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**ORIGINAL RESEARCH ARTICLE**

# Optimization and evaluation of alternative village-based breeding plans: the case of goats in Afar region, Ethiopia

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## ABSTRACT

The study aims to design and evaluate alternative village-based breeding plans for Afar goats in Aba'ala, Afar region, Ethiopia. The alternative breeding plans were designed and evaluated using ZPLAN+ computer program following the gene flow method and selection index procedures. Input parameters were sourced from a production system survey study, own-flock ranking exercises and literature. The breeding goal traits included six-month weight, daily milk yield and proportions of weaned kids. Four alternatives were designed based on the variation of the number of the traits in the selection index (recording) while keeping all traits in the aggregate breeding goal. Furthermore, the proposed alternative plans were evaluated by varying the years of breeding buck service period. Higher annual genetic gain was estimated for six-month weight (0.2983 kg) in alternative 4, for daily milk yield (0.0083 kg or 8.3 g) and proportion of lambs weaned (0.0142%) in alternative 1 when the years of buck use for breeding was set to two years. Higher selection accuracy was obtained in alternative 1 when all the traits were included in the selection index while lower selection accuracy was achieved in alternative 4 when six-month weight only was included in the selection index. The highest profit per doe per year was achieved in alternative 1 (1.221€) while the lowest was obtained in alternative 4 (0.885 €) when six-month weight only is included in the selection index. The simulation results gave an acceptable range of genetic gains with little difference across the alternatives. Therefore, village breeding programs with a few traits in the recording and two years of breeding buck use are deemed practicable. The proposed breeding plans should be part of the national development strategies and involvement of local research institutions and universities is very crucial to ensure adequate technical support.

***Keywords:*** agro-pastoral systems; breeding goals; deterministic model; genetic gain

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## 1. Introduction

The sheep and goat population of Ethiopia is estimated to be 42.9 million and 52.4 million, respectively[1], making it one of the largest and most diverse in Africa. In Ethiopia, smallholder pastorals/farmers raise sheep and goats as a major source of meat and immediate cash income. There is an increasing demand for sheep and goat meat globally which is a good market opportunity for countries such as Ethiopia with large small ruminant genetic resources. The indigenous sheep and goat breeds are very well adapted to the rigorous environmental conditions and low input systems in these areas utilizing low-quality shrubs and remaining productive under an escalating disease pressure[2]. This has a vital role towards food security especially in pastoral and agro-pastoral areas where goat density is higher than other livestock species. Afar goats have adapted to drought-prone arid and semi-arid areas of the Afar regional state. The breed inhabits the coastal strip of the Danakil depression and the associated Rift Valley in Ethiopia with the Afar nomadic pastoralists. The climate is mainly desert, but also semi-arid in higher altitude areas. The region is drought prone. The breed has adapted to heat, feed and water shortage, and long trekking. It is mainly kept for meat production[3,4]. However, despite the importance of this goat breed to the pastoral communities of Afar region, the production is constrained by various factors. Among those factors, lack of genetic selection programs contributes to poor utilization of the Afar goat genetic resources, and this is affecting the livelihood of communities who are dependent on them.

Genetic improvement programs are targeting to make proper utilization of livestock resources. However, in the Tropics and Sub-tropics, design and implementation of effective genetic improvement programs under smallholder livestock farming systems is a challenge[5]. In Ethiopia, the livestock populations are characterized by uncontrolled breeding[6,7]. Thus, a coherent and comprehensive breeding program suited to the existing production systems is required to guide stakeholders in the sustainable utilization and management of farm animal genetic resources. Local communities and institutions need to be involved and focus must be given to indigenous genetic resources in order to bring the desired change[8,9]. A sustainable strategy needs to be tailored to the specific goals of the targeted communities considering the socio-economic characteristics, breeding culture and existing production systems/environments[10]. Subsistence farmers, unlike commercial ones, tend to keep animals for family needs rather than purely for economic enterprise[11]. They keep multi-purpose animals which produce meat, milk, wool, skin beside their transport and draught service. As a result, it has been a challenge to identify important traits at a farmer level. But it is clearly indicated that it is important to consider the wish and interest of farmers when defining breeding objectives at breed level[12]. Understanding farmers' trait preferences give knowledge of which attributes are particularly important in their production environment and how these can be incorporated in the design of sustainable genetic improvement programs; however, in most cases this has been missing[5]. Evaluation of alternative breeding plans by introducing genetic selection need to be simulated in order to propose optimized and economical breeding schemes[13]. The elucidation of breeding goal traits using participatory tools with the active participation of farmers and proper evaluation of breeding plans can result in a functional livestock genetic improvement which is more practical and truly reflects livestock keepers' preferences and wishes. Therefore, the objective of this study was to design and evaluate alternative village-based breeding plans for Afar goat population found in Aba'ala, afar region, Ethiopia.

