminant dominated systems. The diversity of Ethiopia's topography, climate and cultural conditions made it difficult to generalize about livestock production systems in the Ethiopia (Alemayehu, 1985).

2.4. Productive and Reproductive Performance of Goats of Ethiopia

In order to effectively design sustainable genetic improvement programs, the relative importance of benefits from small ruminants, and their genetic and production environment characteristics need to be evaluated and clearly understood (Kosgey and Okeyo, 2007). Productive and reproductive performance of goats differed by different agro-ecologies of Ethiopia. The growth performances of goats in lowland agro-ecologies were not better than those in the other agro-ecologies (Dereje *et al.*, 2015). According to the same author, the productive and reproductive performances of goats in Ethiopia were, as well, variable under different management conditions. Age at first kidding and kidding intervals of goats (reproductive traits) in Ethiopia appear to be shorter in the traditional systems while efficiency in terms of growth rate, carcass yield, milk yield, litter sizes and survival rate were higher under improved management systems (Dereje *et al.*, 2015).

Past research reports revealed variations in kidding interval (eight to 14 months) among indigenous goats of Ethiopia. The longer kidding interval reported from some research stations were mainly due to the result of controlled breeding with the objective to achieve the best breeding season and synchronization of birth for research purpose (Dereje *et al.*, 2015). Most indigenous goats had twining rate below 20%, the smallest twining rate in arid areas and the highest twining rate in humid areas of the country.

Different factors were known to affect growth performances of small ruminants and these factors could be categorized in to genetic and non-genetic (Haile *et al*., 2002; Mengiste *et al.*, 2009; Temesgen, 2010). Fixed effects including parity of doe, birth type of kid, sex of kid and season of birth of kid were known to significantly influence productive and reproductive performances of goats. Generally, kids from first parity does were lighter than kids from

higher parity does. Twin born kids were smaller in weight than their single born counterparts (Dadi *et al.*, 2008; Belay and Mengiste, 2013).

2.5. Goat Research in Ethiopia

Research program on small ruminants in Ethiopia was established in the mid-1970's (Tsegahun *et al.*, 2000). The focus by then was even crossbreeding program at Werer Research Center and evaluation of the productivity of Afar indigenous goat and its crossbred with Saanen goat. In addition, on station goat research has been conducted in different universities and research centers among which Haremaya university (the then Alemaya University), Hawassa university (the then Awassa college of agriculture) and Adami Tullu agricultural research centre were some. However, the institutions were blamed for not yielding significant impact at farm level (Duguma *et al.*, 2010).

2.6. Selection Groups

In the improved version of ZPLAN, i.e., ZPLAN+, defining selection groups is the most important step in the definition of the breeding program. The in the manual of ZPLAN, selection groups were confused with selection passes (Willam *et al.*, 2008). A selection group can be defined as a group of animals of the same breed, sex and age, that are used to produce offspring and therefore, are able to transmit their genes to the next generation. The minimum number of selection group could be two: for instance, male and female selection groups. Many parameters are to be defined within a selection group including 'size', 'gender', 'breed', 'number proven', 'number selected,' reproduction cycle', 'productive lifetime', 'age at first reproduction', 'overall survival rate', 'accuracy of selection index',' check box for use of accuracy', 'check box for realization group'. Details of these parameters are found in the manual provided with the ZPLAN+ software (https://service.vit.de/zplanplus/).

Within a given selection group, it worthy to note that 'size' refers to the total number of animals available for selection; 'number proven' is the total number of animals after excluding as many numbers as possible from the 'size'. 'Number selected' is the number of animals

selected from 'number proven'. For example if male selection group is considered, say there could be 100 animals available for selection. This refers to 'size'. All of them could be considered as proven or five animals could be dropped from the 'size'. In that case, the' number proven' become 100 (if all are considered as proven), 95 (if five animals are dropped). Finally, 30 animals could be selected for the breeding purpose which refers to the 'number selected.' Therefore, it should be noted that there is selection, whatever the selection proportion it may be, on both male and female side when breeding programs are optimized using the ZPLAN+. The software, calculates the overall selection intensity based on the selection intensity for males and females. In order to maximize, overall selection intensity, it better to make the maximum possible selection on both gender.

2.7. Community/Village Based Breeding Program

There were no an organized, structured and successful goat breeding program in developing countries (Banerjee *et al.*, 2000). Reasons for lack of successful breeding programs in developing countries included lack of technical and operational capacity, introduction of animal genetic resources from the developed countries without fully assessing their long-term implications, exclusion of livestock keepers from the breeding program, lack of detailed documentation on the operational plans and initiating genetic improvements with the short term projects (FAO, 2010).

On station livestock breeding programs were blamed for not bringing significant impact in the developing countries (Duguma 2010). CBBP particularly for small ruminants, are preferred, to the more common top down breeding programs that are mostly established on governmental stations in developing countries (Mueller *et al*., 2015b). CBBP is defined as programs carried out by communities of smallholders, often at subsistence level (Sölkner *et al.*, 1998); and is a design of breeding scheme that is deemed suitable for smallholder farming system (Gizaw *et al*., 2014a). The CBBPs for livestock have been established in different parts of the world; for sheep and goats in Ethiopia (Duguma, 2010; Duguma *et al*., 2011; Haile *et al*., 2011; Abegaz *et al*., 2014), for goats in Mexico (Wurzinger *et al*., 2013) and in Iran (Mueller *et al*., 2015a).

Two major dilemmas were stated with suggested way outs by Kosgey *et al* (2006) regarding the community based breeding strategy. These were involving farmers from the very beginning at village level and frequently long and complicated bureaucracy involved in the distribution of improved animals from the nucleus to participating farmers. Training farmers and boosting their small ruminant production techniques is suggested for the first dilemma and agreeing up on 'first-come first-served' principle was suggested for the second dilemma. As community based breeding program has advantage in ensuring the involvement of the different stakeholders from the very beginning (Gizaw *et al.*, 2009; Wurzinger *et al.*, 2013), which was not the case in conventional breeding practice, confronting the challenges through repeated discussions will remain vital in the planned activity as well.

2.8. Optimization of Breeding Schemes

The literal meaning of optimization is making the best or most effective use of resource. When that is brought to the context of animal breeding it means that using resources needed for animal breeding most effectively in such a way that optimal gains would be secured both in terms of genetic gains and monetary genetic gains. Owners or farmers usually use their experience for optimizing their farm income. Sometimes, however, their experience does not guarantee their intended results (Alsheikh and El-Shaer 2009; Tsukahara *et al.*, 2011). Accordingly, linear programming should be used as an effective technique to address the limited production resources among different agricultural (cultivation and livestock) activities to provide optimal results for these owners (Alsheikh *et al.*, 2002).

According to Tsukahara *et al*. (2011), simulation models can provide a logical understanding and predictions of outcomes of the production systems including genetic, managerial or environmental variables under different sets of conditions. Biological production efficiencies were estimated and crossbreeding systems were evaluated, for instance for goat, under tropical conditions using a deterministic simulation model (Tsukahara *et al.*, 2011). Bosman *et al.*, 1997 developed a simulation model to assess the efficiency of goat production. Oishi *et al.* (2008) used the simulation method to estimate the effect of culling age of does on productive efficiency. It can be said that simulation modeling has wider applications.

A deterministic simulation model is said to be appropriate for the optimization of alternative breeding plans for livestock. ZPLAN (Willam *et al.*, 2008), the computer program, was used to model the alternative livestock breeding programs. Breeding programs and their parameters are defined by users and the program calculates results such as annual genetic gain for the breeding objectives, genetic gain for single trait and returns for investment periods adjusted for costs (profit). The program is based on a pure deterministic approach. Compared to stochastic simulation models, its advantage is multi-trait including return and costs over a given time horizon and runtime is fast (Willam *et al.*, 2008). User friendly software which is web based (ZPLAN+), but commercial, is available nowadays for the optimization of the different breeding plans (https://service.vit.de/zplanplus/).

3. MATERIALS AND METHODS

This dissertation is based on four manuscripts/articles. The general materials and methods followed in the presentation of the manuscripts/articles is given in this section whereas the detailed methodology is available in the specific papers appended. The first paper is a meta-analysis of genetic parameters from literature in goat traits. Papers II - IV targeted three indigenous goat breed namely AB, CH and WG. Description of the study sites of papers II IV were the same. In this general material and methods section, methodology related to Paper I is presented followed by methodology of the rest papers.

3.1. Average Estimates of Genetic Parameters

A data set of genetic parameters for 41 growth, milk and reproduction traits was constructed from 84 independent publications. Two types of averages, unweighted and weighted, were calculated and presented for h_a^2, h_m^2, c^2, r_g and r_p. Unweighted averages across publications were obtained directly. For the calculation of weighted average h_a^2, h_m^2, c^2 and R, the inverse of their variances were used. Weighted average phenotypic and genetic correlations were transformed to an approximate normal scale using Fisher's Z transformation and then transformed back to correlations (detailed procedures are indicated in paper I).

3.2. Description of The Study Areas

The studies related to production and productivity assessment (Paper II), optimization of alternative breeding scenarios (Paper III), and whether recording birth weight has significance in CBBP (Paper IV) were conducted in six villages and on three indigenous goat breeds, two villages per breed, in Ethiopia. The goat breeds were AB, CH and WG. The villages for AB, CH and WG are located in Tigray and Amhara, Amhara and Oromia and in SNNP's (Southern Nations, Nationalities, and People's) region, respectively. The AB goat breed reared by producers at Dingur village of Hadinet Kebele found in Tanqua Abergelle and Blaku village of Tsitsika kebele found in Ziquala district were monitored. Tanqua Abergelle is one of the

districts in Central Tigray zone of Ethiopia. Yechila is the city of the district and it is found at about 893 kilo meters from Addis Ababa. Zikuala district is one of the districts in Wag-Himra zone of Amahara region, Ethiopia. Tsistika is the capital of the district and it is found at 784 kilometres (km) north of Addis Ababa. The districts were described in Alubel (2015).

The CH goats of the present study are reared by producers of Waykaw and Zentey vilages of Kamfanta Kebele of Lay Armachiho district and Tatessa village found in Lume Tatessa Kebele of Meta-Robi district. Lay Armachiho is one of the districts in North Gonder zone of Amhara region whereas Meta-Robi is one of the districts in west-shewa zone of Oromia region, Ethiopia. Tikil dingay and Shino are cities of Lay Armachiho and Meta-Robi districts, respectively. The former city is found at 758 km north of Addis Ababa and the latter is found at about 100 km north west of Addis Ababa. Further elaboration of the former is found in Alubel (2015) and the latter is found in Netsanet (2014). Massale and Arkisha villages are found in Konso district, Segen zuria zone of Southern Nations Nationalities and People's region (SNNP), Ethiopia. Karat is the capital of Konso district and it is found at 595 km southwest of Addis Ababa. WG goat breeds, kept by producers in the villages as well as in the district are one of the targeted breeds in the current work. The district's additional information is also found in Nestanet (2014). The present work is part of the project initiated in these villages and on the three breeds which is a follow-up of the production systems characterization (Alubel, 2015; Zergaw *et al*., 2016) and definition of the breeding objective traits by Tatek *et al*. (2016).

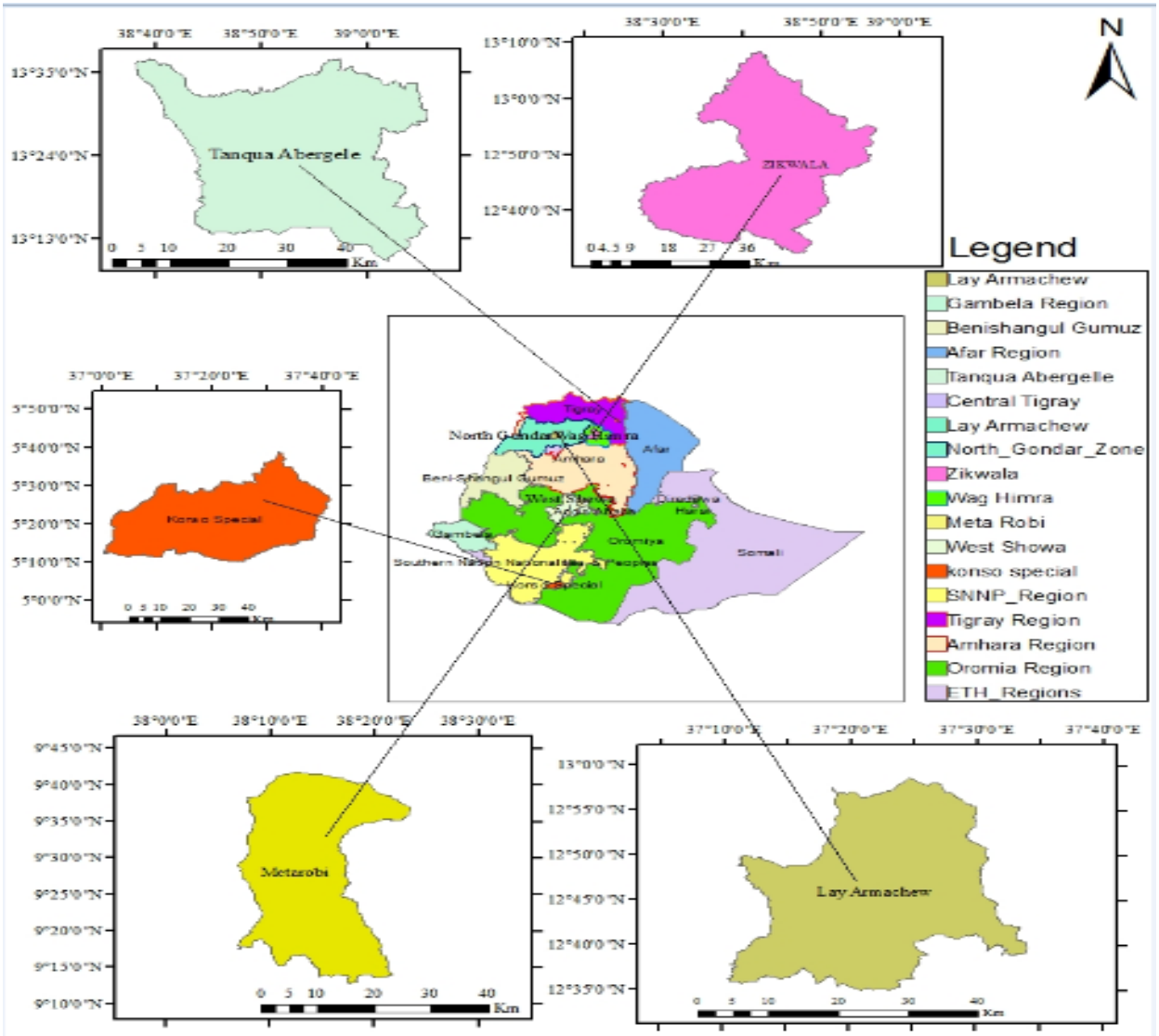

Figure 1. Geographycal locations of research sites (name of districts)

3.3. Assessment of Production Parameters

The effect of different non-genetic factors on production traits including 3mw KI and LSB were investigated. In the analysis of all traits, fixed effects of villages, year, season, type, sex, and parity of kids' birth were investigated. Parities of does were captured from owners at beginning of monitoring work of the base flock. In addition, effects of flock size and post-partum weight (ppw) of does were fitted. Three categories of flock size were created based on number of goats per household. These categories included <10 goats/household (HH), ≥10

&<20/HH and ≥20/HH. Doe ppw was fitted as linear covariate for the analyses of 3mw. The data collection duration was from mid July 2013 to Mid April 2015 for all breeds. *Ad hoc* enumerators were hired to collect data of production traits. The goat breeders' cooperatives formed in all villages backstopped enumerators in the data collection.

3.4. Productivity Analysis

Individual level productivity were assessed using two productivity indices including productivity expressed as the body weight of a 90 day old kids produced per doe per year (Index I) and per kg ppw per year (Index II). In this case, live weight at three months (LW3M) were calculated as the sum of weights per parturition per doe at three months from the collected data for the respective breeds. The influences of breed, year of birth and parity of birth were investigated for the indices using general linear model procedure of SAS (2002).

$y\ (Index\ I) = \frac{LW3M}{KI} \times 365$ (Peacock, 1987; Bosman *et al*., 1997) (1)

$\text{Index II} = \frac{\text{Index I}}{\text{PPW}}$ (Gbangboche *et al*., 2006) (2)

where y=live weight production per parturition in kg, standardized per annum, LW3M = Litter weight at three months after birth; KI=subsequent kidding interval.

Overall productivity was assessed and compared across the three indigenous goat breeds using index given bellow.

$y = \frac{N \times LSB \times S3M \times 3mw}{PPWm}$ (Peacock, 1987; Bosman et al., 1997) (3)

where y = productivity in kg live weight per kg post-partum weight per year; N = number of parturitions per year; LSB = litter size at birth; S3M = survival rate until three months; 3mw = live weight at three months (3mw = 3mwc for AB); PPWm = mean postpartum weight of does.

3.5. Description Of Simulated Alternative Breeding Scenarios

One tier community based breeding practice was taken as the base scenario (SN1) while three alternative scenarios were simulated in this study. The scenarios were; 1) addition of dam-side selection onto SN1 (SN2), 2) inclusion of genomic selection (SN3) and 3) systematic expansion of one tier to the two tier breeding (SN4). In the SN4, the number of additional breeding does targeted were assumed to be about three times the number of does in SN1.

3.6. Cost Calculation

With regard to costs, only additional variable costs (Nitter *et al*., 1994) were calculated . First, total variable costs per village were calculated. These variable costs relate to record keeping, animal identification and health care costs. Then the total variable costs were equally divided to each selection group. Within the selection group, the total variable costs were divided to the total number of animals in the selection group. Contrary to Mirkena *et al*. (2012) and Abegaz *et al*. (2014), higher interest rate of discounted returns than costs was assumed as such assumptions lead to more conservative discounted profit (Ehret *et al*., 2012). All costs were computed as of 15-April-2015 (1€ ≈ 21.9251 Birr). Breeding costs of SN2 and SN4 were assumed to be similar with that of SN1. Such assumption could be logical as larger selection proportion (80%) or lesser selection intensity is applied to young females in SN2 which could not necessarily require additional cost.

The step one selected bucks (S1Bs) that are assumed to be used for mating in additional breeding females in SN4 have been produced through SN1; there may be additional organizational costs but these would not be adequately estimated and thus were assumed to be negligible. On the other hand, additional €112.66 per animal variable cost was assumed for pre-genotyping and genotyping in SN3 on top of the variable costs in the SN1.

3.7. Phenotypic Correlation And Regression

Pearson correlation ("r") among growth traits in three indigenous goat breeds was made. Regression of market weights on BWT and 3MW was also analyzed. The CORR and REG procedures in the SAS (2004) were used to calculate the correlation and regression coefficients, respectively. The statistical significances were tested for the coefficients. The phenotypic correlation of BWT and 3MW, BWT and 6MW, BWT and 9MW, 3MW and 6MW, 3MW and 9MW were investigated. In addition, 6mw and 9mw were regressed on BWT and 3MW and presented.

The present data analysis was reinforced by referring to the available weighted average genetic parameter estimates. The weighted average estimates included phenotypic and genetic correlations and direct genetic and direct maternal heritability estimates. The weighted average estimates are considered to be reliable and were presented based on pooled literature parameter estimates.

4. GENERAL RESULTS

4.1. Average Literature Genetic Parameters

Average literature genetic parameters including h_a^2, h_m^2, c^2, R, r_g and r_p are presented for 41 growth, reproduction and milk production traits in goats. The averages were unweighted and weighted (Paper I). Considering unweighted h_a^2 only, the most studied traits measured by number of independent studies (in parenthesis) in order of importance, were birth weight (54), three month weight (41), six month weight (23), 12 month weight (21), pre-weaning daily gain (17) and litter size at birth (17). Unweighted average h_a^2 ranged from 0.05 to 0.51, 0.06 to 0.29 and 0.19 to 0.53 for growth, reproduction and milk production traits, respectively. The ranges of weighted average h_a^2, h_m^2 and c^2 estimates for growth traits were from 0.03 to 0.45, 0.05 to 0.27 and 0.02 to 0.10, respectively.

For traits allowing comparison, unweighted repeatability (R_u) was higher than their weighted reputability (R_w). The repeatability estimates of pre-weaning growth traits were not always higher than estimates for the post weaning growth traits as it is expected. For instance, R_u for birth weight (bwt) was not greater than R_u for three month weight (3mw), six month weight (6mw), nine month weight (9mw) and average daily gain from weaning to six months (ADG2). On the other hand, R_u for 1mw was higher than R_u for all growth traits including birth weight.

Unweighted average r_p and r_g among growth traits ranged from -0.25 to 0.95 and from -0.20 to 0.98, respectively. The range of weighted average r_p and r_g among growth traits were from -0.06 to 0.84 and from 0.01 to 0.94, respectively. Unweighted average r_p was accompanied by smaller standard errors whereas unweighted r_g had larger standard errors.

4.2. Production And Productivity Parameters

4.2.1. Three months weight, kidding interval and litter size at birth

The overall mean of 3mw (kg) were 7.44, 10.96 and 9.38 for AB, CH and WG goat breeds, respectively. Generally, wet season, male sex, single birth and smaller flock size resulted in significantly ($p<0.05$) higher 3mw in the three breeds. The overall means of KI were 362, 268 and 309 days for AB, CH and WG goat breeds, respectively. While KI of does for CH did not significantly ($p>0.05$) differed by villages of production, none of the fixed effects significantly ($p>0.05$) captured the variations of KI in WG. The overall means of the LSB for AB, CH and WG goat breeds were 1.03, 1.40 and 1.09 per doe per parturition, respectively. LSB from earlier parities were significantly ($p<0.05$) smaller than LSB from latter parities in all the breeds.