## 2. Materials and methods

The study was carried out in Aba'ala district in Afar Regional State, Northeastern Ethiopia. The mean annual precipitation of Aba'ala district is 150 mm, and mean daily temperature is about 28 ℃, with maximum 33 ℃ in June and a minimum 23 ℃ in November. In general, the study area is hot with high diurnal temperature and it experiences severe heat, during the dry periods (May-June)[4].

Selection of research site and respondents was done using purposive sampling procedures. A research site which is accessible and with representative potential for goat production were selected based on discussion with Agricultural Officers and Development Agents of the district. Two study sites were selected representing pastoral and Agro-pastoral production systems. Goat producers in the pastoral site are characterized with periodic movement with their livestock in search of feed and water. Unlike the goat producers in the pastoral area, goat producers in the Agro-pastoral area are settled and use an irrigation system for crop and pasture production. For the purpose of this study, the Agro-pastoral production system was considered and details on the study area description can be found on Yfter et al.[4].

A purposive sampling technique was employed and a total of ninety (90 households) (45 from each production systems) of which 69 male and 21 female household respondents who own a minimum of 5 breeding does and at least 1 breeding buck were purposely selected based on their willingness to participate in the research. Relevant data on goat producers' perception on village-based breeding programs, breeding goal traits and existing breeding practices were collected using semi-structured questionnaire interviews, own-flock ranking experiment[4]. Moreover, a focus group discussion was also held to dig out about the overall production and breeding practices aspects of Aba'ala Districts' goat producers. Additional secondary information on feed resources and goat marketing were obtained from Aba'ala District Office of Agriculture.

Economic values for the breeding goal traits were estimated using an Excel tool developed to suit smallholder systems based on a so-called bio-economic model[14]. All inputs required by the model related to flock structure, animal performance levels, and phenotypic parameters for the traits were derived from Yfter[4] data collected on Aba'ala goats in Afar region and Aba'ala District Office of Agriculture. The costs of production included costs of feed, health, management, and marketing. Feed requirements for the various classes of goats were calculated based on nutrient requirements of sheep in developing countries[15] and nutritive values of Ethiopian feeds was obtained from the International Livestock Research Institute (ILRI) feed composition database[16]. The underlying herd model is based on a deterministic approach. A traditional goat production system with the selling of surplus male kids was simulated. The marginal economic value for each trait was estimated as a change in profit resulting from an increase by one additive genetic standard deviation in the trait value due to selection while keeping the changes in the other traits constant. Further details on the bio-economic model can be obtained by Gizaw et al.[17]. **Tables 1** and **2** present the herd structure of the goat population and input values used to run the model, respectively. All results were expressed per average doe place and year.

The economic values were calculated separately for each trait keeping all other traits constant in order to avoid double counting. Economic values for six-month weight, daily milk yield, and proportions of kids weaned traits were derived. The economic values are presented in Euros for the purpose of this study based on the exchange rate of October 2018 which is 1 € to 31.58 ETB (Commercial Bank of Ethiopia). The estimated economic values are presented in **Table 3** and were used as input for designing the alternative village-based (community-based) breeding plans.