Considering all the three traits studied, CH goat breed had the highest 3mw, shortest KI and the highest litter size at birth and the AB goat breed is on the other end. This could be due to the fact that CH goat breed are suited and reared in favourable environments where relatively sufficient feeds are available. The AB goat breed is adapted to the very harsh environment where feed shortage is the limiting factor of their performances.

4.2.2. Productivity at individual and flock level

Goat productivity at individual and flock level were assessed using three indices (Paper II). Live weight production (kg) per parturition or per doe (Index I) was used to compare goats based on the amount of 3mw produced per doe per year. The overall mean values of Index I was 16.66 kg. Index I values were 7.91, 22.19 and 12.91 kg, for AB, CH and WG goat breeds, respectively. Using index II, the amount of 3mw produced per ppw was assessed which was 0.32, 0.69 and 0.52, respectively for AB, CH and WG goat breeds, respectively. The CH breed had significantly ($p<0.001$) higher index I and index II followed by the WG breed. Generally, CH goat breed had the highest overall flock productivity and AB goat breeds had moderate overall flock productivity.

4.3. Predicted Annual Genetic Gains And Breeding Costs

Four breeding scenarios including the current breeding practice (sire side selection only) were optimized for the three indigenous goat breeds (AB, CH and WG) in Ethiopia. The breeding scenarios were compared based on PAGGs and discounted profitability. PPAGG in 6mw (kg) were highest in SN3 followed by SN2, SN1 and SN4. The PAGGs in 6mw, from all the scenarios, ranged from 0.308 to 0.467 for CH from Gonder site, 0.209 to 0.311 for CH from Ambo site, 0.188 to 0.270 for WG and 0.174 to 0.249 for AB. The highest PAGGs in 6mw were obtained for CH Gonder site, followed by CH Ambo site; the smallest values for the PAGG in 6mw were for AB goat breed. The same sequence of superiority of PAGG in KI, for WG goat breeds from the scenarios (SN3>SN2>SN1>SN4) as in 6mw, was observed which ranged from 0.167 to 0.419. PAGG in LSB, LSW, SURV is small. All the alternative breeding scenarios made considerable improvements to the current breeding scenarios especially in 6mw. The PAGG in the rest selection criteria were not impressive implying adequate management actions should be part of the breeding activity.

Except for SN3 all the rest scenarios resulted in positive marginal profitability. SN4 resulted in the highest marginal profits, followed by SN2 for three sites while the profit from SN2 was higher than from SN4 for CH Ambo site. The genomic selection scenario, SN3, was not profitable, due to the assumed highest pre-genotyping and genotyping costs. The alternative breeding programs for AB were more profitable than for the other goat breeds and sites, while the smallest profits were achieved with WG. The values (€; 1€ = 21.9251 Birr on 15-April-2015) for profitable scenarios ranged from 0.134 to 0.345 for AB, from 0.048 to 0.098 for CH Ambo, from 0.035 to 0.158 for CH Gonder and from 0.005 to 0.167. The highest profitability in AB was due to the fact that the number of animals involved in the breeding program was the highest compared to the other goat breeds (Paper III).

4.4. Pearson Correlation of Birth Weight with Market Weights

Acknowledging that keeping accurate birth weights under farmer's condition is cumbersome, the phenotypic correlation of birth weight with market weight was investigated to reach at informed decision whether to drop birth weight recording in the CBBPs. The present study, from the three goat breeds (AB, CH and WG), revealed that Pearson correlations ("r") of BWT

with the market were small or even equal to zero in some cases. For instance, the "r" between BWT and 6MW for WG and between BWT and 9MW for CH were not significantly ($p>0.05$) different from zero. It was indicated that BWT had weak "r" with both 6MW (0.099 to 0.176) and 9MW (0.051 to 0.163) regardless of the goat breeds. Literature reports on genetic correlations between birth weight and subsequent weight also revealed very weak associations (Koots *et al.*, 1994b; Lobo *et al.*, 2000; Safari *et al.*, 2005). The weak association of birth weight with both 6MW and 9MW could be due to the fact BWT is affected by the maternal environments in the uterus compared to 3MW. Regardless of their satisfactory " **b"** values (ranging from 0.311 to 0.996), the adjusted R-square for regressing 6MW and 9MW on BWT was considerably low, ranging from 0% to 3 %, lessening the reliability of using BWT to regress market weights.

5. GENERAL DISCUSSION

5.1. Average Literature Genetic Parameters

Genetic parameters are required to plan genetic improvements in livestock. These genetic parameters are either lacking or estimated based on small dataset in the developing countries. When the genetic parameters are estimated based on small dataset, the accuracy of estimating the genetic parameters is generally low making the reliability of the estimates questionable. In quantitative genetics, it is commonly believed that estimates of genetic parameters should refer to the population in which they are estimated. On the other hand, reports are available concluding that the belief that genetic parameters should refer to the population in which they are estimated should not be a universally accepted principle (Koots and Gibson, 1996).

In Paper I, literature average genetic parameters were presented for 41 goat traits. Initially, calculating average estimates of genetic parameters were meant for the CBBP of goats initiated in Ethiopia; however, latter on the meta-analysis was presented in such a way that its application could be at global level. The genetic parameters presented could be extracted as needed where such information is lacking.

The most studied traits, considering h_a^2 only, measured by number of independent studies (in parenthesis) in order of importance, were bwt (54), 3mw (41), 6mw (23), 12mw(21), pre (17) and LSB (17). The number of studies per average estimates could be an indication of the attention given to a trait, ease of measuring a trait and the associated costs of recording the traits as well.

The reliability of average estimate from literature, both unweighted and weighted, could be measured, among others, by comparing the SD and PSE. Generally, the SD is expected to be smaller than PSE which was estimated based on formula. The differences between SD and PSE could indicate gross underestimation of PSE, the possibility of real differences among heritabilities or both (Koots *et al*., 1994a; Koots and Gibson, 1996). In the earlier reports, it is generally recommended that weighted averages, especially in the ratios (h_a^2, h_m^2 and c^2),

should be preferred to the unweighted ones. In the present study, we found that SDs of unweighted ratios (h_a^2, h_m^2 and c^2) were less than or equal to the PSE for some traits. On top of this, some unweighted ratios were conservative (smaller in magnitude) than the weighted ones. When such situations happen, one should not insist on using the weighted average; we mean that there could be also situations where unweighted estimates could be preferred to the weighted average estimates.

Generally, maternal influence tended to be high on traits manifested in early life and magnitude of h_a^2 shows an increment with age of animals when individual animals become independent of their mothers (Niekerk, 1996; Rashidi *et al*., 2008; Gholizadeh *et al*., 2010; Osman, 2013). However, the relatively small values of h_m^2 and c^2, in general, in the present study indicate that it could be less likely for h_a^2 to be inflated if h_m^2 and c^2 are excluded from a model.

Moderate or high repeatability estimates indicate that successful selection could be feasible for that trait (Alade *et al*. 2010; Faruque *et al*., 2010; García-peniche *et al*., 2012; Hasan *et al*., 2014).

The correlation values tended to be higher for age-adjacent traits. For instances, the unweighted r_g value between bwt and 3mw was higher (0.55) compared to the unweighted r_g between bwt and 12mw (0.33). This could be due to the fact that adjacent traits are most likely to be affected by common genes. In some of the cases, for instances both r_p and r_g, the correlations between pre and 3mw were negative but with the magnitude around zero, which could mean two of the traits may not have genes in common in the case of genetic correlation and common phenotypic factors in common in the case of phenotypic correlations. In general, when the magnitude of a correlation is positive and high, improvement in one traits also improves the correlated trait and when the magnitude of a correlation is negative and high improving one trait will degrade the correlated trait. Therefore, care should be taken in planning the co-improvement of traits especially when their genetic correlation is negative; for instance the litter size at birth and the weight traits in the present study.

5.2. Production And Productivity Studies

Three month weight was one of the production trait investigated in the present study. Generally, wet season, male sex, single birth and smaller flock size resulted in significantly ($p<0.05$) higher 3mw in the three breeds.

Wet season of birth could have positive effect on 3mw because kids born in wet seasons had two advantages: 1) in the wet seasons the availability of feed is likely to be high; when the feed availability is high does produce more milk for their kids, by feeding more feeds; 2) when the feed availability is high, kids eat the available feeds in addition to the milk they suckle from their mothers. If kids are favoured by such conditions around their birth time (wet season of birth), their 3mw is likely to be high.

Concerning the effect of sex, male kids had higher 3mw than female kid which could be associated to hormonal difference of the two sexes. In relation to endocrinal system, oestrogen hormone has a limited effect on the growth of long bones in females and resulted in lighter body weight of females than males (Ebangi *et al*., 1996; Rashidi *et al*., 2008; Roshanfekr *et al*., 2011).

The single born kids had significantly ($p<0.05$) higher 3mw than twin born kids. This could be associated with resource competition. Starting from the uterine environment, single born kids have no competition on resources compared to the twin born ones. That means the birth weight of single born kids is likely to be higher than twins. After birth, the same situation continues: kids born with the highest birth weight (single born ones) have the chance to suckle their dams being one whereas the twin born kids (born with smaller birth weight) compete on their dam's milk. Such situations could have resulted in the smaller 3mw of twin born kids compared with singles. This effect of litter size on live weight, 3mw here, could imply that additional management situation, which could be supplementation, should be designed to favour the twin born kids.

5.2.1. Kidding Interval and Litter Size at Birth

The availability of feed is most likely to be the modulating factor (Mukasa-Mugerwa and Lahlou-Kassi, 1995; Gbangboche *et al.*, 2006; Bushara *et al.*, 2013) of KI and LSB, among other factors. When feeds are available in abundant, does have high chance of conceiving following a given parturition, but also with the high chance of multiple ovulation. Generally, the environments in which, AB, CH and WG live are arid pastoral, crop-livestock mixed farming and semi-arid pastoral production systems (Tatek *et al.*, 2016). The feed availability rating based on the production systems (from high to low) could be crop livestock-mixed farming, semi-arid agro pastoral and arid pastoral (one can relate the rating to the moisture availability in the production systems). That could be the reason why the KI and LSB of AB goat breed was the longest and the smallest, respectively compared to the other goat breeds. Owing to the same reason, the KI and LSB of CH was the shortest and the highest, respectively.

5.2.2. Goat Productivity Indices

Comparing the production performance of animals reared in different production systems could not be fair. For example, it is neither informative, nor fair to compare different breeds on their 3mw. On the other hand, the breeds could be compared after standardizing performances, like using productivity indices (Peacock, 1987; Bosman *et al.*, 1997). The indices used for comparing the breeds in the present study were the measure of the productivity efficiencies. Such indices could be used to compare different breeds or sub-breeds reared in different environments. Additional, efficiency measuring indices could also be considered including expression 3mw doe productivity expressed in terms of metabolic body weight and Klieber ratio (Kiliber ratio is body weight gain per weaning weight, for example).

5.3. Selection Criteria Versus Predicted Annual Genetic Gain and Profitability

Definition of breeding objective traits and hence selection criteria has its own procedures (Duguma, 2010; Haile *et al.*, 2011;Tatek *et al.*, 2016; Zergew *et al.*, 2016). While working

with the community, it is important to consider the ideas of the community. Higher PAGG in a given selection criteria is expected if it has higher variability preferably in terms of genetics (high heritability). Therefore, one can ask a question "Why one attempts to improve a trait, by selection, when it has low heritability?" It may be simply to address the ideas of farmers, but considering such traits to be improved by selection is out of the principle of quantitative genetics and should be thought over in the subsequent CBBPs.

The other issues associated with the selection criteria is in relation to calculation of breeding costs. The marginal profitability is calculated as the difference of marginal value selling price of a unit of a trait and the marginal cost of a unit of a trait. For instance, if a unit of additional cost is invested on a trait, then additional unit of a trait will be produced to be sold (if two additional birr is invested on milk production of a goat, it may improve the milk production by 0.5 lit; if the selling price of a unit of milk is five birr, then the economic value of milk for instance is birr 2.5 - birr 2.0 = birr 0.50 (Täubert, email communication, November 2, 2016; email: helge.taeubert@vit.de,). For some of the selection criteria, it is difficult to calculate a unit improvement associated with additional costs (for example survival traits and reproduction trait). In such cases, relative economic weight (illustrated in FAO (2010)) could be used but it also had its limitation. Therefore, while determining a selection criteria for a breeding program, traits on which effects of additional cost could be reflected in their additional unit improvement should be considered.

5.4. Alternative Breeding plans

The three alternative breeding scenarios/plans optimized in the present work resulted in a better genetic improvement than the current breeding scenario (the sire side selection only) especially in terms profitability except for the genomic selection scenario. In the genomic selection scenario, higher pre-genotyping and genotyping costs were assumed leading to negative profitability. As the genotyping costs are getting down, the application of genomic selection could be promising in the CBBP of small ruminants, probably in near future.

In the CBBP, considerable number of female kids are produced like the male kids. Currently, new born female kids in the CBBP are not given due attention or are considered for the replacement only (Mirkena *et al.*, 2012; Gizaw *et al.*, 2014a; Gizaw *et al.*, 2014b). Two points can be raised in relation to assuming all the female kids for replacement: 1) the new born kids join the real breeding situation after few months which means the number of these new born female kids should be considered in the calculation of the male to female ratio; 2) the number of the new born female kids is not small to ignore them from selection (for instance, about 220 new born female kids were projected based on 303 initial does in the case of CH Gonder site - Paper III). For these facts, planning selection on the female side could be logical in the CBBP for goats and sheep as well.

Selection on the females would not be as easy as selection of sires. The fact that females are used by individual owners in the community-based breeding program complicate the design of females selection. This needs alternative approaches to be tested; having frequent discussion with the farmers could be one approach. Another approach is considering females selection at individual owner level which could be by far better than ignoring female kids from selection. Sires selection is not that much difficult because bucks (sires) could be used in common. Systematic expansion of one tier breeding program in to two tier was the most profitable breeding scenario which should be considered as an alternative to the current breeding scenario.

5.5. Recording Birth Weight in the Community-Based Breeding Program

Community based breeding programs have been implemented in different parts of the world, particularly for small ruminants (Dugumal, 2010; Haile *et al.*, 2011; Abegaz *et al.*, 2014; Muellur *et al.*, 2016a; Muellur *et al.*, 2016b). In Ethiopia, village based sheep and goat breeding programs have been initiated and are on-going. Since the start of these CBBPs, birth weight was among the traits identified to be recorded (Alubel, 2015; Duguma, 2010). In practice, however, keeping accurate birth weight is difficult. Enumerators hired to keep records, could not keep accurate birth weight records; for instance, reporting more than 5kg birth weight of sheep was common in the CBBP of sheep at Horro. The challenge was that

enumerators could not capture birth weights within 24 hours after birth probably due to the scattered settlement of the farmers and weak communication between farmers and enumerators on new born kids.

The base of paper IV was failure to keep accurate birth weight. In order to systematically report that recording birth weight was of no use, Pearson correlation of birth weight with market weights was conducted. Birth weight had weak phenotypic (our results) and genetic (literature reports) correlation with the market weights indicating that the trait could not be used for indirect improvement of the market weight traits.

It does not mean that keeping birth weight records is of no use; for instance birth weight could be an indication of survival ability of the kids. The point is, as long as accurate birth weight is not kept, right implications of birth weights could not be captured. As an alternative, kids weight within three to five days after birth could be considered. It should be noted that the date of birth of kids could be kept easily even by owners.

6. GENERAL CONCLUSION AND RECOMMENDATION

A meta-analysis of average estimates of h_a^2, h_m^2, c^2, R, r_g and r_p were presented for 41 growth, reproduction and milk production goat traits. Such types of estimates are presented for the first time for goats but are available for cattle (Koots *et al.*, 1994a, b; Koots and Gibson, 1996; Lobo *et al.*, 2000; Cammack, 2009) and for sheep (Safari *et al*., 2005). The estimates could be used globally where such information is lacking. The weighted average h_a^2, h_m^2, c^2, R and r_g should be preferred to unweighted averages. The weighted estimates h_a^2 for some growth traits were more conservative than the corresponding average values based on relatively higher number of records. The absence of significant differences for the tested fixed factors on parameter estimate in growth traits also reinforces reliability of the weighted averages presented here. In general, accurate estimation of genetic parameters in developing countries could not be easily possible. The reason is that, maximum possible number of breeding animals, which is one way of estimating accurate genetic parameter, could not be ensured in developing countries; hence, better to combine the local estimates with the weighted averages presented in this dissertation.

In general, CH goat breed was found to be the most productive using the three indices. The higher productivity index values from these indices for CH breed is associated with higher LW3M, LS3M and shorter KI compared to the other two breeds. KI in AB breed was longest compared to the other two breeds due to harsh environments not favouring fastest onset of subsequent parturitions. Improvements in the production traits and then productivity at individual and flock level could be attained by minimizing the effects of environmental stresses.

The present productivity indices can be used in comparison of within and/or between breeds of goat productivity in particular and small ruminant productivity in general. When comparison is to be made between breeds of between breeds like AB and CH (milk is important trait in AB goat breed but not in CH goat breed), correction should be made to growth of kids by considering the amount of milk consumed by owners which would have been consumed by

kids, especially when calculating the overall flock productivity. The indices could be used under on-farm productions where recording required parameters are manageable.

All the four scenarios optimized in paper III resulted in relatively higher PAGGs, especially for 6mw. PAGGs from SN3 were the highest, but this scenario was associated with the highest variable costs resulting in negative discounted profit. The PAGGs for the rest traits were not impressive. Generally, SN4 resulted in the highest profitability.

Birth weight had weak phenotypic correlation with 6MWand 9MW in the three indigenous goat breeds in Ethiopia. The regression of 6MW and 9MW on BWT was not reliable because of low (less than three per cent) adjusted R-square.

SCOPES FOR FUTURE STUDY

- In the present study, effects of management levels and statistical methodology were investigated. Future studies should confirm the present finding by generating sizable dataset from literature. The effect of breed/population on the parameter estimates also need to be investigated. The covariance among genetic parameters could also be another area demanding investigation.

- In the present study, only few productivity indices were used to compare the three indigenous goat breeds. Future works shall focus on other productivity indices so that the productivity efficiency of different breeds or sub-breeds could be clearly seen.

- In the present work, selection on the dam-side was recommended as an alternative to the current scenario of CBBP of small ruminants. Future works should focus on how to make the approach practical.

- Since accurate recording of birth weight was found to be difficult under CBBPs of small ruminants, dropping record keeping of birth weight was suggested. Future works should investigate if three to five days weight could serve the function of birth weight.

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8. APPENDICES

8.1. Paper I

Meta-analysis of average estimates of genetic parameters for growth, reproduction and milk production traits in goats

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Abstract

A meta-analysis of 84 published reports on goats was conducted to calculate weighted and unweighted average direct heritability (h_a^2), maternal genetic effect (h_m^2), ratio of common environmental effect (c^2), repeatability (R), genetic (r_g) and phenotypic (r_p) correlations for growth, reproduction and milk production traits. Weighted average h_a^2, h_m^2, and c^2 for growth traits ranged from 0.03 to 0.45, 0.05 to 0.27, and 0.02 to 0.10, respectively. Corresponding weighted average h_a^2 for reproduction and milk production traits ranged from 0.00 to 0.17 and 0.15 to 0.22, respectively. Weighted R for the growth, reproduction, and milk traits ranged from 0.06 to 0.56, 0.06 to 0.13, and 0.50 to 0.61, respectively. Weighted averages of r_p and rg among growth traits ranged from -0.06 to 0.84 and 0.01 to 0.98, respectively. Weighted average r_p among milk traits ranged from 0.18 to 0.94. In most cases average h_a^2 and r_g had higher observed standard deviations compared to the theoretical standard error. Based on the present findings, it seems that weighted average h_a^2, h_m^2, c^2 , R, and r_g are more reliable for two reasons: estimates of h_a^2 for some growth traits were more conservative than values based on relatively higher number of records and the absence of significant effects of the tested fixed factors on some parameter estimates. More studies on genetic parameter estimations are required for growth, reproduction, and milk traits in goats.

Key words: Correlation; goat; heritability; weighted averages; reliability.

1. Introduction

Goats significantly contribute to the national economy and livelihood of the poor in many developing countries (Peacock, 2005; Aziz, 2010). However, their productivity in developing world systems is often low as a result of many interrelated factors including the genetic potential of the indigenous stock. Planning and implementing sustainable breeding programs has the potential to contribute to bridging the performance gap with developed countries. Genetic parameters including genetic correlations and heritabilities are required for planning breeding strategies and genetic evaluation programs in livestock (Willam *et al*., 2008).

In quantitative genetics it is commonly believed that the genetic parameters refer to the population in which they are estimated. However, sufficient time and suitable data limit the parameter estimations available for specific populations (Koots *et al*., 1994a, b). Even when parameter estimates are available, according to these authors, precision is generally low. On the other hand, Koots and Gibson (1996) indicated that referring estimates of genetic parameters to the population in which they are estimated should not be a universally accepted principle. Values estimated elsewhere could be used for populations with no parameter estimates. Little or no differences in parameter estimates between populations or breeds (Koots and Gibson, 1996) encouraged the use of parameters estimated elsewhere. Hence, the genetic parameters might be more accurately estimated by pooling results from literature and combining them with specific population estimates (Koots *et al*., 1994a, b; Koots and Gibson, 1996; Lobo *et al*., 2000), where available.

There are different ways to pool and present genetic parameter estimated from literature. For instance, Cammack *et al*. (2009) summarized in the form of ranges; Utrera and Vleck (2004) presented in the unweighted form; Safari *et al*. (2005) presented in the weighted form; Koots *et al*. (1994a, b) and Lobo *et al*. (2000) presented both unweighted and weighted forms.

Different genetic parameters were reported by different authors. for instance, in Cammack *et al*. (2009) and Utrera and Vleck (2004) direct heritabilities were summarized. In Koots *et al*. (1994a, b) and Loblo *et al*. (2000) comprehensive estimates, including weighted and unweighted heritability and correlations were presented; in Safari *et al*. (2005) weighted

parameters were estimated. Comparison of the theoretical or predicted standard error (PSE) with observed standard deviation (SD) was also made in Koots *et al*. (1994a, b). Higher PSE than SD could indicate the presence of systematic differences between breeds in estimates. Studies made so far did not report maternal heritability, ratio of common environmental effect and repeatability estimates.

While literature estimates of genetic parameters are available for cattle (Koots *et al*., 1994a; Koots *et al*., 1994b; Lobo *et al*., 2000; Utrera and Vleck, 2004; Cammack *et al*., 2009) and sheep (Safari *et al*., 2005), such reports are lacking for goat traits. Therefore, this review aims at filling these gaps and contributing to the global goat genetic improvement initiatives. While the need for genetic parameters in goats was realized during the implementation of a community based breeding program of goats in Ethiopia, the average of the meta-analysis presented here targeted towards global application. The specific objectives this paper are to present unweighted and weighted average direct heritability (h_a^2), maternal genetic effect (h_m^2), common environmental effect (c^2), repeatability (R), and correlations for growth, reproduction, and milk production traits in goats based on meta-analysis of published literature. To reveal reliability of estimates, values from this meta-analysis were also compared with the average values from studies with relatively high records.

2. Materials and methods

2.1. Construction of the dataset: choice of papers and traits studied

A data set of genetic parameters for growth, milk and reproduction traits was constructed from 84 independent publications. The following criteria were used for including estimates from a paper in this study: the paper (1) that presented informative descriptions of estimates and (2) presented reports standard errors for heritability and/or the number of observations. One thousand two hundred twenty-nine estimates (551 including h_a^2, h_m^2, c^2 and R and 678 correlation estimates) were used. The number of papers by country and citations by breed are presented in Tables 1 and 2, respectively. Traits related to growth, fertility, milk production, survival and productivity which have practical importance for goat breeding programs were included in the study (Table 3).

Table 1. Number of reports by countries

№ of reports	Countries
10	Iran
8	India
5	Bangladesh, China, Nigeria, South Africa, Thailand
3	Ethiopia, France, United States of America
2	Brazil, Croatia, Italy, Mexico, New Zealand, Saudi Arabia, Serbia, Sudan
1	Arab Emirate, Caribbean, Gambia, Indonesia, Iraq, Japan, Mediterranean basin, Morocco, Norway, Pakistan, Poland, Ruanda, Slovenia, Syria, Tanzania, Turkey
84	Total reports

Table 2. Papers cited by breed

Breed	References
Alpine	Bélichon *et al*., 1998; Brenik *et al*., 2000; Mourad and Anous, 1998; McManus *et al*., 2008; García-peniche *et al*.2010; Kantanamalakul *et al*., 2010; Brito *et al*., 2011; Kasap *et al*.,2012; Montaldo *et al*., 2012.
Saanen	Bélichon *et al*., 1998; Brenik *et al*., 2000; Kosum *et al*., 2004; Valencia *et al*., 2007, Kantanamalakul *et al*., 2008; McManus *et al*., 2008; Supakorn and Pralomkarn, 2009;Torres-Vázquez *et al*., 2009; Montaldo *et al*., 2010; Morris *et al*., 2011; Brito *et al*., 2011; Ishag *et al*., 2012; Supakorn and Pralomkarn, 2012, Thepparat *et al*., 2012; Kasap *et al*., 2013.
Angora	Snyman and Olivier, 1996; Snyman, 2012,
Anglo-Nubian	Kantanamalakul *et al*., 2008; Supakornand Pralomkarn, 2009; Supakorn and Pralomkarn, 2012; Thepparat *et al*., 2012.
Thai-Native	Kantanamalakul *et al*., 2008; Supakorn and Pralomkarn, 2009; Anothaisinthawee *et al*., 2012; Supakorn and Pralomkarn, 2012; Thepparat *et al*., 2012.
Arsi-Bale	Bedhane *et al*., 2012; Kebede *et al*., 2012; Bedhane *et al*., 2013.

Table 2 Continued

Black-Bengal	Faruque *et al*., 2010; Mia *et al*., 2013a; Mia *et al*., 2013b; Mia *et al*., 2014
Boar	Nieker, 1996; Schoeman *et al*., 1997; Hongping *et al*., 2002; Zhang *et al*., 2008, Zhang *et al*., 2009a, Zhang *et al*., 2009b
Creole	Gunia *et al*., 2011
Draa	Boujenane and Hazzab, 2008
Iranian indigenous	Shamshirgaran and Tahmoorespur, 2012
Kotchi	Yadav *et al*., 2004; Yadav *et al*., 2009
Markhoz	Rashidi *et al*., 2008; Rashidi *et al*., 2011; Rashidi *et al*., 2015
Nubian	Montaldo *et al*., 2010; García-peniche *et al*., 2011
Raeini	Gholizadeh *et al*., 2010; Barazandeh *et al*., 2012a; Barazandeh *et al*., 2012b; Mohammadi *et al*., 2012.
Toggenburg	McManus *et al*., 2008; Montaldo *et al*., 2010; García-peniche *et al*., 2012;
Jamunapari	Roy *et al*., 2008; Singh *et al*., 2009a; Singh *et al*., 2009b
LaMancha	Montaldo *et al*., 2010; García-peniche *et al*., 2012
Zaraebi	Shaat *et al*., 2007; Hamed *et al*., 2009; Shaat and Maki-Tanila, 2009; Osman, 2013.
West African Dwarf	Odubote, 1996; Bosso *et al*., 2007; Otuma and Onu, 2013
Adani	Dashtizadeh *et al*., 2012
Naeini	Baneh *et al*., 2012
Aradi	Al-Saef, 2013; Al- Saef and Mousa, 2013
Norwegian	Bagnicka *et al*., 2007
Polish	Bagnicka *et al*., 2007
Balkan	Petrović *et al*., 2012
Oberhasli	García-peniche *et al*., 2011
Blended	Rege and Shibre, 1994
Emirate	Al-Shorepy *et al*., 2002
New Zeland Cashmere	Baker *et al*., 1991
Red Sokoto	Ishag *et al*., 2012
Ettawa Grade	Hasan *et al*., 2014
Exotic	Hassan *et al*., 2013
Sahelian	Otuma and Osakwe, 2008
German fawn	Ćinkulov *et al*., 2006
Sirohi	Gowane *et al*., 2011
Iraqi local	Hermiz *et al*., 2009

Table 2 Continued

Jakhrana	Mandal *et al*., 2010
	Portolano *et al*., 2002
Sicilian	
Girgentana	
Table 2 Continued	
Long leg goat	Otuma and Onu, 2013
Local (Goat)	Alade *et al*., 2010
Sudanese	Ballal *et al*., 2008
Nubian	
Maltese	Delfino *et al*., 2011
Marwari	Raj *et al*., 2001
Matabele	Assan *et al*., 2011
Mediterr	Mavrogenis, 1988
anean	
US Dairy goat	Castañeda-Bustos *et al*., 2014
Teddy	Tahir *et al*., 1995
Common West	Mouradand Anous, 1998; Kantanamalakul *et al*.,
African Dwarf	2010

Table 3. List of traits included in the study (with abbreviations)

Weight traits	birth weight (bwt), 20 (20d) and 70 (70d) days weights, one (1mw), two (2mw), three (3mw), four (4mw), five (5mw), six (6mw), seven (7mw), eight (8mw), nine (9mw), 11 (11mw), 12 (12mw), 16 (16mw) and 18 (18mw) month weights
Growth traits	average daily gains during pre-weaning (ADG1), daily gain from three to six months (ADG2), six to 12 months (ADG3)
Reproduction traits	kidding interval (KI), 1st kidding interval (1st KI), litter size at birth (LSB), litter size at weaning (LSW), litter weight at birth (LWB), gestation length (GL) and age at first kidding (AFK).
Efficiency traits	Kleiber Ratio (KR)
Survival rate	survival to weaning
Milk production traits	average daily yield (ADM), ninety days (90DMY), five months (150MY), nine months (270MY) first lactation (1stLMY) and lactation (LMY) milk yields; protein (PROTY) yield, fat (FATY) yield, protein percentage (P%), fat percentage (F%), combined protein and fat (COMB P&F), ratio of protein to fat (Ratio P:F) and lactation lengths (LL).

2.2. Average genetic parameters

Unweighted and weighted average parameters including direct heritability (h_a^2), maternal heritability (h_m^2) and ratio of common environmental effect (c^2), repeatability (R) and phenotypic (r_p) and genetic (r_g) correlations were calculated. Unweighted averages across publications were obtained directly for h_a^2, h_m^2, c^2 and R and correlations, with SD, where applicable. In addition, PSE (average of weighted standard errors) were presented for h_a^2, h_m^2, c^2 and R. For both r_p and genetic r_g, average of weighted standard errors and observed standard deviations were provided.

For the calculation of weighted average h_a^2, h_m^2, c^2 and R, the inverse of their variances were used as per the procedure described by Koots *et al*. (1994a). For estimates reported with number of records but without standard errors, weighted averages were calculated by the variance proportional to inverse of the number of records as proposed by Safari *et al*. (2005).

Applying the procedure proposed by Koots *et al*. 1994a, weighted averages of the h_a^2, h_m^2, c^2 and weighted repeatability (R_w), from published estimates were pooled as follows: $p^2\ pooled = P/E$: where P is $\sum_{i=1}^{y} p_i/(SE_{p_i^2})^2$ and E is $\sum_{i=1}^{y} 1/(SE_{p_i^2})^2$; where y is number of studies (note that p_i^2 and $SE_{p_i^2}$ represent h_a^2, h_m^2, c^2 and R_w and their respective weighted standard error in the formula). Safari *et al*. (2005) calculated $SE_{p_i^2}$ based on the number of records for the trait as follows: $SE_{p_i^2}\ is\ \frac{WSD}{(n)^{1/2}}$ where WSD is weighted mean of reported standard errors and n is number of records; WSD was again calculated as follows where s_i is reported standard error, n_i is number of records and y is number of studies)

$$WSD = \left[\sum_{i=1}^{y} s_i^2 n_i^2 \Big/ \sum_{i=1}^{y} n_i\right]^{1/2}.$$

When reported heritability estimates were not accompanied with the number of records, published standard error ($SE_{\hat{h}^2}$) was adjusted to the mean heritability and calculated using the

following formula (Koots et al., 1994a): $SE_{\hat{h}^2} = \left[\left(\bar{p}^2 / \hat{p}^2 \right) \times SE_{\hat{p}^2} \right]^{1/2}$. The standard error for the pooled heritability estimates was estimated as follows (y = number of studies) (Koots *et al*., 1994a). $SE\ (\hat{p}^2\ pooled) = \left[\frac{1}{\sum_{i=1}^{y} 1 / SE_{\hat{p}_i^2}} \right]^{1/2}$

2.3. Weighted average correlations

Weighted average phenotypic and genetic correlations were transformed to an approximate normal scale using Fisher's Z transformation as follows (r= correlation value): $Z = 0.5 log \left[\frac{r+1}{r-1} \right]$. The standard error ($SE_Z$) of Z was obtained using the following equation (n= number of records for phenotypic correlations (Safari *et al*., 2005) and number of sires for the genetic correlations (Koots *et al*., 1994b): $SE_Z = [n-3]^{-1/2}$. Then values for Z were pooled over studies by weighing with the inverse of their sampling variance (squared SE_Z) as follows: $Z_{pooled} = \frac{\sum_{i=1}^{n} Z_i / (SE_{Z_i})^2}{\sum_{i=1}^{n} 1 / (SE_{Z_i})^2}$.

The mean pooled Z values were then transformed back to correlations as follows: $r = \frac{((e^{2Z}) - 1)}{((e^{2Z}) + 1)}$.

2.4. Least squares analyses of variance for some growth traits

Least squares analyses of variances were conducted for the most frequently estimated growth traits including bwt, 3mw, 6mw, 9mw and 12mw. These allowed to test the effects of management level and methods of genetic parameter estimation on average genetic parameter estimate, namely h_a^2, r_g and r_p, The following model was used:

$Y_{ijk} = \mu + P_i + M_j + e_{ijk}$,

where Y_{ijk} is parameter estimates (h_a^2, r_g and r_p), μ = overall mean, P_i is the management level as defined in the methodology of papers (extensive, semi-intensive and intensive) and M_i is method of estimation (animal method and regression of offspring on parents) and e_{ijk} is the error term.

In order to reveal the reliability, average estimates of h_a^2, r_g and r_p from relatively higher number of records (h_a^2 (n>3000), r_g and r_p (n>1000)) were compared with values presented here.

3. Results and Discussion

This study presents unweighted and weighted average estimates (h_a^2, h_m^2, c^2 and R) and correlations (r_g and r_p) from 84 independent studies for growth, reproduction and milk production traits in goats. The present study is more comprehensive compared to former studies on sheep and cattle that presented h_a^2 and correlations only. The number of publications or papers used for such type of study on cattle and sheep is higher; for instance, Koots and Gibson (1996) used 286 papers; Koots *et al*. (1994a) used 287 papers; Lobo *et al*. (2000) used 490 papers; Safari *et al*. (2005) used 165 studies. However, Utrera and Vleck (2004) used 72 papers. The availability of numerous studies on cattle and sheep could be due to the fact that cattle and sheep received more attention than goats.

3.1. Unweighted average heritabilities and ratio of common environmental effects

Unweighted average h_a^2, h_m^2 and c^2 for growth, reproduction and milk production traits in goats are presented in Tables 4 and 5. The h_a^2, h_m^2 and c^2 were calculated for all, 10 and 13 of the 41 traits studied, respectively. The fact that most studies did not partition heritability into h_a^2, h_m^2 and c^2 can be attributed to the methods used in the estimation of parameters. When genetic parameters are estimated based on the sire model or regression of offspring on parents, heritabilities were usually not partitioned, in contrast to studies applying animal models.

In total, 68 unweighted h_a^2, h_m^2 and c^2 were obtained (Tables 4 to 5). Considering unweighted h_a^2 only, the most studied traits measured by number of independent studies (in parenthesis) in

order of importance, were bwt (54), 3mw (41), 6mw (23), 12mw(21), pre (17) and LSB (17). The h_a^2 for 9mw, LMY, PROTY, FATY, and KI were reported in 10 to 15 independent studies. Despite their economic importance, survival traits were reported in few studies. The number of studies per average estimates could be an indication of the attention given to a trait, ease of measuring a trait and the associated costs of recording the traits as well. Unweighted average h_a^2 ranged from 0.05 to 0.51, 0.06 to 0.29 and 0.19 to 0.53 for growth, reproduction and milk production traits, respectively. The unweighted average values of h_m^2 and c^2 for the growth traits were considerably small ranging from 0.03 to 0.35 and 0.02 to 0.13, respectively. The range of unweighted average c^2 for reproduction traits was from 0.04 to 0.07 whereas unweighted average c^2 (0.31) was obtained for ADM only among the milk traits studied. Unweighted average h_m^2 were lacking for reproduction and milk traits.

Table 4. Unweighted average of direct heritability (h_a^2), maternal genetic effect (h_m^2) and common environmental effect (c^2) for growth traits in goats

Traits	n	h_a^2±SD	PSE	n	h_m^2± SD	PSE	n	c^2±SD	PSE
Birth weight	54	0.31±0.17	0.21	15	0.13±0.08	0.07	13	0.13±0.10	0.09
20 days weight	1	0.14	0.07	1	0.07	0.05		-	-
One month weight	6	0.36±0.36	0.19		-	-		-	-
Two months weight	8	0.32±0.24	0.14	2	0.35±0.37	0.02	1	0.04	0.01
70 days weight	1	0.15	0.04	1	0.03	0.03		-	-
Three month weight	41	0.27±0.17	0.12	12	0.09±0.05	0.06	12	0.09±0.03	0.05
Four months weight	3	0.37±0.13	0.13		-	-		-	-
Five months weight	6	0.51±0.23	0.09	2	0.09±0.01	0.12		-	-
Kleiber Ratio	6	0.19±0.34	0.23	4	0.07±0.04	0.18	3	0.02±0.02	0.03
Six months weight	23	0.35±0.21	0.15	3	0.08±0.08	0.09	4	0.08±0.04	0.03
Seven Months weight	1	0.39	0.17		-	-		-	-
Eight months weight	1	0.12	0.22	1	0.03	0.02	1	0.06	0.02
Nine Months weight	16	0.34±0.14	0.17	4	0.06±0.05	0.14	3	0.07±0.03	0.03
11 months weight	2	0.30±0.03	0.03		-	-		-	-
12 months weight	21	0.31±0.15	0.19	3	0.04±0.03	0.18	3	0.07±0.04	0.06
16 months weight	1	0.58	0.03		-	-		-	-
18 months weight	3	0.39±0.26	0.54		-	-		-	-
Pre-weaning daily gain	17	0.22±0.18	0.10	4	0.04±0.02	0.05	7	0.08±0.05	0.03
3 to 6 months DG	12	0.24±0.30	0.12		-	-	3	0.09±0.08	0.74
6 to 12 months DG	3	0.05±0.04	0.04		-	-	1	0.02	0.02

SD=observed standard deviation; PSE=mean of predicted standard error of heritability estimates; n=number of studies from which means were calculated; DG=daily gain.

Table 5. Unweighted average direct heritability (h_a^2) and common environmental effect (c^2) for milk and reproductive traits in goats

Traits	n	h_a^2±SD	PSE	n	c^2±SD
Litter size at birth	16	0.13±0.10	0.10	3	0.07±0.02
Litter size at weaning	6	0.06±0.05	0.07	1	0.04
Litter weight at birth	8	0.08±0.06	0.03	2	0.05±0.02
Gestation length	2	0.14±0.06	0.02		-
Age at first kidding	9	0.29±0.14	0.02		-
Kidding interval	11	0.06±0.04	0.15		-
1st Kidding interval	4	0.08±0.05	0.04		-
Average daily milk yield	8	0.26±0.09	0.14	1	0.31
90 days milk yield	5	0.31±0.15	0.22		-
150 days milk yield	2	0.33±0.21	0.19		-
270 days milk yield	1	0.19			-
Lactation milk yield	13	0.32±0.17	0.14		-
1st lactation milk yield	11	0.41±0.08	0.17		-
Protein yield/lactation	12	0.43±0.19	0.16		-
Fat yield/lactation	12	0.40±0.15	0.15		-
COMB P & F	6	0.45±0.09	0.17		-
Fat percentage	6	0.51±0.06	0.18		-
Protein percentage	6	0.53±0.09	0.19		-
Ratio of protein to fat	6	0.39±0.10	0.19		-
Lactation length	7	0.24±0.27	0.14		-
Survival rate to weaning	2	0.10±0.06	0.03		-

n=number of studies; SD=observed standard deviation; PSE=mean of predicted standard error of heritability estimates; COMB P&F is fat and protein components.

Of the 68 estimates of unweighted h_a^2, h_m^2 and c^2, considering the growth, reproduction and milk production traits, three estimates originating from a single study were not accompanied by SD. When compared with PSE, 20 SD were greater, 27 smaller and 18 equal to PSE. In Koots et al. (1994a) 46 out of 59 heritability estimates, had greater SD than PSE and the magnitude of SD was about twice that of PSE. In the present study, the magnitude of average SD (0.16) was about twice that of PSE (0.09) in h_a^2 (1mw, 2mw, 3mw, 5mw, KR, 6mw, pre, LSB, GL, AFK, 150MY, LMY, PROY, LL and SUR), h_m^2 (bwt and 2mw) and c^2 (bwt, 2mw and 6mw). The differences between SD and PSE could indicate gross underestimation of PSE, the possibility of real differences among heritabilities or both (Koots *et al*., 1994a; Koots and Gibson, 1996). From analysis of weighted least squares of genetic parameter estimates, however, it was indicated that most such variations were not due to population or breed differences; rather, due to random variation not accounted for in the method of estimating error variances (Koots *et al*., 1994a; Koots and Gibson, 1996).

When estimates are accompanied by narrow SD for a trait, it might be an indication of similarities of estimates from different populations. In that case weighted and unweighted averages would be very close to one another which was the case for 16 estimates out of 63 in the present study.

3.2. Weighted average heritabilities and ratio of common environmental effect

The weighted averages for h_a^2, h_m^2 and c^2 are presented in Tables 6 to 7 for growth, reproduction and milk production traits in goats. The ranges of weighted average h_a^2, h_m^2 and c^2 estimates for growth traits were from 0.03 to 0.45, 0.05 to 0.27 and 0.02 to 0.10, respectively. The pooled standard errors (SE) for the majority of weighted average estimates were small (<0.100). The range of weighted average h_a^2 for reproduction and milk production traits were from 0.00 to 0.17 and 0.15 to 0.52, respectively with very small SE. The weighted average estimate of c^2 for reproduction traits ranged from 0.04 to 0.06. Due to lack of information in the reviewed papers, weighted average estimates of h_m^2 and c^2 were not calculated for milk traits.

For growth traits the difference between weighted average h_a^2 and weighted average h_m^2 and c^2 increased with age. For instance, the values of weighted h_a^2 for bwt, 3mw, 6mw and 12mw were 0.16, 0.22, 0.28 and 0.31, respectively compared to h_m^2 of 0.12, 0.08, 0.13 and 0.09 and c^2 of 0.09, 0.09, 0.08 and 0.05, respectively for these traits (Table 6). Small values of h_m^2 and c^2 for early life or pre-weaning traits could be an indication that these are influenced by both maternal genetic and common environmental effects.