**Table 1.** The herd structure of Afar goat per household by production system.

| Goat age class | Agro-pastoral | | Pastoral | | Overall | | *t*-test | |
|---|---|---|---|---|---|---|---|---|
| | **N** | **Mean ± SD** | **N** | **Mean ± SD** | **N** | **Mean ± SD** | ***F*-value** | ***p*-value** |
| Kids <6 months | 208 | 4.62 ± 3.00 | 235 | 5.22 ± 3.90 | 443 | 4.92 ± 3.48 | 0.67 | 0.42 |
| Females 6 to 12 months | 169 | 3.93 ± 2.71 | 197 | 4.8 ± 3.67 | 366 | 4.36 ± 3.23 | 1.55 | 0.22 |
| Males >1 year | 51 | 1.5 ± 0.93 | 67 | 1.67 ± 2.03 | 118 | 1.59 ± 1.61 | 0.21 | 0.65 |
| Females >1 year | 555 | 12.33 ± 7.62 | 723 | 16.07 ± 11.49 | 1,278 | 14.20 ± 9.88 | 3.29 | 0.07 |
| Castrated male | 4 | 1.33 ± 0.58 | 26 | 2.17 ± 1.27 | 30 | 2 ± 1.19 | 1.18 | 0.29 |
| Total | 987 | 23.71 ± 14.85 | 1248 | 29.93 ± 22.36 | 2235 | 27.7 ± 20.9 | - | - |

SD, standard deviation; N, number of goats by age for all sampled households; Females 6 to 12 months, female replacements; Females >1 year, breeding does; Males >1 year, breeding bucks.

**Table 2.** Input parameters used to estimate economic values of the breeding goal traits.

| Parameters | Input values |
|---|---|
| **Production and reproduction parameters** | - |
| Flock size | 540 |
| Birth weight (kg) | 2.5 |
| Weaning weight (kg) | 9.5 |
| Six moth weight (kg) | 18 |

**Table 2.** (*Continued*).

| **Parameters** | **Input values** |
|---|---|
| **Production and reproduction parameters** | - |
| Mature buck weight (kg) | 29 |
| Mature doe weight (kg) | 26.5 |
| Conception rate (%) | 85 |
| Liter size | 1.03 |
| Doe survival rate (%) | 90 |
| weaning age of kid (month) | 3 |
| Age at first kidding (yr) | 1.5 |
| **Revenue variables** | |
| milk price Euro/kg | 0.57 |
| price of live kid Euro/kg | 2.18 |
| **Cost variables** | |
| cost of feed (Euro/kg of feed) | 0.84 |
| heath care (Euro/doe/yr) | 0.67 |
| management and marketing (Euro/head/yr) | 0.34 |
| Fixed assets (costs) Euro/doe/year | 0.26 |

kg, kilogram; %, percent.

**Table 3.** Estimated discounted economic values for the breeding goal traits.

| **Breeding goal traits** | **Selection criteria (unit)** | **Economic value in €/$\sigma_a$** | $\sigma_a$ | $\sigma_p$ |
|---|---|---|---|---|
| Body size | Six months weight (kg) | 0.36 | 1.140 | 2.154 |
| Milk yield | Daily milk yield (kg) | 0.85 | 0.053 | 0.095 |
| Kid survival | Proportion of kids weaned (%) | 1.77 | 0.109 | 0.363 |

Kg, kilogram; €, Euro; $\sigma_a$, additive genetic standard deviation; $\sigma_p$, phenotypic standard deviation.

## 2.1. Design and optimization of alternative breeding programs

Two focus group discussions were conducted for both goat producers in the pastoral (Gubi kebele) and agro-pastoral (Adi-Haremeli kebele) areas to assess their perception of village-based breeding programs and its feasibility under their situation. In the focus group discussion, 10 farmers per group from knowledgeable local peoples, female headed households, medium aged and young owners were included. Goat producers in the pastoral site were not in favor of village-based breeding programs due to recurrent drought and the seasonal movement of goat flocks in search of feed and water. On the other hand, goat producers in the agro-pastoral site had a positive perception on the village-based breeding program and thus the agro-pastoral site was selected because the farmers in this site are settled and practiced crop production with an irrigation system which could be also a good feed resource opportunity for the breeding goat populations. Then the goat flocks from the 45 household goat producers in the agro-pastoral site were treated as a single breeding population for the purpose of this study.