Generally, maternal influence tended to be high on traits manifested in early life and magnitude of h_a^2 shows an increment with age of animals when individual animals become independent of their dam (Shorepy *et al*., 2002; Niekerk, 1996; Rashidi *et al*., 2008; Gholizadeh *et al*., 2010; Osman, 2013). However, the relatively small values of h_m^2 and c^2 in the present study indicate that it is less likely for h_a^2 to be inflated if h_m^2 and c^2 are excluded from a model. The number of studies contributing to the weighted average estimates was smaller than those contributing to the unweighted average estimates because studies with

neither number of records nor standard errors were excluded in the calculation of weighted averages, which was also the case in Koots *et al*. (1994a) and Lobo *et al*. (2000). Of 63 weighted average estimates (h_a^2, h_m^2 and c^2), 17 were greater than, 16 were almost equal to and 29 were less than the unweighted average estimates. Koots *et al*. (1994a) indicated that in the absence of systematic differences among datasets, weighted average heritability estimates would be appropriate. They proposed the following conditions for using weighted average heritability estimates: (1) if factors contributing to variation in heritability estimates are essentially random or (2) if individual heritability estimates from a random sample subjected to representative set of factors affecting true heritability.

Table 6. Weighted average of direct heritability (h_a^2), maternal genetic effect (h_m^2) and common environmental effect (c^2) for growth traits in goats

Traits	n	h_a^2±SE	n	h_m^2±SE	n	c^2±SE
Birth weight	52	0.16±0.014	15	0.12±0.013	9	0.09±0.009
20days weight	1	0.14±0.070	1	0.07±0.050		
One month weight	5	0.49±0.080				
Two months weight	8	0.26±0.100	2	0.27±0.016	1	0.04±0.010
70 days weight	1	0.15±0.040	1	0.03±0.030		
3 months weight	40	0.22±0.011	12	0.08±0.011	12	0.09±0.011
4 months weight	3	0.40±0.075				
5 months weight	6	0.45±0.098	2	0.09±0.010		
Klieber Ratio	5	0.22±0.010	3	0.08±0.010	3	0.03±0.017
Six months weight	22	0.28±0.015	3	0.13±0.010	3	0.08±0.016
7 months weight	1	0.39±0.170				
8 months weight	1	0.12±0.220				
9 months weight	15	0.38±0.018	3	0.09±0.009	3	0.10±0.030
11 months weigh	2	0.30±0.021				
12 months weight	21	0.31±0.018	3	0.05±0.024	3	0.05±0.024
16 months weight	1	0.58±0.030				
18 months weight	3	0.17±0.319				
Pre weaning daily gain	16	0.17±0.012				
DG from 3-6 months	7	0.28±0.014			3	0.11±0.138
DG from 6-12 months	2	0.03±0.289			1	0.02±0.020

SE=pooled standard errors over studies; n=number of studies from which averages were calculated.

Table 7. Weighted average of direct heritability (h_a^2) and common environmental effect (c^2) for reproductive and milk production traits in goats

Traits	n	h_a^2±SE	n	c^2±SE
Kidding interval	11	0.09±0.010		
1st Kidding interval	4	0.002±0.018		
Litter size at birth	16	0.05±0.004	3	0.06±0.015
Litter size at weaning	3	0.06±0.017	1	0.04±0.020
Litter weight at weaning	8	0.04±0.003	2	0.06±0.018
Gestation length	2	0.10±0.010		
Age at first kidding	9	0.17±0.012		
Average daily milk yield	6	0.31±0.015		
90 days milk yield	4	0.23±0.076		
150 days milk yield	2	0.36±0.129		
Lactation milk yield	12	0.33±0.011		
1st Lactation milk yield	11	0.43±0.048		
Protein yield/lactation	11	0.40±0.018		
Fat yield/lactation	11	0.36±0.018		
Fat percentage	6	0.52±0.066		
Protein percentage	6	0.54±0.068		
Comp F &P	6	0.41±0.069		
Lactation length	7	0.15±0.035		
Survival rate to weaning	2	0.09±0.020		

n=number of studies; SE=pooled standard error, COMPF&P is fat and protein components.

3.3. Repeatability average estimates

Unweighted (R_u) and R_w repeatability estimates for some growth, reproduction and milk traits in goats are given in Table 8. For traits allowing comparison, R_u was higher than their R_w. The repeatability estimates of pre-weaning growth traits were not always higher than estimates for the post weaning growth traits as it is expected. For instance, R_u for bwt was not greater than R_u for 3mw, 6mw, 9mw and ADG-2 (Table 8). On the other hand, R_u for 1mw was higher than R_u for all growth traits including bwt. This may be explained by the fact that R_u for 1mw was sourced from a single study with a higher repeatability value. Both R_u and R_w values for reproduction traits were smaller than R_u and R_w for growth traits. The R_u and R_w for milk traits were almost comparable to R_u and R_w for growth traits with the magnitude ranging of moderate to high except for LL.

Repeatability estimates set upper limits to heritability estimates. Moderate or high repeatability estimates indicate that successful selection could be feasible for that trait (Alade

et al. 2010; Faruque *et al*., 2010; García-peniche *et al*., 2012; Hasan *et al*., 2014). Lower repeatability estimates, on the other hand, suggest higher proportion of environmental variation (Alade *et al*. 2010; Faruque *et al*., 2010). The moderate to high repeatability estimates for both growth and milk traits presented here indicate that genetic improvements to these traits can be made by selection. The traits with higher repeatability estimates also showed relatively higher h_a^2 estimates.

Table 8. Average estimates of unweighted (R_u) and weighted (R_w) repeatability for growth, reproduction and milk traits in goat

Trait	n	R_u ±SD	n	R_w ± SE
Growth traits				
Birth weight	4	0.57±0.324	3	0.26±0.017
One month weight	1	0.97		
Two months weight	1	0.24		
Three months weight	5	0.67±0.327	3	0.24±0.029
Six months weight	4	0.68±0.326	2	0.56±0.021
Nine months weight	3	0.53±0.338		
12 months weight	3	0.35±0.348	2	0.06±0.034
Pre-weaning average daily gain	2	0.27±0.140	2	0.18±0.214
Three to six months Average daily gain	1	0.53		
Six to 12 months average daily gain	1	0.004		
Reproduction traits				
Kidding interval	8	0.06±0.036	6	0.06±0.057
Litter size at birth	5	0.14±0.022	4	0.13±0.084
Litter size at weaning	2	0.14±0.064		
Litter weight at birth	1	0.16		
Milk traits				
Average daily milk yield	1	0.52		
90 days milk yield	1	0.28		
270 days milk yield	1	0.37		
Lactation milk yield	10	0.49±0.100	5	0.56±0.044
Fat yield/lactation	8	0.51±0.058	8	0.51±0.040
Protein yield/lactation	8	0.54±0.065	8	0.55±0.038
COMP F&P	6	0.55±0.052	6	0.54±0.044
Fat percentage	6	0.60±0.021	6	0.60±0.043
Protein percentage	6	0.60±0.066	6	0.61±0.043
Ratio of protein to fat	6	0.46±0.124	6	0.50±0.043
Lactation length	1	0.11		

n=number of studies, SD=observed standard deviation, SE=pooled standard error, COMPF&P is fat and protein components

3.4. Estimated average correlations

3.4.1. Unweighted average correlations

Unweighted average estimates of phenotypic (r_p) and genetic (r_g) correlations among growth traits (Table 9) and between reproduction, milk production traits, between reproduction and milk production traits and between litter size at birth and growth traits (Table 10) were calculated.

Table 9. Unweighted phenotypic (r_p) and genetic (r_p) correlations among growth traits with standard deviations (SD) where applicable

*Trait 1	Trait 2	r_p	r_g	Trait 1	Trait 2	r_p	r_g
Bwt	Pre	0.17±0.14b	0.33±0.26c	2mw	3mw	0.86±0.11c	0.85±0.14c
bwt	1mw	0.43±0.13c	0.90±0.12c	2mw	4mw	0.76±0.08c	0.73±0.10c
bwt	2mw	0.59±0.23c	0.74±0.25c	2mw	5mw	0.66±0.09c	0.66±0.15c
bwt	3mw	0.35±0.20a	0.55±0.17a	2mw	6mw	0.64±0.07c	0.74±0.14c
bwt	4mw	0.29±0.12c	0.63±0.20c	2mw	7mw	0.59	0.54
bwt	5mw	0.31±0.09c	0.44±0.10c	2mw	ADG2	0.03	0.13± 0.16
bwt	6mw	0.32±0.18b	0.37±0.21b	3mw	4mw	0.87±0.11c	0.86±0.16c
Bwt	ADG2		0.18±0.15c	3mw	5mw	0.63±0.28c	0.88±0.15c
bwt	7mw	0.30	0.50±0.27c	3mw	6mw	0.67±0.13b	0.72±0.24b
bwt	8mw	0.25	0.29	3mw	ADG2	-0.01±0.04c	-0.01
bwt	9mw	0.35±0.19b	0.31±0.17c	3mw	7mw	0.69	0.64
bwt	12mw	0.26±0.17b	0.33±0.25b	3mw	8mw	0.60	-0.02
Bwt	ADG3		-0.02	3mw	9mw	0.58±0.15b	0.62±0.23b
bwt	16mw	0.24	0.57	3mw	ADG3		0.61
bwt	18mw	0.23	0.15	3mw	12mw	0.54±0.14b	0.52±0.22b
Bwt	KR		0.25±0.29c	3mw	16mw	0.54	0.03
20d	70d	0.12	0.17	3mw	18mw	0.64	0.64
20d	3mw	0.10	0.14	3mw	KR		0.95±0.04c
20d	5mw	0.11	0.14	4mw	5mw	0.94±0.04c	0.98±0.01c
20d	6mw	0.10	0.14	4mw	6mw	0.85±0.13c	0.95±0.03c
20d	9mw	0.09	0.11	4mw	7mw	0.98	0.89
20d	12mw	0.09	0.10	5mw	6mw	0.95±0.05c	0.95±0.06c
20d	3mw	0.19	0.99	5mw	7mw	0.97	0.94
1mw	2mw	0.81±0.10c	0.86±0.15c	5mw	9mw	0.77	0.73
1mw	3mw	0.59±0.68c	0.83±0.19c	5mw	12mw	0.71	0.64
1mw	4mw	0.63±0.08c	0.56±0.0.38c	5mw	DAG2	0.80	0.93
1mw	5mw	0.56±0.11c	0.55±0.30c	6mw	ADG2	0.74	0.54±0.35c
1mw	6mw	0.40±0.19c	0.45±0.34c	6mw	7mw	0.98	0.88
1mw	7mw	0.55	0.54	6mw	9mw	0.80±0.07b	0.71±0.27c
70d	5mw	0.26	0.93	6mw	ADG3	-0.25	0.64
70d	6mw	0.25	0.90	6mw	12mw	0.70±0.08b	0.68±0.22b
70d	9mw	0.19	0.51	6mw	18mw	0.74	0.74
70d	12mw	0.19	0.55	8mw	12mw	0.83	0.97
Pre	2mw	0.85	0.99	8mw	16mw	0.76	0.94

Table 9 Continued

Pre	3mw	0.81±0.25c	0.87±0.19c	9mw	12mw	0.83±0.08c	0.86±0.12c
Pre	5mw	0.58	0.49	9mw	ADG2	0.49	0.71
Pre	6mw	0.47±0.25c	0.58±0.23	9mw	ADG3	0.13	0.65
Pre	ADG2	0.24±0.50c		12mw	ADG2	0.41±0.13c	0.50±0.33c
Pre	9mw	0.63±0.01c	0.67±0.04	12mw	ADG3	-0.003	
Pre	ADG3	-0.28		12mw	Post	0.32	0.26
Pre	KR	0.88	0.96±0.04c				

bwt=birth weight; 20d and 70d are weights at 20 and 70 days of age, respectively; 1mw, 2mw, 3mw, 4mw, 5mw, 6mw, 7mw, 8mw, 9mw, 11mw, 12mw, 16mw, 18mw are, in respective order, weights at one, two, three, four, five, six, seven, eight, nine, 11, 12, 16 and 18 months of age; KR= kleiber ratio; pre, ADG2, and ADG3 are average daily gains during pre-weaning, three to six month and six to 12 months of ages, respectively; c=estimates were from less than 10 papers/studies; b=estimates were from 10 – 20 papers/studies; a=estimates were from more than 20 papers/studies; *=values without standard deviation were sourced from single study.

Unweighted average r_p among growth traits ranged from -0.25 (6mw, ADG3) to 0.95 (5mw, 6mw), whereas the unweighted average r_g ranged from -0.20 (3mw, ADG2) to 0.98 (4mw, 5mw) among growth traits. The ranges of unweighted average r_p among reproduction traits were in between zero and 0.24 except for (LSB, GP) which was as high as 0.54. The unweighted average r_g among reproduction traits were a bit higher than unweighted average r_p ranging from 0.34 (LWW, AFK) to 0.79 (LSB, LSW). The unweighted r_p and r_g among milk production traits ranged from 0.14 (150MY, LL) to 0.95 (90MY, 150MY) and 0.36 (90MY, LL) to 0.94 (DMY, LMY), respectively.

The correlation values tended to be higher for age-adjacent traits. For instances, the unweighted r_g value between bwt and 3mw was higher (0.55) compared to the unweighted r_g between bwt and 12mw (0.33). The trend was also the same in the case of weighed r_g. This could be because genes affecting adjacent traits are more similar than genes affecting distant traits as genes have "switch off" and "switch on" times. Hence, pre-weaning growth traits have less potential to predict post weaning growth traits. In the same fashion, early life growth traits had smaller unweighted average r_p with the latter age weights. These findings are in agreement with Koots *et al*. (1994b) and Lobo *et al*. (2000).

For 57% of the unweighted average r_p and r_g, no SD could be calculated as they were contributed by single studies. In the reports of Koots *et al*. (1994b), this figure was about 60%. In about 30% of the unweighted average values, two to ten studies contributed to the estimates while the remaining estimates were contributed by more than 10 studies. In most cases the unweighted averages of r_p were smaller than unweighted average r_g.

Table 10. Unweighted phenotypic (r_p) and genetic (r_g) correlations between milk production and reproductive traits in goat

Trait 1	Trait 2	r_p	r_g	Trait 1	Trait 2	r_p	r_g
Among reproduction traits				Between reproduction and milk traits			
LSB	GP	0.54	0.48	LSB	LMY	0.25	0.08
LSB	LSW	0.24	0.79±0.131c	AFK	LMY	0.04	-0.18
LSB	LWB	0.21		AFK	PROTY	0.05	-0.17
LSB	LWW	0.21		AFK	FATY	0.08	-0.09
LWB	KI		0.53	KI	LL	0.35±0.704c	
LSB	AFK	0.15	0.61	Among milk production traits			
LSB	KI	-0.06	0.69	DMY	90MY	0.75±0.048c	0.91±0.137
LSW	AFK	0.11	0.34	DMY	150MY	0.87	
LSW	KI		0.59	DMY	LMY	0.47±0.573c	0.94±0.115c
LWW	KI	-0.03		90MY	150MY	0.95±0.057c	
LWB	AFK	0.09	0.61	90MY	LMY	0.81±0.013c	
LWW	AFK	0.05	0.39	90MY	LL	0.16±0.042c	0.36±0.702
Between reproduction and growth traits				150MY	LMY	0.93	
LSB	Bwt	0.30	-0.11±0.320c	150MY	LL	0.14±0c	
LSB	Pre	-0.07	-0.22±0.141c	LMY	PROTY	0.94.016c	0.89±0.025c
LSB	9mw	-0.20	-0.12	LMY	FATY	0.85±0.010c	0.75±0.026c
LSB	12mw	-0.44	-0.50	LMY	LL	0.50±0.194c	0.50±0.438c
LSB	ADG2		-0.15±0.099c	PROTY	FATY	0.88c	0.83

DMY, 90MY, 150MY, LMY, and LL, are average daily, 90 days, 150 days, lactation milk yields and lactation length, respectively; PROTY and FATY, are protein yield, fat yield, in respective order; LSB, LSW, LWB, LWW, KI, AFK, are litter size at birth, litter size at weaning, litter weight at birth, litter weight at weaning, kidding interval, first kidding interval, respectively; bwt, pre, 9mw, 12mw and post are birth weight, pre-weaning weight, 9 months weight and 12 months weight, respectively; c=estimates were from less than 10 studies.

Table 11. Weighted mean genetic (above diagonal) and phenotypic (below diagonal) correlations among most frequently recorded growth traits in goat with number of studies in parenthesis.

Traits	bwt	3mw	6mw	9mw	12mw	pre	ADG2
bwt		0.54(12)	0.39(8)	0.32(7)	0.32(8)	0.23(5)	0.02
3mw	0.36(14)		0.76(10)	0.63(8)	0.31(8)	0.98(4)	0.10
6mw	0.37(10)	0.28(12)		0.90(7)	0.74(7)	0.74	0.29
9mw	0.34(7)	0.61(8)	0.81(7)		0.89(7)	0.64(2)	0.59
12mw	0.27(8)	0.61(8)	0.74(8)	0.84(6)			0.26
Pre	0.13(5)	0.55(4)	0.65	0.63(2)	0.56		0.01(2)
ADG2	0.02	-0.06	0.30	0.13	0.32	0.04(2)	

bwt=birth weight; 3mw, 6mw, 9mw and 12mw are, in respective order, weights at three, six, nine and 12 months of age; pre and ADG2 are average daily gains during pre-weaning and weaning to 6 months of age.

3.4.2. Weighted average correlations

Weighted average r_p and r_g among growth and reproduction traits, were given in Tables 11 and 11. The range of weighted average r_p and r_g among growth traits were from -0.06 to 0.84 and from 0.01 to 0.94, respectively. The weighted average r_p among milk production traits ranged from 0.18 to 0.94 whereas weighted average r_g among milk production traits were only available in few studies. Weighted averages r_p and r_g among reproduction traits were not presented due to lack of number of records required to calculate r_p and number of sires required to calculate r_g in the reviewed papers for these traits. Among the reproduction traits reviewed, weighted average r_p between LSB and some growth traits were calculated (Table 12) resulting in negative values indicating an antagonism between LSB and growth traits. The larger the litter size, the more the competition among kids for nutrients, milk for instance.

The number of studies contributing to weighted average correlations, as in the case of h_a^2, h_m^2, c^2 and repeatability, was smaller than for unweighted average correlations because of two facts: (1) correlation estimates sourced from single studies were not included as the Fisher's transformation returns the same value both for unweighted and weighted correlations; (2) where the number of sires for r_g and number of records for r_p were not indicated in the methodology of the study, weighted average correlations were not calculated. Thirdly, correlation values less or equal to - 1.00 or greater or equal to +1.00 such as those in Barazandeh *et al*. (2012) were also ignored from the calculation of weighted average

correlations. Except for the weighted average r_p between 3mw and ADG2, all weighted average correlations were positive.

Overall, weighted genetic correlations among growth traits ranged from moderate to high, indicating the possibility of indirect selection among these traits. However, the genetic correlation between bwt and subsequent weights declined after three months of age, which means bwt, may not be a trait of choice for indirect improvement of weights at a later age like 6mw, 9mw or 12mw. Instead 3mw to 6mw growth traits could be targeted for direct or indirect genetic improvement.

Table 12. Weighted mean phenotypic (r_p) and genetic (r_g) correlations among growth, milk and reproduction trait in goat with number of studies from which weighted mean was calculated in parenthesis.

Trait 1	Trait 2	r_p	r_g	Trait 1	Trait 2	r_p	r_g
Among growth traits				4mw	6mw	0.97	0.76
Bwt	1mw	0.48(3)	0.935(3)	5mw	6mw	0.99(2)	0.91
Bwt	2mw	0.74(3)	0.959(3	5mw	9mw	0.73	0.77
Bwt	KR	-0.001(2)	0.418(2)	Between reproduction and growth traits			
Bwt	4mw	0.16	0.740	LSB	bwt	0.20(2)	
Bwt	5mw	0.21	0.400	LSB	pre	-0.31(2)	-0.02(2)
Bwt	7mw	0.30	0.690	LSB	9mw	-0.12	
Bwt	16mw	0.24	0.570	LSB	12mw	-0.50	
1mw	2mw	0.84(2)	0.983(2)	LSB	ADG2	-0.09(2)	
1mw	3mw	0.59(2)	0.945(2)	Among milk production traits			
1mw	4mw	0.57	0.830	DMY	90MY	0.73(2)	
1mw	5mw	0.48	0.760	DMY	150MY	0.87(1)	
1mw	6mw	0.30(2)	0.521(2)	DMY	LMY	0.25(2)	
2mw	3mw	0.85(3)	0.927(2)	DMY	LL	0.77(2)	
2mw	4mw	0.74(2)	0.800	90MY	150MY	0.97(2)	
2mw	5mw	0.82	0.669(2)	90MY	LMY	0.78(4)	0.93(2)
2mw	6mw	0.82(2)	0.669(3)	90MY	LL	0.18(3)	
3mw	4mw	0.98	0.856(2)	150MY	LMY	0.93(2)	
3mw	5mw	0.97(2)	0.605(3)	150MY	LL	0.14(2)	
3mw	KR	0.98(2)	0.784(2)	LMY	PROTY	0.94(3)	
4mw	5mw	0.99	0.605(2)	LMY	LL	0.51(3)	0.52(2)

bwt=birth weight; 1mw=weight at one month of age; 2mw, 3mw, 4mw, 5mw, 6mw, 7mw, 9mw, 12mw, 16mw, 18mw are, in respective order, weights at two, three, four, five, six, seven, nine, 12, 16 and 18 months of age; KR= kleiber ratio; pre and ADG2 are average daily gains during pre-weaning and from three to six months, respectively; LSB, DMY,90MY, 150MY, LMY, LL, PROTY are litter size at birth, Average daily milk yield, 90 days milk yield, 150 days milk yield, lactation milk yield, lactation length and protein yield, respectively.

3.4.3. Least Squares Analysis

Neither method of estimation nor management level had significant effect ($p>0.05$) on h_a^2 for bwt, 3mw, 6mw, 9mw and 12mw in goats. This is in contrast to the findings of Koots *et al*. (1994a) who stated that heritability estimates from an animal model were expected to be higher than from other methods because the animal model traces back to the base population prior to selection and therefore, variance should be higher. The explanation could be h_a^2 estimates from regression of offspring on parents did not take the maternal genetic variances into account and hence resulted in inflated values.

Heritability estimates were supposed to be lower in extensive management systems (Koots *et al*., 1994a), given the shortage of feed energy for expression of genetic variances under extensive management conditions. The absence of significant difference between different management levels in the present finding could be, however, due to the fact that most of the heritability estimates from intensive management levels were estimated using animal model and most of the heritability estimates in extensive and semi-intensive management levels were calculated using parent offspring relationship.

In the same fashion, neither management nor methods of estimation had significant effect ($p>0.05$) on least squares mean values of r_p and r_g. Other authors (Koots *et al*., 1994a; Koots *et al*., 1994b; Koots and Gibson, 1996) stated that of the largest proportion of the variation in estimates among populations/breeds is likely due to error variances. If the estimates are not affected by systematic factors, average estimates from literature should be applicable when specific estimates are lacking. However, it should be noted that since most of traits reviewed here were not studied very frequently, further genetic parameter estimation in growth, reproduction and milk traits of goat is required to confirm this finding.

The numbers of estimates reviewed in the present study were not sufficient to determine factors affecting parameters systematically across populations. Many traits lack considerable number of estimates and did not allow fitting analysis of variance models. In our work, the number of studies contributing for the analysis of variance of correlations ranged from 8 to 22 whereas the number of estimates contributing to h_a^2 ranged from 11 to 38.

3.4.4. Observed standard deviations and theoretical standard errors

Observed standard deviation of phenotypic (PSD) and genetic (GSD) and predicted standard error of phenotypic (PPSE) and genetic (GPSE) correlations are presented in Table 13. The combinations of traits presented were those for which number of studies was greater or equal to seven for the calculation of PSE. Mean of observed standard deviation for a correlation is direct average of standard deviations of a correlation calculated from different traits and mean of theoretical standard error is average of theoretical standard errors of a correlation calculated from different traits based on a formula. Comparison of the two parameters for a correlation could indicate the source (s) of variation (s). For instance, if the mean observed standard deviation is greater than mean of theoretical standard error, for a correlation, it could indicate that the presence of variation in true correlations, estimation error or both (Koots *et al*., 1994a). In the present study (Table 13), mean of observed standard deviation of a correlation was always higher than the mean of theoretical standard error (for r_p, 0.139 (PSD) versus 0.027 (PPES); for r_g, 0.218 (GSD) versus 0.136 (GPSE)). We investigated the effect of variation of true correlations by fitting different exogenous factors including methods of parameter estimation and management levels of animals while estimating the parameter. We could not find sufficient evidence to indicate the presence of variation in true correlation. Koots and Gibson (1996) indicated that the variation between the observed standard deviation and theoretical error could be due to estimation errors. This and the former finding indicate that estimates are not as such influenced by exogenous factors including management levels of animals for parameter estimation, methods of estimation or breed encouraging the utility of the average estimated presented here as needed.

Table 13. Comparison of observed standard deviation (SD) and theoretical standard error (PSE) of genetic correlations for some of trait combinations allowing comparison

	r_p		r_g	
Traits	PSD	PPSE	GSD	GPSE
Bwt, 3mw	0.197	0.028	0.171	0.144
Bwt, 6mw	0.183	0.028	0.206	0.029
Bwt, 9mw	0.192	0.032	0.165	0.174
Bwt, 12mw	0.167	0.027	0.251	0.168
3mw, 6mw	0.133	0.026	0.238	0.134
3mw, 9mw	0.149	0.030	0.229	0.163
3mw, 12mw	0.136	0.027	0.217	0.131
6mw, 9mw	0.069	0.022	0.270	0.127
6mw, 12mw	0.027	0.029	0.216	0.144
Average	0.139	0.027	0.218	0.136

PSE = mean of reported standard errors for phenotypic correlations, PSD = Observed standard deviation of phenotypic correlations, PPSE = theoretical standard error of phenotypic correlations, GSE = Mean of reported standard errors of genetic correlations, GSD= standard deviations of genetic correlations, GPSE=theoretical standard error of genetic correlations, Bwt=birth weight, 3mw= three month weight, 6mw=six month weight, 9mw=nine month weight, 12mw=12month weight, r_p=phenotypic correlation, r_g=genetic correlation

3.4.5. Revealing reliability of presented estimates

The means of genetic parameter estimates for some growth traits (h_a^2, r_g and r_p) based on relatively higher number of records are given in Table 14. Average estimates, both weighted and unweighted, from literature are generally regarded as more reliable estimates than single estimates even when these were calculated from a higher number of records (Koots *et al*., 1994b). Making simple comparison of average estimates with estimates based on a higher number of records could help in determining the reliability of the average estimates.

Unweighted average values of h_a^2 were smaller than the mean values of h_a^2 from studies with a relatively high number of records (greater than 3000) only for 12mw. For all other growth traits, namely bwt, 3mw, 6mw and 9mw, unweighted h_a^2 was higher than the respective average h_a^2 estimated from a relatively higher number of records. In contrast, weighted average h_a^2 values for all growth traits were either smaller (bwt and 12mw) or almost equal to the average h_a^2 from relatively higher number of records. Most of the average correlation values based on higher number of records were smaller than both the unweighted and weighted average correlation values. The r_g correlations were estimated with higher standard

errors, even from relatively large number of records, contrary to r_p which were reported with small standard errors. Therefore, even though the average r_g based on relatively large records seem to be conservative estimate, it is suggested to use weighted r_g due to the large standard errors of r_g.

Table 14. Average of genetic parameter estimates estimated based on relatively higher number of records (h_a^2 - diagonal, r_g - above diagonal and r_p - below diagonal) for comparison with average estimates

Traits*	N	Bwt	3mw	6mw	9mw	12mw
Bwt	13	0.24	0.57(10)	0.29(6)	0.31(5)	0.29(5)
3mw	12	0.32(10)	0.20	0.64(8)	0.54(6)	0.44(6)
6mw	6	0.29(10)	0.65(10)	0.28	0.57(6)	0.64(5)
9mw	5	0.30(7)	0.55(6)	0.78(6)	0.31	0.83(5)
12mw	5	0.29(5)	0.52(10)	0.71(5)	0.80(5)	0.35

*=Estimates included in this average were those estimated based on > 3000 records (h_a^2) and >100 records correlations, n= number of studies for h_a^2, numbers in the parenthesis are number of studies for correlations.

3.5. Conclusion

Based on our findings and those of others (Koots *et al*., 1994a, b; Lobo *et al*., 2000; Safari *et al*., 2005), weighted average h_a^2, h_m^2, c^2, R and r_g should be preferred to unweighted averages where information is lacking. The weighted estimates h_a^2 for some growth traits were more conservative than the corresponding average values based on relatively higher number of records. The absence of significant differences for the tested fixed factors on parameter estimate in growth traits also reinforces reliability of the weighted averages presented here. The average estimates should be combined with the local/specific estimates to plan goat breeding strategies and genetic evaluation programs. For the r_p, local estimates should be used instead of averages presented here due to the fact that r_p was estimated with larger theoretical standard errors than mean standard errors. The average estimates of parameters calculated in the present study could be extracted for a wide range of conditions and could complement goat genetic improvement initiatives. However, it should be noted that since most of the traits reviewed here were not frequently studied, further genetic parameter estimations for growth, reproduction, and milk traits of goat are required.

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8.2. Paper II

Production parameters and productivity assessment in goat breeds of Ethiopia

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1. Abstract

Assessments of production parameters and productivity indices were made in three indigenous goat breeds of Ethiopia. The indigenous breeds included Abergelle (AB), Central Highland (CH) and Woyto-Guji (WG). Objectives of this work were two: to estimate production parameters including 3mw (three month weight), kidding intervals (KI) and litter size (LSB) at birth for the breeds; and to assess their productivity at individual and flock level. As AB is used for milk production, adjustment was made to their 3mw. Three month weight productivity of doe per year (index I) and 3mw productivity of doe per year per parturition weight and overall flock productivity were the productivity indices assessed. The overall mean of 3mw (kg) were 7.44, 10.96 and 9.38 for AB, CH and WG goat breeds, respectively. Generally, wet season, male sex, single birth and smaller flock size resulted in higher 3mw in the present study in the three breeds. The overall means of KI were 362, 268 and 309 days for the breeds in respective order. The overall means of the LSB for the goat breeds, in respective order, were 1.03, 1.40 and 1.09 per doe per parturition. Overall means of index I and index II were 16.66 and 0.50 kg, respectively. Higher 3mw and ppw and shorter KI were associated with higher values of index I and index II. The overall flock productivity ranged from 0.27 to 0.53. Higher number of parturition per year (N), LSB, survival to three months (S3M) and 3mw resulted in higher overall flock productivity. In general, CH goat breed was the most productive using the three indices. The parameters estimated in this paper could be used as benchmark for the designed CBBP of goats in the localities.

Key words: Doe; growth; litter size; kidding interval; milk; productivity

2. Introduction

In increased human population, urbanization and changing climate, goat population in Ethiopia showed an increasing trend (FAO, 2014). According to CSA (2014) Ethiopian goat population was about 28 million and almost all of these are owned by smallholder farmers. The economic significance of small ruminants in general and goats in particular include small requirement initial investment, high survival rate during drought conditions, higher off-take and complementary feeding habit (ESGPP, 2009; Aboul-Nagaa *et al*., 2014). Such characteristics of goats invite improving goat production and productivity in Ethiopia.

Studies made so far has focused on characterization (Netsanet, 2014; Alube, 2015; Netsanet *et al*., 2016) and parameters estimation (Kebede *et al*., 2012; Badhane *et al*., 2013). Even though assessment of productivity is vital to improve the efficiency of the goat production in a particular system, it was rather overlooked.

As opposed to prevailing assumptions, comparison of breeds, in different ecological zones, production systems and under different management levels could be possible by productivity indices (Peacock, 1987). In order to arrive at the productivity indices, however, production parameters need to be assessed first. Among others, goat productivity could be assessed per individual animal and at flock level (Peacock, 1987; Bossman *et al*., 1997).

Community based breeding program (CBBP) has become popular especially in small ruminants in developing countries (Mueller *et al*., 2015). CBBP of sheep has been implemented in Ethiopia (Duguma, 2010; Haile *et al*., 2011; Duguma *et al*., 2012). CBBP of goat was also initiated in different sites in Ethiopia following success reports of sheep CBBP.

In order to maximize to contribution of the initiated CBBP of goats, there is a need to assess the productivity of indigenous goat breeds in Ethiopia at site of CBBP implementation. We first estimated some production parameters to be used in the assessment of the productivity indices and measured reproductive performances and overall flock productivity. The

production parameters estimated here could be used as the benchmarks for the designed CBBP of goats.

Objectives of this work were two: to estimate some production parameters including three month weight (3mw), milk corrected 3mw (3mwc) for AB, kidding intervals (KI) and litter size at birth (LSB) for Abergelle (AB), Central Highland (CH) and Woyto-Guji (WG) indigenous goat breeds in Ethiopia; and to assess the productivity of these goat breeds at individual and flock level.

3. Materials and Methods

3.1. Description of the study sites

The study was conducted in six villages and on three indigenous goat breeds, two villages per breed, in Ethiopia. The goat breeds were AB, CH and WG. The villages for AB, CH and WG are located in Tigray and Amhara, Amhara and Oromia and in SNNP's (Southern Nations, Nationalities, and People's) region, respectively. Specific villages were *Dingur* (Tigray region) *and Blaku* (Amahara region) for AB, *Waykaw* (Amahara region) and *Tatessa* (Oromia region) for CH and *Messale* and *Arkisha* (SNNP's) for WG. Details of the villages is detailed in Table 1. Study sites' identification was guided by the respective district agriculturalists. In addition, the villages were where other projects are operating so that initiatives would be sustained. Goat producers in all the sites attended series of trainings on the CBBP of goat and finally engaged in the work.

3.2. Estimation of growth and reproduction traits

Ad hoc enumerators were hired to collect data of production traits. The goat breeders' cooperatives formed in all villages backstopped enumerators in the data collection. The production traits recorded for this study included 3mw KI and LSB. The data collection duration was from mid July 2013 to Mid April 2015 for all breeds.

Table 1. Latitude, longitude, altitude and rainfall of the study villages

Parameters	*Dingur*	*Blaku*	*Waykaw*	*Tatessa*	*Massale*	*Arkisha*
Latitude	$13^0 22'$	$12^0 81'$	$12^0 86'$	$9^0 54'$	$5^0 21'$	$5^0 26'$
Longitude	$38^0 98'$	$38^0 76'$	$37^0 35'$	$38^0 23'$	$37^0 26'$	$37^0 34'$
Altitude#	1731	1405	1192	2176	1383	1326
Rainfall (ml)*	710.65	546.95	1879.3	910.85	510.75	510.75

*=average rainfall of 2013 and 2014 (national Meteorology agency of Ethiopia) and meteorology stations for rainfall were Abi Adi, Sekota, Tikil Dingay, Ambo Agricultural rsearch, and Konso (for Massalle and Arkisha), for the villages from left to right, respectively; # = meters above sea level.

In the analysis of all traits, fixed effects of villages, year, season, type, sex, and parity of kids' birth were investigated. Parities of does were captured from owners at beginning of monitoring work of the base flock. Numbers of records were unbalanced across year, type and parity of births. Records from triplets, parity ≥ seven and the year 2015 were small. Due to these reasons, records from 2015 and 2014, from triplets and twins and from parity ≥ seven and parity six were merged.

In addition, effects of flock size and post-partum weight (ppw) of does were fitted. Three categories of flock size were created based on number of goats per household. These categories included <10 goats/household (HH), ≥10 &<20/HH and ≥20/HH. Doe ppw was fitted as linear covariate for the analyses of 3mw.

Seasons were categorized into 'dry' and 'wet' based on 2013 and 2014 rain fall data obtained from the national meteorology agency of Ethiopia. Accordingly, 'wet' months were July, August and October in *Dingur*; July, August and September in *Blaku*; June, August, September, October and November in *Waykaw*; from April to October in *Tatessa*; and January, March, June, August, September, October and November in *Massale* and *Arkisha*. The rest months, in the respective villages, were 'dry' season.

3.3. Productivity analyses

Using the estimated biological parameters and other literature estimates, two productivity analyses, at individual and flock level, were made. Bosman *et al* (1997) criticized and

modified former indices. Limitations of earlier indices included length of observation period, practicality in determining fraction of actually reproducing females, and failure to consider inflow of animals. The modified indices by Bosman *et al* (1997) still had limitations related to number of parameters required. Age at first kidding and flock mean weight or metabolic weights are required parameters in the modified indices which are cumbersome to generate in field conditions. Due to these reasons, flock mean weight was replaced by ppw in the present study.

3.3.1. Analyses of reproductive potential of individual does

Individual level productivity were assessed using two productivity indices including productivity expressed as the body weight of a 90 day old kids produced per doe per year (Index I) and per kg ppw per year (Index II). In this case, live weight at three months (LW3M) were calculated as the sum of weights per parturition per doe at three months from the collected data for the respective breeds. The influences of breed, year of birth and parity of birth were investigated for the indices using general linear model procedure of SAS (2004).

$$y\ (Index\ I) = \frac{LW3M}{KI} \times 365$$ (Peacock, 1987; Bosman *et al*., 1997) (1)

$$\text{Index II} = \frac{\text{Index I}}{\text{PPW}}$$ (Gbangboche *et al.*, 2006) (2)

where y=live weight production per parturition in kg, standardized per annum, LW3M = Litter weight at three months after birth; KI=subsequent kidding interval.

3.3.2. Analyses of overall flock productivity

Overall productivity was assessed and compared across the three indigenous goat breeds using index given bellow.

$$y = \frac{N \times LSB \times S3M \times 3mw}{PPWm}$$ (Peacock, 1987; Bosman et al., 1997) (3)

where y = productivity in kg live weight per kg post-partum weight per year; N = number of parturitions per year; LSB = litter size at birth; S3M = survival rate until three months; 3mw = live weight at three months (3mw = 3mwc for AB); PPWm = mean postpartum weight of does.

In the calculation of overall flock productivity, measurements were lacking on bucks, fraction of females not actually reproducing and goats entering/exiting the flock. For this reason, PPWm was used instead of overall flock mean weight. Overall mean values of N, 3mw (3mwc for AB), LSB, S3M, KI and PPWm, were used in the calculation of indices. Except S3M, all values were estimated the same data of the respective breeds. The S3M was sited from ligature. N was calculated based on overall mean KI values. When KI is less than 365 days, N is definitely more than one times and when the KI is more than 365, N is less than one times.

Milk was economically important trait in AB where producers compete for milk with kids. From CH and WG breeds, however, farmers do not milk goats and kids did not have competent on milk. If this circumstance is not taken into account, overall flock productivity of AB would be under estimated. Therefore, the amount of milk consumed by producers which would otherwise be used by kids for growth was converted in to growth based on information contained in Table 2.

Table 2.Metabolizable energy (ME) required per gram growth in kids (ME/g growth), ME content of Abergelle goat milk and percentage milk consumed by producers

Parameters*	Values	Citations
ME/g growth	6.7	Kearl, 1982
ME of AB goat milk (range) per kg	881.75 (567.70 – 1306.63)	Muhi (unpublished data)
% of milk consumed by producers	50% (about milk from one teat)	Peacock, 1996

*From present data = ADM was 453.38 ml and 308.10ml in *Dingur* and *Blaku* villages, respectively.

Based on information contained in Table 2, kids at *Dingur* and *Blaku* were losing about 226.69 (453.38*50%) g and 154.05 g (308.10*50%) g daily and these were about 199.88 kcal (226.69*881.75/1000) and 135.83 kcal (154.05*881.75/1000), respectively. When converted to growth that was 29.83 g (199.88/6.7) and 20.27 g (135.83/6.7) in the villages which was, in

respective order, 2.68 kg and 1.82 kg, in the villages, hence these values were added on actual 3mw of AB goat breed in order to favour them while assessing the overall flock productivity.

4. Results

Least squares means of 3mw are given in Table 3 for AB, CH and WG goat breeds. The overall mean of 3mw (kg) were 7.44, 10.96 and 9.38 for AB, CH and WG goat breeds, respectively. Generally, wet season, male sex, single birth and smaller flock size resulted in significantly ($p<0.05$) higher 3mw in the three breeds (Table 3). However, fixed effects of sex and birth type did not have significant ($p>0.05$) effect on 3mw in AB and WG. Similarly, the effects of village, season of births and flock size were not significant ($p>0.05$) on the 3mw of CH, WG and AB, respectively. The 3mw showed a significant ($p<0.001$) increment with a unit increment of the does ppw in all the goat breeds (Table 3). The effect of parity of birth was not significant ($p>0.05$) on 3mw of all the breeds. AB and WG kids born in 2013 had significantly ($p<0.001$) higher 3mw than those born in 2014. For CH kids, the vice versa was observed where kids born in 2014 had significantly ($p<0.001$) higher 3mw than those born in 2013.

The least squares means and standard errors of kidding intervals (KI), in days, are given in Table 4 for AB, CH and WG goat breeds. The overall means of KI were 362, 268 and 309 days for the breeds, in respective order. Does that had their previous parturition in 2014 had significantly ($p<0.001$) shorter KI in AB and CH does. AB does having their previous parturition in *Blaku* had significantly ($p<0.001$) longer KI than does that had their previous parturition in *Dingur*. KI of does for CH did not significantly ($p>0.05$) differed by villages of production. On the other hand none of the fixed effects fitted in the model significantly ($p>0.05$) captured the variations in KI in WG.

Table 3. Least squares means ($\bar{X}$)± standard errors (SE) of three month weight (3mw) (kg) by fixed factors in three indigenous Ethiopian goat breeds under farmers' production practices

Factors[₵]	Abergelle		Central Highland		Woyto-Guji	
	n	$\bar{X}$±SE	n	$\bar{X}$±SE	n	$\bar{X}$±SE
Overall	885	7.44±1.41	779	10.96±2.30	504	9.38±1.44
Village[¥]	*		Ns		***	
1	351	7.58±0.16a	376	10.63±0.16	199	7.39±0.14b
2	534	7.34±0.18b	403	10.94±0.16	305	10.64±0.11a
Year	***		***		***	
2013	539	7.94±0.17a	198	10.23±0.19b	157	9.33±0.14a
2014	346	6.98±0.16b	581	11.35±0.11a	347	8.70±0.10b
Season	*		*		ns	
Dry	829	7.20±0.14b	250	10.59±0.17b	243	8.98±0.12
Wet	56	7.72±0.24a	529	10.98±0.11a	261	9.05±0.11
Sex	Ns		**		Ns	
Male	447	7.51±0.17	394	11.02±0.13a	280	9.14±0.11
Female	438	7.40±0.17	385	10.56±0.14b	224	8.90±0.11
Flock[ϕ]	ns		**		***	
<10	32	7.47±030	158	10.97±0.20a	205	9.30±0.12a
≥10 to <20	221	7.43±0.16	296	11.02±0.15a	137	9.22±0.13a
≥20	632	7.49±0.14	325	10.37±0.15b	162	8.53±0.15b
Birth type	ns		***		ns	
Single	837	7.58±0.12	315	11.56±0.17a	419	9.19±0.08
Twin	48	7.35±0.25	464	10.01±0.13b	85	8.84±0.17
PPW	0.05±0.01		0.09±0.02		0.06±0.02	

n= number of observations; *** = p<0.001; **=p<0.01; *p<0.05; ns=p>0.05; ₵= least squares means with different letter are significantly different; ¥=1=*Dingur*, *Waykaw* and *Massale* for AB, CH and WG breeds, respectively and 2=*Blaku*, *Tatessa* and *Arkisha* for AB, CH and WG, respectively; ϕ=average number of goats per household; PPW=Post-partum weight.