The Alternative breeding plans were designed and evaluated using the web-based computer program ZPLAN+[18]. The program is commercial, and it is available on https://service.vit.de/zplanplus/. Using the gene flow method and selection index procedures, the program enables to simulate different breeding plans by deterministic approach. The program calculates the genetic gain for the aggregate breeding value, the annual response for each trait and discounted profit for a given investment period. Four selection groups were defined to indicate the selection pathways. A selection group is defined by the type of parents (one sex) passing genes and type of offspring receiving their genes. The selection groups were Bucks to produce Bucks

(B>B), Bucks to produce Does (B>D), Does to produce Bucks (D>B) and does to produce Does (D>D). Strong selection of male animals was assumed. The assumption was that the genetic gain obtained through selection would be disseminated by the selected bucks. The female animals would be selected only for the replacement. The young bucks at the age of six months would be selected based on their own performance for growth and the information from their dams for the proportion of kids weaned and daily milk yield traits. Early age of selection (six months weight) was assumed to be more appropriate for the existing production systems of the study areas where negative selection is very common due to selling of the fast-growing buck kids at an early age to get attractive market price. During the simulation, ten percent selection proportion and two-time units (TU), three TU, and four TU of breeding buck use for breeding were used. One TU is usually one year for goats[19].

The important input parameters of the Aba'ala goat population for modeling breeding programs (running ZPLAN+) are presented in **Table 4**. The information for the input parameters were derived from the production system study (survey questionnaire), and own flock ranking experiment results of this particular study area[4].

Flock projection was done considering the population and biological parameters given in **Table 4**. The number of proven (candidate) animals in each TU (year) were projected using the reproductive parameters and survival rate of Afar goat Aba'ala area. For instance, the numbers of proven male animals were calculated as follows: In the study area the average breeding does per household was 12.33±7.62 as reported by Yfter[4]. From the 45 participated goat producers a total of 540 (45×12) breeding does will be available for the village selection scheme. Only 85% of them have kidding within one TU (year), 0.6-year kidding interval, 1.03 liters per kidding, 1.5 kidding per year (TU), 80% of survival rate and 50% sex ratio. It gives 283 male selection candidates (540 × 0.85 × 1.03 × 1.5 × 0.80 × 0.5 = 283). Therefore, the number of proven male animals used in this study was 283.

Following Nitter et al.[19], only costs that are additional to the normal husbandry practices of goat producers were considered. These were costs of animal identification, animal health and recording costs (**Table 4**). Those costs were calculated per individual breeding doe per year as presented below:

1) Recording cost (labor cost for recording): One enumerator for 540 does: Enumerator salary 2,000 ETB/month = 24,000 ETB/year; 24,000 ETB/540 does; 44.4 ETB/doe/year which is equivalent to 1.41 €/doe/year.
2) Identification cost: 1 tags/animal/year (a doe and her 1.5 kids/year) 7 ETB/tag = 1×2.5×7 = 17.5 ETB/doe/year which is equivalent to 0.56 €/doe/year.
3) Animal health (drug): 8 ETB/doe/year which is equivalent to 0.26 €/doe/year.

The economic values estimated (**Table 3**) in this study were used as input for designing of the breeding program. Genetic parameter estimates of traits performance of Ethiopian goats are very scant and only available for Arsi-Bale goat breeds[20–22]. Jembere et al.[23] also presented a meta-analysis of average estimates of genetic parameters for growth, reproduction, and milk production traits in goats. Therefore, for the purpose of this study, heritability estimates for the breeding goals traits were taken from Jembere et al.[23] while genetic and phenotypic correlations were obtained from Abegaz et al.[24] and are summarized in **Table 5**. However, it should be borne in mind that the genetic parameters used in this study were obtained from literature with different sample size and husbandry systems but can serve as fair estimates since information for Afar goat is currently lacking. The ZPLAN+ program accepts costs in Euros (€). Therefore, all the input costs were converted to Euro and based on the exchange rate of October 2018 which is 1€ to 31.58 ETB. ZPLAN+ cannot consider reduced genetic variance due to selection (Bulmer effect) and inbreeding. Thus, rates of inbreeding per generation ($\Delta F$) were estimated using a formula $\Delta F = (1/[8N_m]) + (1/[8N_f])$, where $N_m$ and $N_f$ refer to the number of male and female breeding animals, respectively, relating to the effective population size[25].