Table 4. Least squares means ($\bar{X}$)± standard errors (SE) of kidding intervals (days) in three indigenous Ethiopian goat breed under farmers' production practices

Factors[₵]	Abergelle		Central Highland		Woyto-Guji	
	n	$\bar{X}$±SE	n	$\bar{X}$±SE	n	$\bar{X}$±SE
Overall	229	362±82	162	268.11±72.21	59	309.47±89.42
Village[¥]	***		ns		ns	
1	98	304.77±21.08b	72	252.10±11.06	-	-
2	131	348.39±20.34a	90	276.20±9.31	-	-
Year	***		***		ns	
2013	203	371.88±18.55a	101	293.98±9.94	36	312.63±28.94
2014	26	281.28±24.29b	61	234.233±10.48	23	268.79±34.12

n= number of observations; *** = p<0.001; **=p<0.01; *p<0.05; ns=p>0.05; ₵= least squares means with different letter are significantly different; ¥=1=*Dingur*, *Waykaw* and *Massale* for

AB, CH and WG breeds, respectively and 2=*Blaku*, *Tatessa* and *Arkisha* for AB, CH and WG, respectively; ϕ=average number of animals per household.

Least squares means of litter size at birth (LSB) are given in Table 5 for AB, CH, and WG goat breeds. The overall means of the LSB for the goat breeds, in respective order, were 1.03, 1.40 and 1.09 per doe per parturition. LSB from earlier parities were significantly smaller than LSB from latter parities in AB ($p<0.01$), CH ($p<0.001$) and WG ($p<0.001$). CH does from *waykaw* had higher ($p<0.001$) LSB than same breed does from Tatessa village. In similar fashion, CH does that had births during dry seasons had significantly ($p<0.05$) higher LSB than does that had births during wet seasons.

Three month weight productivity per year per doe (index I) and per year per doe ppw (index II) are given in Table 7. Overall means of index I and index II were 16.66 kg and 0.50, respectively. The CH breed had significantly ($p<0.001$) higher index I and index II followed by the WG breed. Index I was significantly ($p<0.001$) higher for births in 2014 than births in 2013 and index II was significantly ($p<0.05$) smaller for births in 2014 than births in 2013. Earlier parities (parity 1 and 2) were characterized by significantly ($p<0.001$) lower index I than latter parities. However, the effect of parity of birth was not significant ($p>0.05$) on index II. The overall flock productivity and parameters used in the index calculation are given in Table 7 by breeds and villages. The overall flock productivity ranged from 0.27 (Massale) to 0.53 (Waykaw) villages.

Generally, CH goat breed had the highest overall flock productivity and the AB goat breeds had moderate overall flock productivity. Divergent overall flock productivity was obtained from WG goat breed where the smallest value was in Massale (0.27) and the larger was from Arkish (0.44). Higher N, LSB, S3M and 3mw(c) resulted in higher overall flock productivity and the vice versa (Table 7).

Table 5. Least squares means of litter size at birth in Abergelle (AB), Central highland and Woyto-Guji (WG) breeds.

		AB		CH		WG
Fixed factors[z]	n		n		n	
Overall	1159	1.03±0.17	714	1.40±0.45	601	1.09±0.29
Village[¥]		ns		***		ns
1	541	1.029±0.008	290	1.56±0.03a	245	1.10±0.02
2	618	1.023±0.009	424	1.34±0.03b	356	1.14±0.02
Season		ns		*		ns
Dry	1009	1.032±0.005	216	1.49±0.03a	284	1.11±0.02
Wet	150	1.020±0.014	498	1.41±0.02b	317	1.13±0.02
Parity		**		***		***
1	247	0.999±0.012b	135	1.17±0.04b	146	1.02±0.02b
2	157	1.00±0.014b	136	1.25±0.04b	137	1.02±0.03b
3	204	1.027±0.013ab	135	1.45±0.04a	107	1.08±0.03b
4	223	1.028±0.012ab	124	1.60±0.04a	97	1.18±0.03a
5	190	1.049±0.013a	81	1.62±0.05a	63	1.18±0.03a
≥6	138	1.053±0.015a	103	1.60±0.05a	51	1.21±0.04a

n=number of observations; ***=p<0.001; **=p<0.01; *=p<0.05; ns=p>0.05; z=least square means with different letters are significantly different. ¥=1=*Dingur*, *Waykaw* and *Massale* for AB, CH and WG breeds, respectively and 2=*Blaku*, *Tatessa* and *Arkisha* for AB, CH and WG, respectively.

Table 6. The influence of year and parity of previous parturition and breed on 3mw doe productivity

	Index 1		Index 2	
Parameters	n	LS means ± S.E	n	LS means ± S.E
Overall means	731	16.66±7.37	720	0.50±0.21
Breed		***		***
Abergelle	345	7.91±0.41c	337	0.32±0.01c
Central Highland	295	22.19±0.19a	292	0.69±0.01a
Woyto-Guji	91	12.91±0.79b	91	0.52±0.02b
Year		***		*
2013	333	13.22±0.47b	327	0.53±0.01a
2014	398	15.45±0.45a	393	0.49±0.01b
Parity		***		Ns
1	78	11.99±0.86b	78	0.51±0.02
Table 6 Continued				
2	106	12.65±0.74b	104	0.49±0.02
3	159	15.46±0.61a	158	0.54±0.01
4	168	15.16±0.59a	164	0.51±0.01
5	120	15.78±0.70a	117	0.52±0.02
≥6	100	14.97±0.78a	99	0.49±0.02

N=number of observations; ***=p<0.001; **=p<0.01; *=p<0.05; ns=p>0.05; z=least square means with different letters are significantly different.

Table 7. Summary of productivity parameters used in calculation of productivity indices in the three goat breeds

Parameters*	Abergelle		Central Highland		Woyto-Guji	
	Dingur	*Blaku*	*Waykaw*	*Tatesa*	*Massale*	*Arkisha*
LSB	1.029	1.023	1.56	1.34	1.10	1.14
LS3M	0.96	1.15	1.22	1.16	1.14	1.20
3mwc(kg)	10.26	9.16	10.63	10.94	7.39	10.64
INV (year)	0.83	0.95	0.69	0.76	0.85	0.85
PPWm (kg)	24.35	24.44	35.37	29.83	28.01	25.37
N	1.20	1.05	1.45	1.32	1.18	1.18
S3M	0.628	0.888	0.785	0.785	0.777	0.777
Flock productivity	0.33	0.36	0.53	0.51	0.27	0.44

*Overall mean values were used; LSB= litter size at birth; 3mwc = weight at three months of age corrected for milk consumed by producers for AB breed; LS3M= litter size at three months of age; INV= parturition interval; PPWm=mean values of post-partum weights; N=number of parturitions per year; S3M= survival rate to three months of age.

5. Discussion

In the present study non-genetic factors influencing biological production traits including 3mw, LSB and KI were investigated for three indigenous goat breeds in Ethiopia. Using the estimated parameters as input, productivities at individual and flock level were presented. The effect of year and village of birth were significant on most of the production parameters. Those years and villages of birth characterized by favorable conditions for feed production had significantly better values that were in agreement with available literature (Ndlovu and Simela, 1996; Hailu *et al*., 2005; Bharathidhasan *et al*., 2009; Meza-Herrera *et al*., 2014).

5.1. Three month weight

Generally, wet season, male sex, single birth and smaller flock size resulted in higher 3mw in the present study in the three breeds. The present result was in agreement with various reports (Ndlovu and Simela, 1996; Hailu *et al*. 2005; Yilmaz *et al*., 2007; Ukanwako *et al*.2012; Meza-Herrera *et al*., 2014). In relation to endocrinal system, oestrogen hormone has a limited effect on the growth of long bones in females and resulted in lighter body weight of females than males (Ebangi *et al*., 1996; Rashidi *et al*., 2008; Roshanfekr *et al*., 2011). Environmental conditions like temperature, humidity and rains known to have positive influence on live

weights (Ndlovu and Simela, 1996; Hailu *et al*., 2005) might have been more favourable in the villages, seasons and year with superior 3mw.

5.2. Kidding Interval

Year of previous parturition in AB and CH does and village of previous parturition in the AB had significant influence on the KI. The present values of KI for CH and WG were in agreement with values reported by Ndlovu and Simela (1996) for east African goat, Đuričić *et al.* (2012) for Boer goat and Ćinkulov *et al.* (2009) for German fawn goat. The KI of the CH and WG goat breeds were shorter than reports of Marai *et al.* (2002). However, KI of AB breed were longer than the KI values in these report. Availability of feeds has direct influence on ovulation rate and fertility, since the nutritional stress appears to be a prime probable cause of long kidding interval in goats (Bushara *et al.*, 2013). Differences in KI could be attributed to differences in genetic makeup and managements (Gbangboche *et al.*, 2006) as well.

5.3. Litter size

Parity of birth had significant effect on LSB in all the breeds ($p<0.01$ in AB; $p<0.001$ in CH and WG). In agreement with this finding parity of birth affected LSB of kids in Red Sokoto (Awemu, *et al*., 1999) where LSB from mid parities were significantly higher than the other parities. However, the values reported in the present study were lower than the values reported (1.57 – 1.77) by Maz-Harrera *et al*. (2014). In general, LSB is largely influenced by ovulation rate which was in turn substantially controlled by genotype and environment and can be increased by the pre-mating nutrition management in the case of ewes (Mukasa-Mugerwa and Lahlou-Kassi, 1995) which may also hold true in does.

5.4. Goat productivity

Breed and year of birth had significant effect on index I and Index II. Index I of Nigerian goat reported by Bosman et al. (1997) was smaller (8.3 kg – 10.2 kg) than any of the values of index I in the present study (10.73 – 18.92 kg) regardless of their shorter parturition intervals

(260 – 279 days) than that of AB and WG of present study (305 – 348 days). This was probably because the weaning weights composing the index calculation in Bosman et al. (1997) study (4.7 – 5.8 kg) was smaller than that used in the present study (7.39 – 10.94 kg).

On the other hand, Gbangboche *et al*. (2006) studied productivity of Djallonke sheep expressed as the body weight of 90 days old lamb produced per breeding female per year and found that 17.0±3.10 kg. This value was smaller than that from CH and quite higher than the rest. As indicated in equation 1, index I was calculated as the ratio of 3mw to KI. This means higher 3mw and smaller KI leads to higher index I. In the reports of Gbangboche *et al*. (2006), the weight used as 3mw were about 10.62 kg (higher than almost all of the values in the present work) and lambing intervals of 0.665 years, shorter than the kidding interval values reported in this work, hence, considerably higher values of index I than ours in Gbangboche *et al*. (2006). In agreement with the present report, parity and year of birth had significant ($p<0.001$) on the index I in Gbangboche *et al*. (2006) reports where higher values were associated with older parities. The effect of year of birth of animals on index I was not consistent in their reports.

The overall mean of index II for Djallonke sheep was 0.56 kg (Gbangboche *et al*., 2006), higher than overall mean value (0.50) in our work. The equation 2 is expressed in terms of both variables in equation 1, it becomes product of 3mw and ppw divided by KI. In such scenario, higher values of 3mw and ppw and shorter KI leads to higher value of index II. In reports of Gbangboche *et al* (2006), both numerators were higher than the values in our report and the KI was shorter.

In general, higher index I and index II were associated with higher 3mw and ppw and shorter KI. These indices showed significant difference for the fixed effect of breed where the highest values were for CH followed by WG. High values from these breeds is associated with the desired values (higher 3mw and shorter KI were the desired values for instance) of the parameters to calculate the indices.

The overall flock values in the present study were higher than the overall flock productivity from Nigerian goat studied by Bosman *et al*. (1997) that ranged from 0.19 – 0.22 kg. The variation in the productivity indices, generally, is attributed to the values of the parameters composing the calculation of productivity indices. Higher N, LSB, S3M and 3mw(c) resulted in higher overall flock productivity and the vice versa. As the result, CH goat breed had the highest overall productivity. The moderate overall flock productivity of the AB was due to the correction made to the three month weight by converting milk consumed by households to the live weight of kid.

6. Conclusion

Locations with favourable environmental factors, 2013 year of birth or kidding, wet months of birth, male kids, smaller or medium flock sizes, single born animals and higher doe ppw were associated with higher 3mw. On the other hand, parity had no significant effect on 3mw.

In general, CH goat breed was the most productive using the three indices. The higher productivity index values from these indices for CH breed is associated with higher LW3M, LS3M and shorter KI compared to the other two breeds. KI in AB breed was longest compared to the other two breeds due to harsh environments not favouring fastest onset of subsequent parturitions. Improvements in the production traits and then productivity at individual and flock level could be attained by minimizing the effects of environmental sources.

The parameters estimated in this paper could be used as benchmark for the planned CBBP of goats in the localities. The present productivity indices can be used for comparing within and/or between breeds of goat productivity in particular and small ruminant productivity in general. When comparison is to be made between breeds of multipurpose like AB, correction should be made to growth of kids by considering the amount of milk consumed by owners which would have been consumed by kids. The indices can be used under on-farm productions where recording required parameters are manageable.

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8.3.Paper III

Dam-side and genomic selection scenarios enhance genetic gains in community based goat breeding program in Ethiopia

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1. Abstract

Application of dam-side (SN2) and genomic selection (SN3) onto the current breeding practice (SN1) and expansion of SN1 to a two tiers programs (SN4) were evaluated for three indigenous goat breeds of Ethiopia to determine the optimal scenario(s). The goat breeds included (Abergelle (AB), Central Highland (CH) and Woyto-Guji (WG)), whereas the goal traits were six month weight (6mw, kg) in all breeds, litter size at birth (LSB) in CH and WG, average daily milk yield (ADM, ml) and survival to six months of age (SURV, %) in AB and litter size at weaning (LSW) in CH and kidding intervals (KI, days) in WG. ZPLAN+ software was used to deterministically compare the scenarios. The breeding scenarios were compared based on the predicted annual genetic gain (PAGGs) and annual discounted profit per animal. The PAGG in 6mw ranged from 0.308 to 0.467 (CH Gonder site), 0.209 to 0.311(CH Ambo site), 0.188 to 0.270 (WG) and 0.174 to 0.249 (AB). The PAGGs in KI for WG goats ranged from 0.167 to 0.419 from all the scenarios. The PAGG in ADM for AB ranged from 0.617 to 0.970, and SURV ranged of 0.008 to 0.013. The PAGGs in LSB and LSW were small (0.001 to 0.002). The discounted profit from SN3 was negative for all breeds which could be associated to high genotyping costs. Based on the PAGGs and discounted profitability, we recommend SN2. SN4 could also be applied, compared to SN1, in view of low risk of inbreeding, higher profitability and suitability of addressing emerging demands. The PAGGs in LSB, LSW and SURV were small implying that improvements of these traits are best achieved through improved management levels as part of the overall improvement program.

Keywords: *selection group; selection intensity; reproduction cycle; ZPLANPLUS*

2. Introduction

Community based breeding program (CBBP) is design of breeding scheme that is deemed suitable for smallholder farming system (Gizaw *et al*., 2014a). The CBBPs for livestock have been established in different parts of the world; for sheep and goats in Ethiopia (Duguma, 2010; Duguma *et al*., 2011; Haile *et al*., 2011; Abegaz *et al*., 2014), for goats in Mexico (Wurzinger *et al*., 2013) and in Iran (Mueller *et al*., 2015a). CBBPs particularly for small ruminants, are preferred, to the more common top down breeding programs that are mostly established on governmental stations in developing countries (Mueller *et al*., 2015b).

The CBBPs being studied here were supported and implemented by International Livestock Research Institute (ILRI), International Centre for Agricultural Research in Dry Areas (ICARDA) and national agricultural research systems of Ethiopia in six villages, two villages for each breed for three indigenous goat breeds. The breeds included Abergelle (AB) kept in arid pastoral, Central Highland (CH) inhabiting crop-livestock production system and Woyto-Guji (WG) from semi-arid agro-pastoral production systems (Tatek *et al*., 2016).

Currently one-tier CBBPs of sheep (Haile *et al*., 2011; Mirkena *et al*., 2012) and goats are being implemented in various communities in Ethiopia where neither dam side nor genomic selection are being applied. The focus was merely on the selection of males. The objective of the present work, therefore, was to optimize the current breeding program by designing and testing alternative breeding scenarios for AB, CH and WG goat breeds applicable to their respective production systems. Three alternative breeding scenarios were simulated: 1) dam-side selection: inclusion of dam-side selection could increase the genetic gain through improving selection intensity; even though the selection intensity to be realized on dam-side is low, application of selection on dam-side could be better than focussing only on male selection; 2) genomic selection: various reports are available indicating that genomic selection could be promising in livestock breeding (Carvalheiro, 2014; Din *et al*., 2013; Larroque *et al*., 2014; Rupp *et al*., 2016). According to report of Schaeffers and Weigel (2012), the rate of genetic progress could be doubled by application of genomic selection, which is promising for dairy or dual-purpose goats 3) two tier breeding program: assuming that the expansion of the

one tier CBBP of goats to two tier would allow quicker dissemination of genetic progress (Gizaw *et al*., 2014b).

3. Materials and Methods

3.1. Description of the study sites

Optimizations scenarios were based on the data collected from CBBPs established in two villages per breed. From each of the two sites for AB and WG, averages number of breeding females were considered. Due to long distances between villages for CH, the two villages (Gonder and Ambo) were considered as separate villages bringing the total to four villages for the alternative scenarios. Detailed geographical information of the study sites are given in Table 1.

3.2. Breeding goals and selection criteria

Body size was identified as the breeding objective trait for all the three goat breeds. In addition, producers keeping CH goats indicated twinning and mothering abilities as the most targeted traits to be improved whereas twinning ability and short kidding interval were the most preferred traits by producers keeping Woyto-Guji (Alemu, 2015; Tatek *et al*., 2016; Zergaw *et al*., 2016).

Table 1. Description of the study sites by breeds

	Abergelle		Central highland		Woyto-Guji
District	Tanqua Abergelle	Ziquala	Lay Armachiho	Meta-Robi	Konso
District's zone	Centeral Tigray	Wag Himra	North Gonder	West shoa	Segen Zuria
District's center*	Yechila	Tsitsika	Tikil Dingay	Shino	Karat
Distance from Addis (km)	893	784	758	100	595
Village (s)	Dingur	Blaku	Waykaw	Tatessa	Messale and Arkisha

Table 1 Continued

Altitude (m.a.s.l.)	1574	1462	2052	1200-2900	500-2200
Latitude (North)	$13^0$22'	$12^0$48'	$12^0$58'	$9^0$20'	$5^0$17'
Longitude (East)	$38^0$99'	$38^0$47'	$37^0$04'	$38^0$10'	$37^0$29'
Temperature (^{0}C)**	20-28	22	17-24	23-31	12- 30
Rainfall (annual, ml)	539	255	840-1200	750-110	400-1000

m.a.s.l.=meters above sea level; *= Ranges of district altitudes were given for CH from Ambo and WG goat breed from Konso; **=mean daily temperature

Increased milk yield and survivability were the additional targeted breeding objective traits in the case of AB goat breeds. Selection criteria were six month weight (6mw), average daily milk yield (ADM), survival to six month of age (SURV), litter size at birth (LSB), litter size at weaning (LSW) and kidding interval (KI) for body size, milk yield, survivability, litter size, mothering ability and reproduction performance, respectively. Economic weights for the selection traits were derived according to the procedure illustrated by FAO (2010). The relative importance of selection traits, in an index form, for the goat producers were adopted from reports on productivity studies of the same breeds (Alemu, 2015; Zergaw *et al*., 2016; Tatek *et al*., 2016).

3.3. Description of the goat breeds

The description of the indigenous goat breeds is given in Table 2. AB goat breed is kept in arid production system whereas the WG goat breed is kept in the semi-arid production system. Central highland is suited to crop-livestock mixed production system.

3.4. Description of simulated alternative breeding scenarios

One tier community based breeding practice was taken as the base scenario (SN1) while three alternative scenarios were simulated in this study.

Table 2. Description of the goat breeds

Parameters	Abergelle	Central Highland	Woyto-Guji
Distribution	South Tigray, North Wollo, eastern Gonder	Centeral highlands, West of the Rift-valley, Wollo, Gonder and Shoa	North and south Omo, Sidamo, and Wolyta
Production system	Arid	Crop-livestock	Semi- arid
Use	Meat, milk and skin	Meat and skin	Meat and skin
Facial profile	Straight to concave	Straight	Straight to concave
Horn	All horned	All horned	Most horned; there are some polled
Height at wither (cm)			
Male	71.4	76.3	72.9
Female	65	67.9	66.4

The scenarios were; 1) addition of dam-side selection onto SN1 (SN2), 2) inclusion of genomic selection (SN3) and 3) systematic expansion of one tier to the two tier breeding (SN4). In the SN4, the number of additional breeding does targeted were assumed to be about three times the number of does in SN1. In Table 3 are summaries of the descriptions of the scenarios.

The four scenarios are also illustrated in figure 1. Bucks were selected at two stages (stage one (S1B) at the age of three months based on dam's information and stage two (S2B) at the age of six months based on own information). Male and female kids are produced from initial does and bucks in the villages. Candidate males and candidate females are identified after excluding few kids (≈5%) from getting into the breeding program based on their physical flaws. Instead of considering all of the candidate bucks for step one selection, about 5% of them were dropped (in ZPLAN+, there is such option: 'size' = total animal available for selection; 'proven' = total animals available for selection but after excluding some from 'size'; 'selected' = animals selected finally. This is for all the selection groups.) Therefore, in step one, selected bucks are obtained by selecting about half of the candidate male cohorts ('proven') based on their dam's S1B trait information. S1B improve, with the mind that they also improve body size, milk yield and survivability in AB, twining and mothering ability in CH and twining and reproduction performance in WG. S2B were filtered from, on body size, S1B. The number of S1B and S2B to be used for mating was determined based on the number

of breeding females available in the village. It was designed as majority of the breeding does are mated to S2B (90%) and the rest mated to S1B in SN1 to SN3. In SN4, majority of production does were designed to be mated to S1B (90%) and the rest mated to S2B.

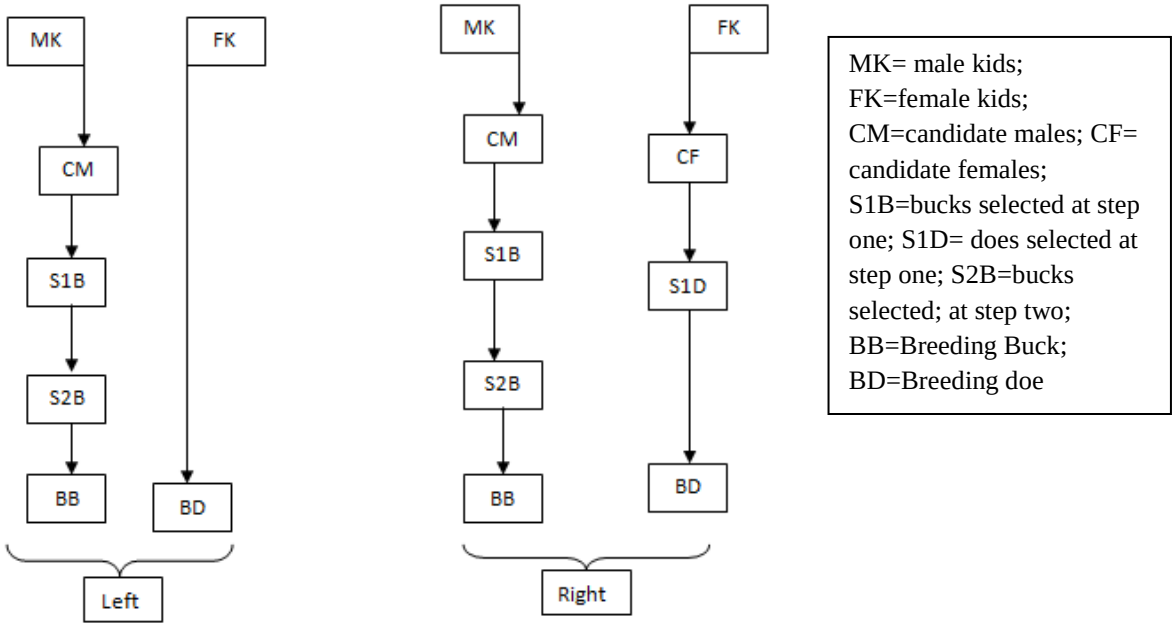

Figure 1. Schematic representation of alternative breeding scenarios: **Left**: representation of SN1, SN2 and SN4 (where S1B in SN4 serve the extra does); there is no dam line selection; new born female kids to be used to replace some of the initial does as necessary; **right**: representation of SN2.

Table 3. Summary of alternative breeding scenarios

Parameter	Current SN (SN1)	SN1+Dam line selection (SN2)	SN1 using genomic selection (SN3)	Two tier SN (SN4)
Male : Female ratio	1:25	1:25	1:25	1:25
Dam line selection	-	√	-	-
Genomic selection	-	-	√*	-
Two steps selection	√	√	√	√
Information sources for S2B	own	Own	own	own
Information sources for S1D	-	Own	-	-
Use of S1B(%)	10	10	10	90
Use of S2B(%)	90	90	90	10
Selection groups	S1B, S2B, BD	S1B, S2B, S1D	S1B, S2B, BD	S1B, S2B, BD, PD

SN = S1B=Step 1 selected bucks; S2B= Step 2 selected bucks; BD = breeding does; S1D = Step 1 selected buck; PD=Production does; * genomic selection was applied to growth only.

The inclusion of genomic selection into the current breeding practice requires calculation of desired accuracy (Ehret *et al*., 2012) that was obtained by the following formula derived by Daetwyler *et al*. (2010):

$$r_{t*g} = w \times \left[\frac{Nr^2}{Nr^2 + Cs}\right]^{1/2}$$

r_{t*g} = Correlation of true BV and GEBV for the genomic trait; w (the calibration factor) = 0.9, determined value for cattle (Erbe *et al*., 2011) was used as there no such value available for goats; N = number of animals in the reference population; r^2 = the reliability of GEBV of the animals in the calibration set, this was obtained from the heritability of the trait; Cs= number of independent chromosome segments which is determined by the following formula:

$$Cs = \frac{2LN_e}{\ln(4LN_e)}$$

where L is length of genome in Morgan which was set to 32, Ne = effective population size. In this scenario N was assumed to be total number of animals in the scenario, r^2 was assumed to be the heritability. Such assumptions were made in genomic selection of goats (Al-Atiyat, 2014), sheep (Shumbusho *et al*., 2014), poultry (Sitzenstock *et al*., 2013) and pigs (Haberland *et al*., 2013) among others.

3.5. Input parameters

Input parameters for the simulation studies are given in Table 4. Population parameters were calculated based on the number of initial does in the respective villages of the breeds. Number of candidate males was calculated as the product of initial does, conception rate, twinning rate, number of parturition per year, survival rate to six month, kidding rate and sex ratio. Candidate females and candidate males were assumed to be equal assuming an equal sex ratio. Number of breeding does was assumed to be the sum of initial does and candidate females since initial does are used together with candidate females in the one selection cycle. Hence, male to female mating ratio was based on breeding does, not on initial does, in this study. The

period for which breeding animals remain in the flock was adopted from previous work on indigenous sheep breeds in Ethiopia (Mirkena *et al*., 2012) whereas generation interval, conception rate and survival rate to six months were based on literature reports and given in Table 4 for the three breeds. KI and LSB were derived from monitoring data for the respective breed (Jembere *et al*. in press (small ruminant research)).

Table 4. Input parameters by breeds

Parameters	Abergelle	Central Highland		Woyto-Guji
		Gonder	Ambo	
Population parameters				
Initial does(IND)	630	303	328	294
Candidate Male (CM) or Candidate Female (CF) per time unit (TU)	250	220	187	125
Stage one selected bucks (S1B)/TU	119	105	88	60
Stage two selected bucks (S2B)/TU	32	21	21	17
Breeding does ((BD)=IND+CF)/TU	880	523	515	420
Biological parameter				
Breeding doe in use (year)	5	5	5	5
Breeding buck in use (year)	2	2	2	2
Mean age of bucks at birth of 1st offspring	1.5	1.4	1.4	1.5
Mean age of does at birth of 1st offspring	1.7	1.5	1.5	1.7
Reproduction cycle (kidding interval) (year)	0.89	0.69	0.75	0.85
Conception rate	0.89	0.89	0.89	0.89
Kidding rate	0.85	0.85	0.85	0.85
Litter size	1.02	1.56	1.34	1.12
Survival rate to six month of age	0.90	0.90	0.90	0.90
Cost parameters				
Variable cost (VC)/animal/S1B/ TU (€)	0.38	0.44	0.52	0.77
VC/animal/S2B/TU (€)	0.81	0.92	1.10	1.62
VC/animal/BD/TU (€)	0.11	0.18	0.19	0.23
Interest rate of discounted costs (%)	5	5	5	5
Interest rate of discounted returns (%)	8	8	8	8
Investment period (year)	15	15	15	15

With regard to costs, only additional variable costs (Nitter *et al*., 1994) were calculated . First, total variable costs per village were calculated. These variable costs relate to record keeping, animal identification and health care costs. Then the total variable costs were equally divided to each selection group. Within the selection group, the total variable costs were divided to the total number of animals in the selection group. Contrary to Mirkena *et al*. (2012), Abegaz *et al*. (2014) and Mirkena *et al*. (2015), we assumed higher interest rate of discounted returns

than costs as such assumptions lead to more conservative discounted profit (Ehret *et al*., 2012). All costs were computed as of 15-April-2015 (1€ ≈21.9251 Birr). Breeding costs of SN2 and SN4 were assumed to be similar with that of SN1. Such assumption could be logical as larger selection proportion (80%) or lesser selection intensity is applied to young females in SN2 which could not necessarily require additional cost.

The S1Bs that are assumed to be used for mating in additional breeding females in SN4 have been produced through SN1; there may be additional organizational costs but these could not be adequately estimated and thus were assumed to be negligible. On the other hand, additional €112.66 per animal variable cost was assumed for pre-genotyping and genotyping in SN3 on top of the variable costs in the SN1.

The phenotypic standard deviations and economic weight of breeding objective traits used in the simulations are given in Table 5. Genetic and phenotypic correlations among the breeding objective traits are presented in Table 6. The phenotypic standard deviations were obtained from the respective data generated on the breeds whereas genetic parameters were based on literature review (Jembere *et al*. un published). ZPLANPLUS, a web-based menu driven software (https://service.vit.de/zplanplus/) was used in the present study. The latest version that was used here allows modelling of genomic selection in contrast to the earlier versions.

4. Results

4.1. Predicted genetic gains in breeding objective traits

Predicted annual genetic gains (PAGG) in six month weights (6mw, kg) were highest in SN3 followed by SN2, SN1 and SN4. This was the same for all goat breeds, except for AB where the PAGG in 6mw from SN4 was higher than in SN1 (Table 7). The PAGGs in 6mw, from all the scenarios, ranged from 0.308 to 0.467 for CH from Gonder site, 0.209 to 0.311 for CH from Ambo site, 0.188 to 0.270 for WG and 0.174 to 0.249 for AB.

The highest PAGGs in 6mw were obtained for CH Gonder site, followed by CH Ambo site; the smallest values for the PAGG in 6mw were for AB goat breed. The same sequence of superiority of PAGG in KI, for WG goat breeds from the scenarios (SN3>SN2>SN1>SN4) as in 6mw, was observed which ranged from 0.167 to 0.419.

While SN3 resulted in the highest PAGG in terms of average daily milk yield (ADM, ml) and in survival rates to six month of age for AB goats, the next highest values were achieved in SN4, followed by SN1 and SN2. The PAGG estimated of ADM ranged between 0.617 and 0.970, and those for SURV between 0.008 and 0.013. The PAGG in LSB in both CH and WG goat breeds from all scenarios, except from SN3 in WG, was found to be same and had the magnitude of 0.001. Smaller LSB (0.0004) was obtained from SN3 in WG.

Table 5. Phenotypic standard deviation (σ_p) and economic weight (EW) for selection criteria by breed

		AB		CH1		CH2		WG	
Traits	Unit	σ_p	EW	σ_p	EW	σ_p	EW	σ_p	EW
6mw	Kg	2.09	0.351	3.90	0.14	2.22	0.24	2.29	0.30
ADM	Ml	157	0.003	0.50	-	-	-	-	-
SURV	%	3.80	0.316	0.70	-	-	-	-	-
LSB	№	-	-	-	3.36	0.47	2.47	0.30	6.29
LSW	№	-	-	-	2.06	0.67	2.19	-	-
KI	Day	-	-	-	-	-	-	88.90	0.01

AB=Abergelle; CH1= Center highland of Gonder site; CH2= Central Highland of Ambo site; WG=Woyto-Guji; 6mw=six month weight; ADM= average daily milk yield; LSB= litter size at birth; SUR= survival to six months; LSW=litter size to weaning; KI= kidding interval (selection criteria:-AB: 6mw, ADM & SURV; CH: 6mw, LSB & LSW; WG: 6mw, LSB and KI)

4.2. Predicted monetary genetic gain and discounted profits

Highest mGGs, considering all the scenarios, were realized from AB followed by WG, CH Ambo site and CH Gonder: the values ranged from 0.066 to 0.093 for AB, from 0.065 to 0.085 for WG, 0.060 to 0.082 for CH Ambo site and 0.052 to 0.075 for CH Gonder site. Due to the relatively high costs, the discounted profit from SN3 was negative for all breeds in all sites.

Table 6. Genetic correlation (above diagonal), heritability (diagonal) and phenotypic correlation (bellow diagonal) for selection criteria in three goat breeds

	AB				CH				WG		
Traits	6mw	ADM	SUR		6mw	LSB	LSW		6mw	LSB	KI
6mw				6mw				6mw		-	
	0.28	0.20	0.30		0.28	-0.12	-0.12		0.28	0.12	0.10
ADM	0.10	0.31	0.53	LSB	-0.20	0.05	0.79	LSB	-0.20	0.05	0.61
SUR				LSW				KI		-	
	0.10	0.07	0.09		-0.20	0.24	0.06		0.50	0.06	0.09

AB=Abergelle; CH1= Center highland of Gonder site; CH2= Central Highland of Ambo site; WG=Woyto-Guji; 6mw=six month weight; ADM= average daily milk yield; LSB= litter size at birth; SUR= survival to six months; LSW=litter size to 3 months; KI= kidding interval (selection criteria:- AB: 6mw, ADM & SURV; CH: 6mw, LSB & LSW; WG: 6mw, LSB and KI).

Positive profits were obtained from the three other scenarios except from SN1 for WG goat breed. SN4 resulted in the highest profits, followed by SN2 for three sites while the profit from SN2 was higher than from SN4 for CH Ambo site. Breeding programs for AB were more profitable than for the other goat breeds and sites, while the smallest profits were achieved with WG. The values (Euro) for profitable scenarios ranged from 0.134 to 0.345 for AB, from 0.048 to 0.098 for CH Ambo, from 0.035 to 0.158 for CH Gonder and from 0.005 to 0.167.

5. Discussion

All the three scenarios simulated as alternatives to the current CBBP of goats in Ethiopia had advantages in terms of PAGG and mGG over the baseline CBBP in all the three breeds. Sizable PAGG, however, were obtained for 6mw weight only. The other breeding objective traits did not show substantial predicted annual genetic gain. This is probably because of generally low levels of variability for other traits within each of the populations. Heritability values of twining, mothering ability and survivability were smaller compared to the growth traits (Safari *et al*., 2005; Jembere *et al*. in press). The unfavourable genetic correlations of these traits with growth traits could also be another possible reason for small genetic gain realized in the rest traits compared to growth.

Table 7. Predicted annual genetic gains (PAGG) in selection traits, generation interval (GI) and intensity of selection (IS) from the four scenarios (SN) for Abergelle (AB), Central highland (CH) and Woyto-Guji (WG) goat breeds in Ethiopia

	Abergelle site (AB)				Gonder site (CH)				Ambo site (CH)				Konso site (WG)			
Trait*	SN1	SN2	SN3	SN4	SN1	SN2	SN3	SN4	SN1	SN2	SN3	SN4	SN1	SN2	SN3	SN4
6mw	0.174	0.185	0.249	0.183	0.336	0.364	0.467	0.308	0.223	0.242	0.311	0.209	0.195	0.209	0.270	0.188
ADM	0.743	0.617	0.970	0.868	-	-	-	-	-	-	-	-	-	-	-	-
SURV	0.010	0.008	0.013	0.011	-	-	-	-	-	-	-	-	-	-	-	-
KI	-	-	-	-	-	-	-	-	-	-	-	-	0.265	0.190	0.167	0.419
LSB	-	-	-	-	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0004	0.001
LSW	-	-	-	-	0.002	0.001	0.002	0.002	0.002	0.001	0.002	0.002	-	-	-	-
GI	2.826	2.826	2.463	2.826	2.425	2.425	2.113	2.425	2.575	2.575	2.187	2.575	2.775	2.775	2.415	2.775
IS	0.514	0.567	0.520	0.512	0.563	0.634	0.567	0.559	0.538	0.602	0.558	0.536	0.512	0.560	0.460	0.507

6mw=PAGG in six month weight (kg); ADM= PAGG in average daily milk yield (ml); SURV=PAGG in Survival to six months of age (%); KI=PAGG in kidding interval (days); LSB=PAGG in litter size at birth; LSW=PAGG in litter size at weaning.

Table 8. Monetary genetic gain (mGG), discounted returns (Return), discounted costs (cost) and discounted profit (Profit) in Euro from the four scenarios (SN) for Abergelle (AB), Central highland (CH) and Woyto-Guji (WG) goat breeds in Ethiopia**

	Abergelle site				Gonder site				Ambo site				Konso site			
Parm*	SN1	SN2	SN3	SN4	SN1	SN2	SN3	SN4	SN1	SN2	SN3	SN4	SN1	SN2	SN3	SN4
mGG	0.066	0.069	0.093	0.070	0.055	0.057	0.075	0.052	0.060	0.063	0.082	0.059	0.065	0.067	0.085	0.066
Cost	0.275	0.275	9.224	0.064	0.300	0.300	13.304	0.091	0.325	0.325	13.98	0.173	0.418	0.418	17.42	0.135
Profit	0.134	0.256	-8.59	0.345	0.035	0.081	-12.81	0.158	0.048	0.098	-13.4	0.059	-0.02	0.005	-16.8	0.167

Parm=parameters; *= breeding costs were pre animal and in EURO; **= Abergelle site was for AB; Gonder and Ambo sites were for Konso site was for WG.

Abegaz et al. (2014) reported PAGG in 6mw (kg) of 0.8702 to 0.8724 and 0.360 to 0.365 for Western lowland and AB goat breads, respectively. The authors also reported PAGG in average daily milk yield (kg) for AB breed to be 0.0066 to 0.0114. These values were higher than the ranges of PAGG in 6mw in the three breeds and ADM in AB goat breed predicted from the current study.

Except for Abegaz *et al*. (2014), reports for such comparisons were not available on indigenous goat breeds of Ethiopia. However, similar reports are available on sheep breeds in Ethiopia and elsewhere. Gizaw *et al*. (2014b) reported PAGG of 0.119 to 0.286 kg in 6mw of Menz sheep which is in agreement with this study from the various scenarios except for the higher value reported from the CH Gonder site. However, simulations by Mirkena *et al*. (2012) resulted in much higher values of PAGG in yearling weights for Ethiopian sheep. The values in kg were in the range of 0.813 to 0.894 for Bonga, 0.850 to 0.940 for Horro and from 0.616 to 0.699 for Menz.

The discrepancies between the present results and those reported elsewhere could be attributed to the magnitudes of phenotypic standard deviations and intensity of selection. For instance, in the study reported by Abegaz *et al*. (2014), higher phenotypic standard deviations for 6mw (2.74 kg) and for ADM (230 ml) were reported compared to the phenotypic standard deviations of 2.09 kg (6mw) and 157 ml (ADM) used in this study. In Mirkena *et al*. (2012) high phenotypic standard deviation were used (6.36 kg for Bonga and Horro and 3.46 kg for Menz). Generally, the higher the phenotypic variations, the higher the predicted genetic gains. On the other hand, Mallick *et al*. (2016) estimated smaller annual genetic trend in 6mw amounting 7 gm for Bharat Merino sheep.

The PAGG in mothering ability as represented by the proportion of young weaned per dam per year (%) by Abegaz et al. (2014) and Mirkena *et al*. (2012) were very small and are in agreement with the present report. The PAGG in LSB and survival rate to weaning (%) for Menz sheep were in the range of 0.0013 to 0.0031 and 0.0010 to 0.0022, respectively (Gizaw *et al*., 2014b) thus, in the same order of magnitude as the values presented here.

5. Alternative scenarios

The higher PAGG in 6mw from SN2 were expected, as SN2 benefited from the higher selection intensity contributed from the dam-side selection in addition to that of bucks. Although we assumed a relatively high retention of 80% on the young female side (without applying selection on the old dams), this still resulted in considerably higher overall PAGG and mGG in SN2 compared to SN1. The smaller PAGG values for ADM resulting from SN2 in AB goat breed could be explained by the fact that selection on dam-side was set to be based on own live weight as breeding female animals could be identified for breeding based on either body weight or age (Abebe, 2009). Therefore, 6mw was favoured in SN2 than other breeding objective traits compared to SN1.

Applying a higher selection intensity would result in even higher PAGG on one hand and higher discounted returns on the other. The selection intensity improved via selecting dam-side also increases the breeding return. Lower costs and higher returns on investments then result in higher profitability of breeding. Hence, SN2 was found to be more economical compared to SN1 as no additional investment costs were assumed in SN2 over SN1. From 6 to 9% improvement of PAGG in 6mw (Table 7) and from 91 to more than 100% improvement in PAGG of discounted profit (Tables 8) was made to SN1 by having SN2. This implied that SN2 is better alternative breeding scenario to SN1 in the CBBP of indigenous goat breeds of Ethiopia in particular and for CBBP of small ruminants in general. The culture of keeping all does for breeding purposes in rural households could be a bottleneck in implementing dam-side selection. However, continues engagement and consultations with communities should be the starting point for such initiatives. Within a village, the available does could be categorized based on genetic merits where the 'best' dams could be used for breeding purpose.