**Table 4.** Input parameters used for modeling of alternative breeding plans.

| Parameters | Input values |
|---|---|
| Population parameters | - |
| Population size (Does) | 540 |
| Number of proven males/years | 283 |
| Proportion of bucks selected (%) | 10 |
| Biological parameters | - |
| Breeding doe in use (yr) | 8 |
| Breeding buck in use (yr) | 2/3/4 |
| Mean age of bucks at birth of first offspring (yr) | 1.5 |
| Mean age of does at birth of first offspring (yr) | 1.5 |
| Kidding rate | 85% |
| Mean time period b/n subsequent kidding (yr) | 0.6 |
| Mean number of lambs per litter (litter size) | 1.03 |
| Number of kidding/doe/year | 1.5 |
| Kid survival to six months (%) | 80 |
| Cost parameters | - |
| Animal identification doe/year (€) | 0.56 |
| Animal health related cost (€) | 0.26 |
| Recording cost (€) | 1.41 |
| Interest rate return (%) | 0.05 |
| Interest rate cost (%) | 0.08 |
| Investment period/year | 15 |

%, percent; €, Euro.

**Table 5.** Phenotypic correlation (above the diagonal), genotypic correlation (below the diagonal) and heritability of the traits (along diagonal, in bold).

| Items | Six months weight | Daily milk yield | Proportion of kids weaned |
|---|---|---|---|
| Six months weight | 0.28 | 0.1 | 0.1 |
| Daily milk yield | 0.2 | 0.31 | 0.14 |
| Proportion of kids weaned | 0.3 | 0.53 | 0.09 |

## 2.2. Evaluation of alternatives breeding plans

Four different alternatives were proposed for evaluating optimal breeding program (**Table 6**). The alternatives were based on the variation of the number of the traits in the selection index (recording) while keeping all traits in the aggregate breeding goal. The important considerations of the alternatives were to see the effect of the variation of the number of traits in the recording scheme (selection criteria) on the genetic gains of the individual traits as well as the aggregate response. Though recording is very crucial in genetic improvement of livestock, often it is lacking both in governmental or non-governmental organizations and community/village level breeding programs in Ethiopia. Thus, the inclusion of all traits in the recording scheme might not be feasible in technical and economic terms. Therefore, evaluation of the proposed alternative breeding schemes by varying the number of traits in the selection index is appropriate and very relevant. Furthermore, the proposed alternative breeding plans were evaluated by changing the duration of buck used for breeding. This was done because goat producers in the study area tend to keep breeding bucks in the herd for a longer period for breeding purpose. In the study area, breeding bucks are kept on average for four years for breeding[4]. Therefore, the alternative breeding plans were further evaluated by varying the years of breeding buck used for breeding to 2, 3, and 4 years to evaluate the effect on the genetic gains of the breeding goal traits and profit per doe per year.

**Table 6.** Alternative breeding plans/schemes for genetic improvement of Afar goats.

| Alternatives | Description |
|---|---|
| SMW+DMY+PKW | All traits in the selection index (SMW+DMY+PKW) |
| SMW+DMY | SMW and DMY in the selection index |
| SMW+PKW | SMW and PKW in the selection index |
| SMW | SMW only in the selection index |

SMW, six months weight; DMY, daily milk yield; PKW, proportion of kids weaned.

# 3. Results and discussion

Based on the genetic, biological and economic variables used, the program predicts annual genetic gain for the breeding goal traits. The breeding goal traits were defined based on Yfter[4] report where body size, milk production, and kid survival were the most preferred and top-ranked breeding goal traits in the study area. The authors identified breeding goal traits using a combination of participatory approaches (questionnaire interview, focus group discussion, own-flock exercise, and participatory rural appraisal). In the study area goats are primarily kept for milk production (home consumption) followed by cash income source and meat production. In both production systems, producers practice pure breeding. None of the goat producers keep crossbred bucks since they perceive that the local goats are more adapted to the existing production environment. They utilize breeding males that are originated or sourced from their flock. Majority of the respondents in the agro-pastoral site practiced selection of breeding females after the birth of their first offspring based on their milk production performance. But none of the producers in pastoral areas practiced selection of breeding female since all the available females are used to increase their flock size. Goat producers in both production systems rated twining as the least preferred trait. This is due to the fact that in shortage of feed and water a twin bearer mother could not produce enough milk to feed her new born up to weaning. Goat producers mentioned multiple selection criteria considering the tangible and intangible roles with more focus on physical characteristics for breeding buck selection than replacement doe selection. Selection of male animals is practiced at a younger age starting from three to six months age primarily based on coat colour followed by body size and milk production (pedigree information). Most of the preferred coat colours by goat producers are light brown (red), white, and Zebra. While the three unwanted coat colours are black, black-grey (mixed of black and white hair), and extra white. Selling of young kids with unwanted coat color but with a good body condition to get a better market price in holidays is common practice in the study sites, which can result in poor productivity of the flock. Sharing of breeding males for mating purpose is commonly practiced at a household level and even across communities in the agro-pastoral production system. The average reproductive lifetime (breeding service period in years) of breeding males is 4.3 ± 1.67 with a range of 2 to 9 years based on fitness and feed availability. There is no extra management given for breeding bucks.