By including genomic information into the current breeding practices, PAGGs of the selection criteria and monetary genetic gains from SN3 were relatively higher than those from SN1. In genomic selection scenario, higher accuracy of selection index, shorter generation intervals and higher selection intensity are jointly exploited to result in overall higher predicted annual genetic and monetary genetic gains (Schaeffers and Weigel, 2012). According to Carvalheiro

(2014), breeding schemes combining genomic selection and reproductive technologies provided the best results in terms of genetic gain. In Sahiwal cattle breed of Pakistan, the advantages of genomic selection over progeny testing were spelled out as shortening the generation interval from 10.25 years to 2.75 years, increasing the response to selection by 2.5 time and reducing the costs of proving bulls by 96% (Din *et al*., 2013).

In this study, selection intensities attained were not as high as those reported in dairy cattle. The reason was that the selected best bucks could not serve more than 25-30 breeding females, because of natural mating practiced in goats as opposed to artificial insemination (AI) in cattle, where semen from the best bulls can serve thousands of cows. Thus, the higher PAGGs from SN3 was, therefore, associated with assuming higher accuracy of selection index and shorter generation intervals. The improvement of the PAGG in 6mw ranged from 38-48 % in SN3 compared to SN1 for the three goat breeds (Table 7). Nevertheless, SN3 also improved SURV in AB and KI in WG which could be explained by the favourable genetic correlation between ADM and KI with 6mw. Contrarily, LSB and LSW did not benefit from SN3 due to their antagonistic genetic relationship with the 6mw (Table 5).

Currently, the lack of a cost-effective strategy for applying genomic selection is the main drawback for its widespread use (Carvalheiro, 2014). In the present study, we assumed that male animals are selected based on high density 50K Single Nucleotide Polymorphism (SNP) marker for their 6mw and hence the contribution of genomic selection was fully expressed in 6mw.

The discounted returns from SN3 could not offset the high genotyping costs resulting in non-profitable breeding activity in all the three breeds. Genomic selection scenario was also associated with higher variable costs in the case of French sheep (Shumbusho *et al*., 2014). Carvalheiro (2014) suggested that genotyping strategies need to be defined to better identify the proper densities of marker panels to be used for each category of animal and in which proportion they should be genotyped. Use of lower density SNP Chip could lead to improved profitability. According to Rupp *et al*. (2016), additional limitations of applying genomic selection to small ruminants included small reference population sizes, low linkage

disequilibrium, multi-breed evaluations and lack of phenotype recording in many countries. Even though SN3 resulted in higher predicted genetic gains, its application as an alternative to SN1 is bottlenecked by lack of cost effective genotyping strategies. In addition to the higher costs involved in implementation of genomic selection, lack of adequate infrastructure makes its application under smallholder production systems unattainable. Exploring cost effective techniques of genotyping and improving infrastructures may lead to application of genomic selection of goats in Ethiopia in near future.

SN4 resulted in higher PAGG in 6mw and in ADM than SN1 in AB goat breed. In the other breeding objective traits and for the other goat breeds and sites, however, SN4 was not more favourable than SN1 in terms of genetic gains. The possible explanation could be that SN4 assumed additional number of production does over the SN1. In the present study, extensive use of S1B in SN4 was designed. Therefore, more improvement in the SN4 over SN1 was realized on the traits for which S1Bs were selected. For instance, PAGG in SURV and ADM in the case of AB goat breed were higher from SN4 compared to SN1. In the case of CH goat breeds, LSB and LSW from SN4 did not make improvement at all compared to the gains from SN1 which could be attributed to the low heritability values of the traits. On the other hand, the predicted annual genetic gain in 6mw from SN4 was smaller in all the cases compared to the result from SN1 which is due to the fact that in SN1, S2B selected based body weight were used.

However, in terms of profitability, SN4 was found to be always better than SN1. In such cases, SN4 may work good compared to SN1- SN3. A disadvantage of single tier breeding program, which most likely involves smaller number of animals than two or more tier breeding program, is that they are more prone to inbreeding level build-ups unless the mating schemes are carefully designed and monitored. In this SN4, we designed the flow of male genetic materials from single tier to the production does which could not reduce the risk of inbreeding. Consideration of flow 'best' female genetic materials from the production does to the nucleus could help for such concerns.

6. Conclusion

All the four scenarios resulted in significantly higher PAGGs, especially for 6mw and ADM selection traits and even though, PAGGs from SN3 were the highest, this scenario was associated with the highest variable costs resulting in negative discounted profit. The possibilities of exploiting genomic selections scenario, in CBBP of goats is promising, especially as the genotyping costs are expected to significantly get less and less over time. Increased number of base breeding animals over time, and use of AI techniques would only enhance these advantages.

Based on the PAGGs and profitability we suggest SN2 over SN1. However, SN4 could also be applied, compared to SN1, in view of higher profitability and suitability of addressing emerging demands. The PAGGs in reproduction, mothering ability and survival were small implying that improvements of these traits are best achieved through improved management levels as part of the overall improvement program.

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8.4. Paper IV

Recording birth weight has no significance in village based genetic improvement programs of small ruminants

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1. Abstract

*The present study was conducted to justify that keeping birth weight (BWT) records have little or no significance in genetic improvements of market or adult weights of small ruminants while implementing of community based breeding program (CBBP). Analysis of Pearson correlation ("r") between BWT and six month (6MW), BWT and nine month weight (9MW), three month weight (3MW) and 6MW and 3MW and 9MW was conducted for three indigenous Ethiopian goat breeds, namely Abergelle (AB), Central Highland (CH) and Woyto-Guji (WG). The records used for the trait combination ranged from 365 to 715 for BWT and 6MW, 271 to 543 for BWT and 9MW, 362 to 715 for 3MW and 6MW and 269 to 543 for 3MW and 9MW. The 6MW and 9MW were also regressed on BWT and 3MW for the three indigenous goat breeds. The "r" between BWT and 6MW, BWT and 9MW, 3MW and 6MW and 3MW and 9MW ranged from 0.099 to 0.176, 0.051 to 0.163, 0.598 to 0.706 and 0.370 to 0.546, respectively. The regression coefficients ("**b**") of 6MW on BWT, 9MW on BWT, 6MW on 3MW and 9MW on 3MW ranged from 0.494 to 0.999, 0.311 to 0.996, 0.706 to 0.927 and 0.415 to 0.669, respectively. In general, BWT had weak "r" with 6MW and 9MW in three indigenous goat breeds of Ethiopia. The adjusted R-squared (R^2) for regressing 6MW and 9MW on BWT was less than three percent whereas the R^2 was in the range of 13 to 50% for the regression of the traits on 3MW. Literature reports also indicated weak "r" and genetic correlation (r_g) between BWT and adult or market weight in small ruminants. In addition, the direct heritability is smaller for BWT, compared to adult weights. For these factual, BWT could not be targeted for direct genetic improvement through selection and indirect improvement of other traits. Yet, recording BWT in the CBBP remained compulsory. We conclude that keeping BWT records under the village based breeding program of small ruminants has little or no significance.*

Key words: Correlation; Market weight; Heritability

2. Introduction

Community based breeding program (CBBP) is said to be suitable for small stock keepers of small ruminants in developing countries (Muller *et al.*, 2015a). It is presented as an alternative to the station or government based breeding program. These days, the CBBP is being implemented in many developing countries including Ethiopia (Duguma 2010; Duguma *et al*., 2012; Haile *et al*., 2011; Abegaz *et al* 2014; Wurzinger *et al*., 2013; Mueller *et al*., 2015b).

The approach required record keeping, among others, for which hiring enumerators is mandatory. Recording formats have been developed by breeders to be kept by enumerators for the CBBP implemented in Ethiopia. For instance, detailed recording formats developed and used in CBBP of sheep (Duguma, 2010) and goat (Alemu, 2015) in Ethiopia could be evidences. Growth traits at different ages including birth weight (BWT), three month weight (3MW), six month weight (6MW) and 12 month weight (12MW) in the CBBP of sheep (Duguma, 2010) and BWT, 3MW, 6MW, nine month weight (9MW) and 12MW in the CBBP of goats (Alemu, 2015) are being kept in Ethiopia.

Among the growth traits, we observed that keeping accurate BWT was not easy. Birth weights could be easily recorded within 24 hours after birth in station based breeding program. In the CBBP, however, it is not easy to record BWT within 24 hours after birth. Recording the BWT in CBBP rather depends on the feedback owners provide to enumerators or the activeness of the enumerators to round on all the member farmers participating in the CBBP and monitor new births. Unless special focus is given, for instance hiring as many enumerators as possible, accurate birth weight could not be recorded in the CBBP of small ruminants. Hiring numerous enumerators, on the other hand, could be associated with high variable costs leading to low discounted profitability of a breeding activity (Mirkena *et al*., 2012; Gizaw *et al*., 2014).

The paradox is embarking in the keeping of BWT records under village breeding program where it has little or no implication for the genetic improvement programs. Meta-analysis of literature review in sheep (Safari *et al*., 2005) and in goats (Jembere *et al*., unpublished) showed that birth weight had weak phenotypic and genetic (r_g) correlations with adult or market weights. On top, the BWT had smaller direct additive heritability and higher maternal

heritability compared to the adult or market weights; which means it might not be appropriate selection criteria. We wanted to argue the importance of recording birth weight versus its significance in the CBBP of small ruminants. To reveal that, we analyzed correlation and regression coefficients BWT with adult or market weights. Growth data generated from three indigenous goat breeds namely, Abergelle, Central highland and Woyto-Guji were used. The work was also backstopped by reliable literature parameter estimates.

2. Materials and Methods

2.1. Description of the study sites and breeds

The data used for the correlation and regression analysis in the present work were generated from CBBPs established for three indigenous goat breeds, namely Abergelle (AB), Central highland (CH) and Woyto-Guji (WG). There were two villages per breed. The data were pooled from the two villages and analysed by breed. The villages were where Biosciences for eastern and central Africa - International Livestock Research Institute (BecA-ILRI) goat project was implemented. Detailed information of the study sites were given in Table 1.

Table 1. Description of the study sites by breeds

	Abergelle		Central highland		Woyto-Guji
District	Tanqua Abergelle	Ziquala	Lay Armachiho	Meta-Robi	Konso
District's zone	Centeral Tigray	North Wollo	North Gonder	West shoa	Segen Zuria
District's center*	Yechila	Tsitsika	Tikil Dingay	Shino	Karat
Distance (km)	893	784	758	100	595
Village(s)	Dingur	Blaku	Waykaw	Tatessa	Messale and Arkisha
Altitude (m.a.s.l.)	1574	1462	2052	1200-2900	500-2200
Latitude (North)	$13^0$22'	$12^0$48'	$12^0$58'	$9^0$20'	$5^0$17'
Longitude (East)	$38^0$99'	$38^0$47'	$37^0$04'	$38^0$10'	$37^0$29'

Table 1. Continued

Temperature	20-28	22	17-24	23-31	12- 30

(^{0}C)**					
Rainfall (annual, ml)	539	255	840-1200	750-110	400-1000

m.a.s.l. =meters above sea level; *=altitude ranges for Meta-Robi and Konso were given for the whole district; **=mean daily temperature.

2.2. Description indigenous goat breeds

Abergelle goat breed is kept in arid production system whereas the Woyto-Guji goat breed is kept in the semi-arid production system. Central highland is suited to crop-livestock mixed production system (Tatek *et al*., 2016). The description of indigenous goat breeds is given in Table 2.

Table 2. Description of the indigenous Ethiopian goat breeds

Parameters	Abergelle	Central Highland	Woyto-Guji
Distribution	South Tigray, North Wollo, eastern Gonder	Centeral highlands, West of the Rift-valley, Wollo, Gonder and Shoa	North and south Omo, Sidamo, and Wolyta
Production system	Arid	Semi- arid	Crop-livestock
Use	Meat, milk and skin	Meat and skin	Meat and skin
Facial profile	Straight to concave	Straight	Straight to concave
Horn	All horned	All horned	Most horned; there are some polled
Height at wither (cm)			
Male	71.4	76.3	72.9
Female	65	67.9	66.4

2.3. Phenotypic correlation and regression

Pearson correlation ("r") among growth traits in three indigenous goat breeds was made. Regression of adult or market weights on BWT and 3MW was also analyzed. The CORR and REG procedures in the SAS (2004) were used to calculate the correlation and regression coefficients, respectively. The statistical significances were tested for the coefficients. The phenotypic correlation of BWT and 3MW, BWT and 6MW, BWT and 9MW, 3MW and 6MW, 3MW and 9MW were investigated. In addition, 6mw and 9mw were regressed on BWT and 3MW and presented.

The present data analysis was reinforced by referring to the available weighted average genetic parameter estimates. The weighted average estimates included phenotypic and genetic correlations and direct genetic and direct maternal heritability estimates. The weighted average estimates are considered to be reliable and were presented based on pooled literature parameter estimates.

3. Results and discussion

The present study revealed that Pearson correlations ("r") of BWT with the market or adult weights were small or even equal to zero in some cases. The "r" between BWT and 6MW for WG and between BWT and 9MW for CH were not different from zero (Table 3). In general, "r" of BWT with both 6MW and 9MW from the three breeds were in the range of 0.051 to 0.176 and the "r" of 3MW with both 6MW and 9MW were in the range of 0.370 to 0.706 (Table 3).

Hither "r" between 3MW and 6MW was observed compared to the "r" between BWT and 6MW (Table 3). The "r" of 3MW and 6MW was higher than "r" of BWT and 6MW by more than three, five and six folds the case of CH, AB and WG, respectively. In the same fashion, the 3MW and 9MW had higher "r" than BWT and 9MW where the superiority was by more than three, eight and two folds, for AB, CH and WG, respectively.

Adjacent weights had higher "r" than distant age weights. For instance, the "r" of 3MW and 6MW compared to "r" between 3MW and 9MW was higher for all the three breeds, the magnitude of superiority being 1.29, 1.40 and 1.86 folds for AB, CH and WG, respectively.

The present work indicated that BWT had weak "r" with both 6MW (0.099 to 0.176) and 9MW (0.051 to 0.163) regardless of the goat breeds. Rather, 3MW had higher "r" with the 6MW and 9MW traits. The "r" between 3MW and 6MW (0.598 to 0.706) was, however, higher than "r" of 3MW and 9MW (0.370 to 0.546). The weak association of birth weight

with both 6MW and 9MW could be due to the fact BWT is affected by the maternal environments in the uterus compared to 3MW.

Table 3. Pearson correlation of pre and post weaning growth traits in indigenous goat breeds of Ethiopia

	AB			CH			WG		
Traits	N	"r"	p	N	"r"	p	N	"r"	p
BWT 6MW	715	0.135	0.0003	612	0.176	0.0001	365	0.099	0.0584
BWT 9MW	543	0.144	0.0007	402	0.051	0.3044	271	0.163	0.0073
3MW 6MW	715	0.706	0.0001	605	0.598	0.0001	362	0.690	0.0001
3MW 9MW	543	0.546	0.0001	386	0.427	0.0001	269	0.370	0.0001

AB=Abergelle goat breed; CH=Central highland goat breed; WG= Woyto-Guji goat breed; N= number of observations for the two traits; p= probability value; "r"= Pearson correlation BWT=birth weight; 6MW=six month weight; 9MW= nine month weight; 3MW=three month weight.

The regression of 6MW and 9MW on both BWT and 3MW resulted in high values of regression coefficient ("**b"**) except regression of 9MW on BWT for CH and regression of 6MW on BWT for WG (Table 4). Regardless of their satisfactory " **b"** values (ranging from 0.311 to 0.996), the adjusted R-square for regressing 6MW and 9MW on BWT was considerably low, ranging from 0% to 3 %. This means some other factors contributed to the magnitude of "**b**" which lessens the reliability of regressing 6MW and 9MW on BWT which could indicate that BWT should not be used to predict both 6MW and 9MW.

The "**b**" of 6MW and 9MW on 3MW were not always higher than the "**b**" of 6MW AND 9MW on BWT (Table 4). The adjusted R-Square for the regression of 6MW and 9MW on 3MW were considerably higher (13 to 50%) than adjusted R-Square of regressing 6MW and 9MW on BWT.

Table 4. Regression of post-weaning growth traits on pre-weaning growth traits in indigenous goat breeds of Ethiopia

	Parameters	AB		CH		WG	
		6MW	9MW	6MW	9MW	6MW	9MW
BWT	N	715	543	612	402	365	271
	"b"	0.968	0.996	0.999	0.311	0.497	0.850
	P	0.0003	0.0007	0.0001	0.3044	0.0584	0.0073
	Adj. R^2	0.01	0.02	0.03	0.00	0.01	0.02
	Intercept	7.892	9.953	13.509	18.799	11.83	13.857
3MW	N	715	543	605	386	362	269
	"b"	0.927	0.669	0.706	0.590	0.811	0.415
	P	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	Adj. R^2	0.50	0.30	0.36	0.18	0.47	0.13
	Intercept	2.921	6.958	8.357	13.271	5.024	11.570

AB= Abergelle goat breed; CH=Central highland goat breed; WG= Woyto-Guji goat breed; N= number of observations for the two traits; "b"=coefficient of regression;Adj.R^2=Adjusted R-square; p= probability value; BWT=birth weight; 6MW=six month weight; 9MW= nine month weight; 3MW=three month weight

Weighted average phenotypic correlation among growth traits in goats, sheep and also in cattle was reported to be higher for adjacent age classes. Jembere *et al* (unpublished) reported weighted average "r" of 0.36 between BWT and 3MW and 0.27 between BWT and 12MW for goats; Safari *et al* (2005) reported weighted average "r" 0.37 and 0.26 between BWT and 3MW and BWT and adult weight, respectively in sheep. Lobo et al (2000) also reported weighted average "r", in cattle, 0.46 and 0.38, between BWT and 3MW and BWT and 12MW, respectively. In all the reports, the "r" of BWT and 12MW/adult weight was smaller than the "r" of BWT and 3MW the latter has less practical implication.

On the other hand, "r" between 3MW and 12MW was higher by 2.26, 2.15 and 1.77 folds than "r" between BWT and 12MW in goat (Jembere *et al*., unpublished), sheep (Safari *et al*., 2005) and cattle (Lobo *et al*., 2000), respectively. This may justify that; even based on the meta-analysis result, BWT had weak phenotypic correlation with adult age weights or market weights. The "r" is an estimate of the association between two visible characteristics and it contains genetic and environmental effects. The "r" could be similar with the genetic correlation (r_g) when estimates are made within the same environment (if estimates are made in similar environment, then the environmental covariance between the two traits become zero leading to equal genetic correlation with phenotypic correlation).

Since error variance could not be avoided, judging the genetic association of BWT with different adult weights could be more reliable than the phenotypic association of BWT with the different age weights. The weighted average r_g values in goats were 0.54, 0.32 and 0.31, between BWT and 3MW, BWT and 12MW and 3MW and 12MW, respectively in goats (Jembere et al unpublished). These values were 0.47, 0.22 and 0.75, for the trait combinations in sheep, respectively (Safari *et al* 2005). Lobo et al (2000) reported weighted average r_g values of 0.50, 0.55 and 0.81 between BWT and 3MW, BWT and 12MW and 3MW and 12MW, respectively in cattle.

In all the three reports, high r_g was reported between adjacent age classes; for instance between BWT and 3MW and between 3MW and 12MW. The weighted average r_g between BWT and 12MW or adult age weight was generally smaller than the r_g between 3MW and 12MW. This also, in addition to the "r", could indicate weak r_g between BWT and adult/market.

The BWT of goats, sheep and cattle had smaller direct heritability than 12MW whereas the maternal heritability of BWT for the species was higher than the maternal heritability of 12MW (Table 5). Comparing the direct heritability, same table, of BWT and 3MW, the latter had higher values in most cases. In the case of maternal heritability, it was BWT that had higher values compared to 3MW. The lower values of direct heritability of BWT or the higher values of maternal heritability of BWT might indicate the high influence of maternal environment on the trait. From the two heritability estimates, it is the direct heritability estimates that have more implication on genetic improvement through selection. Therefore, it could be concluded that BWT could not be targeted for selection.

Table 5. Weighted direct and maternal heritability estimates of sheep and goat

Species/breed*	Birth weight	Weaning weight	Yearling weight
Direct			
Goat/dual	0.16	0.22	0.31
Sheep/wool	0.21	0.21	0.42
Sheep/dual	0.19	0.16	0.40
Sheep/meat	0.15	0.18	0.29
Tropical cattle	0.34	0.30	0.37
Maternal			
Goat/dual	0.12	0.08	0.05
Sheep/wool	0.21	0.16	0.04
Sheep/dual	0.18	0.10	0.06
Sheep/meat	0.24	0.10	-

*= sources are Jembere *et al* (un published) for goats, Safari *et al*. (2005) for sheep and Lobo *et al*. (2000) for Tropical cattle

Terefe *et al*. (2013) says that the market weight of Afar goat is in the range of 25 - 30 kg. According to Shija *et al*. (2013), slaughter age (years) and weight (kg) of indigenous sheep and goats in East Africa could be in the range 1.5 to 2 years and 20 to 25. Tibbo *et al*. (2006) suggested market age and market weight for sheep in Ethiopia as 12 months of and 30 kg to be considered in designing the breeding program. The average marketing age (months), for indigenous goats in Ethiopia, was reported to be 11.67 and 12.33 for males and females, respectively (Asefa *et al*., 2015). In the present study, we could not show favourable correlations between BWT and the market weights or adult weights. The direct heritability estimates from literature, were also small.

4. Conclusion

Birth weight had weak phenotypic correlation 6MWand 9MW in the three indigenous goat breeds in Ethiopia. The regression of 6MW and 9MW on BWT was not reliable because of low (less than three per cent) adjusted R-square. Literature reports indicate due to weak phenotypic and genetic correlation between BWT and adult or market weight and low direct heritability, BWT could not be targeted for genetic improvement through selection. Yet, recording BWT in the community based breeding program remained compulsory. We conclude that keeping BWT records under village based breeding program is not only of little or no significance, but also hardly practical.

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