## 3.1. Annual genetic gain in individual traits

The predicted annual genetic gains ($\Delta G$) of individual breeding goal traits for the different alternative plans are presented in **Table 7**. A slight difference was observed in the predicted annual genetic gains for the breeding goals traits in the four alternatives while varying the number of traits in the selection index. A higher annual genetic gain is estimated for six-month weight (0.2983 kg) in alternative 4, for daily milk yield (0.0083 kg or 8.3 g) in alternative 1 and proportion of lambs weaned (0.0142%) in alternative 1, respectively when the years a buck used for breeding is set to two years. As a comparison to the six-month weight, lower genetic gains are estimated for daily milk yield and proportion of kids weaned. This is due to the low additive genetic standard deviation simulated in this study and the low heritability of proportions of kids weaned which indicate the trait is more controlled by the management practices[26]. Therefore, by improving the animal husbandry practices (feeding and health) in combination to the genetic selection more benefit can be gained for these functional traits.

**Table 7.** Genetic gain per year for the breeding goal traits in the different alternatives with varied years of buck used for breeding.

| Alternative plans | Traits | | |
|---|---|---|---|
| | **SMW** | **DMY** | **PKW** |
| 2 years of buck use for breeding | | | |
| SMW+DMY+PKW | 0.2957 | 0.0083 | 0.0142 |
| SMW+DMY | 0.2967 | 0.0079 | 0.0129 |
| SMW+PKW | 0.2970 | 0.0059 | 0.0127 |
| SMW | 0.2983 | 0.0053 | 0.0111 |
| 3 years of buck use for breeding | | | |
| SMW+DMY+PKW | 0.2660 | 0.0074 | 0.128 |
| SMW+DMY | 0.2669 | 0.0072 | 0.0116 |
| SMW+PKW | 0.2672 | 0.0053 | 0.0114 |
| SMW | 0.2684 | 0.0047 | 0.0100 |
| 4 years of buck used for breeding | | | |
| SMW+DMY+PKW | 0.2417 | 0.0068 | 0.0116 |
| SMW+DMY | 0.2425 | 0.0065 | 0.0106 |
| SMW+PKW | 0.2428 | 0.0048 | 0.0104 |
| SMW | 0.2439 | 0.0043 | 0.0091 |

SMW, six months weight; DMY, daily milk yield; PKW, proportion of kids weaned.

The simulation model gave different results when the years of buck use for breeding (breeding service period) was varied. As the years of buck use for breeding increased there was a strong decrease in annual genetic gain estimates. In general, the responses from all schemes may be considered satisfactory and can result in appreciable genetic improvement of Afar goat breed under smallholders' management practices. The model revealed that including daily milk yield and proportion of kids weaned in the selection index would result in slightly higher genetic gains. However, milk recording at village level is operationally difficult and routine milk recording even at monthly intervals is costly. It may be more appropriate to rely on the indirect selection of milk yield through associated traits in this situation which was also in agreement with Abegaz et al.[24] for local goats in Ethiopia. Recording of proportion of kids weaned might not be less challenging in the village-based breeding program since recording of three months, six months and yearling weight is practiced. Recording is a prerequisite for any planned genetic improvement endeavors[5], but it must be simple with limited number of traits for smallholders' management conditions. Realization of these predictions, however, largely relies on accurate recording and record keeping, estimation of reliable breeding values, monitoring and/or guidance, and motivation of the smallholder breeders which demand high support from governmental research centers[7]. The rate of inbreeding per generation was 0.47% which was lower than the accepted level per generation which is 1%[27]. The estimated rate of inbreeding was comparable to the report by Mirkena et al.[7] for Afar sheep but lower than the report by Abegaz et al.[24] for Western Lowland goats. This is due to the higher number of male and female breeding animals used in this study.

## 3.2. Evaluation criteria for the alternatives

Evaluation criteria used for the alternative breeding programs in this study were selection accuracy, annual monetary genetic gain (AMGG) and discounted profit per doe per year (**Table 8**). Higher selection accuracy was obtained in alternative 1 when all the traits were included in the selection index while lower selection accuracy was achieved in alternative 4 when only six-month weight was included in the selection index. This indicates that selection accuracy increases with increased intensity of recording which agrees with the finding of Mirkena et al.[7]. Years of a breeding buck used for breeding doesn't affect the magnitude of selection accuracy as expected. The AMGG, a measure of the average monetary superiority per year of the progeny of the selected animals of one selection cycle, ranges from 0.136 to 0.107 Euros among the alternative breeding plans. The AMGG decreases with the increase of years of a breeding buck is used for breeding. The discounted profit, calculated as the difference between the discounted returns and discounted costs per doe, usually serves as the main evaluation criteria[19]. The highest profit per doe per year is achieved in alternative 1 (1.221€) when all the traits are included in the recording while the lowest is obtained in alternative 4 (0.885€) when six-month weight only is included in the selection index. The profit per doe per year decreases as the years a buck is used in breeding increase. The lowest profit is obtained when the years of buck used for breeding is increased to four years. The profit achieved in this study is lower than Mirkena et al.[7] and Abegaz et al.[24] reports for Afar sheep and Abergelle goat. The differences can be accredited to the difference in returns and costs. Overall, shorter duration of breeding buck use (two years) results in higher AMGG and profit per doe per year.

**Table 8.** Important evaluation criteria simulated from different alternative plans in Afar goats.

| Alternatives | Evaluation criteria | 2 years of breeding buck use | 3 years of breeding buck use | 4 years of breeding buck use |
|---|---|---|---|---|
| SMW+DMY+PKW | Accuracy of selection | 0.503 | 0.503 | 0.503 |
| | AMGG | 0.136 | 0.122 | 0.111 |
| | Profit/doe/year | 1.221 | 1.049 | 0.915 |
| SMW+DMY | Accuracy of selection | 0.497 | 0.497 | 0.497 |
| | AMGG | 0.134 | 0.123 | 0.110 |
| | Profit/doe/year | 1.206 | 1.037 | 0.904 |
| SMW+PKW | Accuracy of selection | 0.494 | 0.494 | 0.494 |
| | AMGG | 0.133 | 0.120 | 0.110 |
| | Profit/doe/year | 1.199 | 1.030 | 0.899 |
| SMW | Accuracy of selection | 0.486 | 0.486 | 0.486 |
| | AMGG | 0.131 | 0.118 | 0.107 |
| | Profit/doe/year | 1.181 | 1.015 | 0.885 |

SMW, six months weight; DMY, daily milk yield; PKW, proportion of kids weaned; AMGG, annual monetary genetic gain.

### 3.3. Practical implementation of the alternative plans

The attitude of goat producers towards working as a cooperative or a group in village-based goat genetic improvement programs was assessed in the focus group discussion. The response was very positive in the agro-pastoral areas; however, goat producers in the pastoral areas raised a concern of seasonal movement of households which agreed with Belete[28]. Therefore, based on their willingness, proximity to the veterinary center, available resources and settlement implementation of village-based selection programs can be feasible in the agro-pastoral areas. In the case of pastoralist, conservation of the existing genetic resource through awareness creation on selective breeding and improved husbandry practices is more appropriate. Besides central or institutional breeding programs can be established in the pastoralist areas where better performing breeding males can be distributed to goat producers.

The alternative plans indicate considering the available resources and management systems a reasonable change in the average performance of a goat herd due to genetic selection can be achieved in village-based goat breeding schemes under smallholder circumstance. Hence, alternative 4 with 2 years of breeding buck use is recommended considering the lower recoding cost and reasonable selection response and profit per doe per year. For sustainability, such breeding programs should be part of the national livestock breeding programs and development strategies of the country[7]. Besides, buck selection events should be done before the major festivals to retain the best male animals in the village herd as breeding bucks[10]. Overall, goat producers should be aware of selective breeding and the alternative breeding plans obtained in this study should be presented to goat producers. Rules and regulations should be developed on the use and share of breeding bucks. This can be done by local research institutes in the study area for further supervision and monitoring of the intended breeding program. The overall presentation of the proposed village-based goat breeding program is summarized in **Figure 1**.

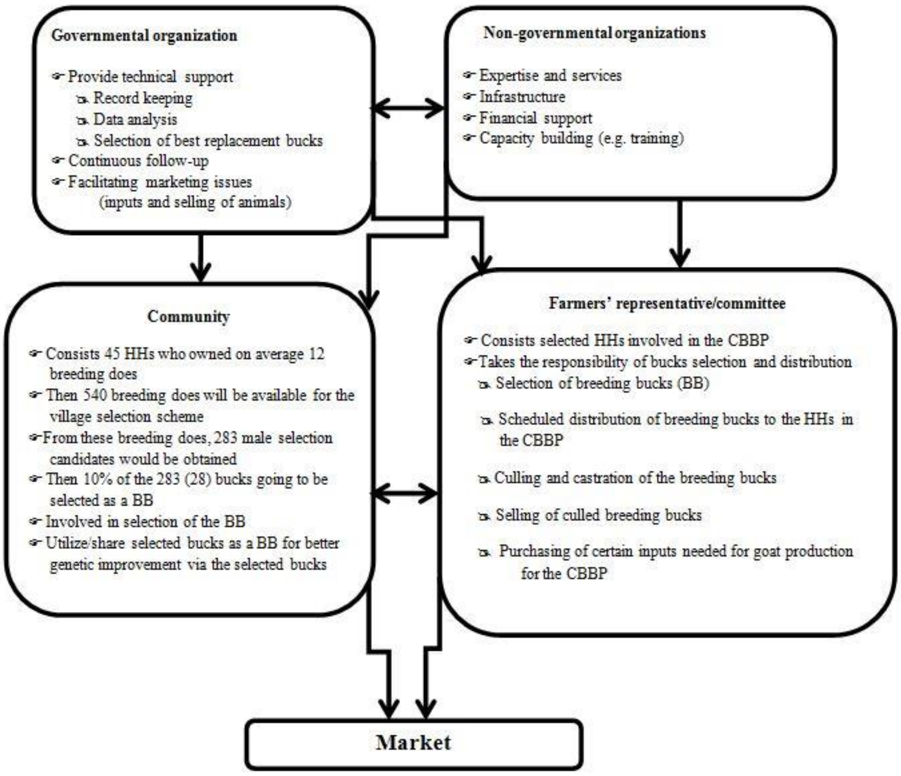


**Figure 1.** Diagrammatic presentation of village-based breeding program for Afar Goats in the agro-pastoral areas. BP, breeding program; BB, breeding buck; CBBP, Community Based Breeding program.

## 4. Conclusion

Though the obtained annual genetic gain for six-month weight, daily milk production and proportion of kids weaned are slightly different, they can be considered satisfactory and can result in reasonable genetic improvements of goats in Aba'ala area. Thus, village-based breeding programs with a few traits in the recording and 2 years of breeding buck use are considered feasible in the agro-pastoral site where seasonal movement of goat producers is not common and feed resources are better, while central breeding program and conservation of the existing genetic resources are suggested for the pastoral site where seasonal movement of goats is commonly practiced. However, proposed breeding programs can only be effective and sustainable if they are part of the national livestock breeding programs and development strategies whereby the continuity of the required technical backup is ensured. Involvement of local research institutions and universities is also very crucial for close technical supervision and monitoring of the breeding program. The simulation model must be further updated and refined using estimates of genetic parameters from actual or observed data since the genetic parameter inputs used in this study were derived from literature.

## Author contributions

Conceptualization, KTG and TGT (Tesfay Gebreselama Teweldemedhn); methodology, KTG and KAY; software, KTG; validation, KAY and TGT (Tikabo Gebremariam Tesfay); formal analysis, KTG and KAY; investigation, KTG; resources, TGT (Tikabo Gebremariam Tesfay) and KAY; data curation, KAY; writing—original draft preparation, KTG; writing—review and editing, TGT (Tesfay Gebreselama Teweldemedhn), KAY and TGT (Tikabo Gebremariam Tesfay); visualization, TGT (Tesfay Gebreselama Teweldemedhn); supervision, KTG and TGT (Tikabo Gebremariam Tesfay); project administration, KTG; funding acquisition, KTG and TGT (Tesfay Gebreselama Teweldemedhn). All authors have read and agreed to the published version of the manuscript.

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## Conflict of interest

The authors declare no conflict of interest.

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