# Breeding objectives and breeding plans for Washera sheep under subsistence and market-oriented production systems

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## Abstract

A Washera sheep breed improvement project has been initiated in Amhara state, Ethiopia. However, breeding objectives and breeding plans/schemes to achieve the objectives have not been formally defined. In this study, we identified two Washera sheep production systems (subsistent and market-oriented). Breeding objectives addressing the two production systems were defined applying bio-economic models. The results indicate that twinning rate is economically the most important trait in both production systems. The results also indicate that a single selection index and hence a single breeding program could meet the breeding objectives of both systems. An index containing six-month weight, twining rate and survival rate (or combined as number of lambs weaned) and feedlot gain could be used in Washera sheep improvement programs. Two alternative nucleus breeding schemes (a regional and zonal scheme) were planned and evaluated for their genetic and economic efficiency and operational feasibility. The regional scheme is designed to address the entire Washera sheep population (1.2 million), while the zonal scheme will serve part of the population. The regional scheme gives 58.9% more returns to investment. However, the nucleus size is too large to operate as a single flock. The nucleus could be split into multiple smaller flocks which need to be genetically linked through ram exchanges and across-flock genetic evaluation so that the nuclei operate as one big nucleus. Yet such a regional scheme seems to be operationally infeasible under the existing conditions. Operationally feasible breeding program for Washera sheep could be developed by setting up multiple independent nuclei for each zone with approximately 10% of the population. Such nuclei could be established for each zone gradually as resources allow.

**Keywords:** *Washera sheep; breeding objective; nucleus breeding scheme; production system; Ethiopia*

## Introduction

Productivity of the indigenous livestock in developing regions is generally low as they have evolved in adaptation to the marginal production environment and are not effectively selected for increased productivity. Selective breeding is an indigenous livestock breed improvement practice among most communities in developing regions (Perezgrovas, 1995; Tano et al., 2003; Ouma et al., 2004; Nduma et al., 2008; Tesfaye, 2008; Solomon

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et al., 2010). However, structured sheep breeding programs in developing regions, particularly in Africa, are lacking (FAO, 2007; Kosgey et al. 2006)). Lack of effective, sustainable breeding programs for local breeds is one reason that such breeds lose their competitive advantage, especially where production systems or external conditions are subject to change (Hiemstra et al., 2007).

Formalizing genetic improvement for smallholder conditions in developing regions is a challenging task (FAO, 2007). Livestock production in developing regions is generally characterized by small flock-size (particularly in mixed crop-livestock systems), communally shared grazing, uncontrolled mating, absence of pedigree and performance recording, diverse and multiple farmer breeding objectives/selection criteria and lack of genetic progress in productivity from traditional farmer selection practices. These characteristics limit the implementation of effective genetic improvement programs. To overcome these problems, nucleus breeding schemes have been suggested, in which genetic improvement is centrally organized in a population maintained in research institutes or government farms (Galal, 1986; Terill, 1986; Ponzoni, 1992; Kosgey, 2004). Nucleus breeding programs are already in place in quite a number of developing countries (for instance Menz, Washera and Bonga sheep nucleus flocks in Ethiopia). An alternative to centrally organized nucleus schemes is village (or community- based) selection programs, which are breeding activities carried out by communities of smallholder farmers (Sölkner et al., 1998; Wurzinger et al., 2008; Solomon et al., 2009). Both schemes have their merits and demerits. Solomon *et al.* (unpublished) proposed a combined nucleus and village-based breeding program.

A nucleus breeding program for Washera sheep has been developed with a very small nucleus size. However, there is no defined breeding objective and designed scheme to date for Washera sheep. Different nucleus schemes (open vs. closed) with different alternatives of nucleus size, proportion of commercial flock served by the nucleus, and migration of animals between the different tiers has been evaluated (Kosgey 2004; Gicheha et al. 2006). The effects of these parameters on the genetic and economic efficiency of breeding programs have been well established. In this study we opted to design a practical breeding program specific to Washera sheep. We evaluate two nucleus schemes in terms of their bio-economic efficiency and operational feasibility based on breeding objectives for Washera sheep defined in this study applying bio-economic models.

## Materials and Methods

### Description of Washera sheep

Washera, also known as Agew or Dangla, is a short-fat-tailed, short-haired, predominantly brown, and polled sheep breed indigenous to Ethiopia. It is one of the most productive sheep breeds in the country with large body size (Solomon et al., 2008a) and litter size of 1.11 (Mengistie, 2008). The breed mainly inhabits the wet, warmer mid-highlands (1600-2000 m a.s.l) of the Amhara Regional State (W. Gojjam, E. Gojjam, and Awi zones, and Alefa Takusa district in N. Gondar zone) and Benishangul-Gumz Regional state (Dangur and Madura districts), Ethiopia (Fig. 1). The Amhara and Agew communities rear the breed under mixed crop-livestock system.

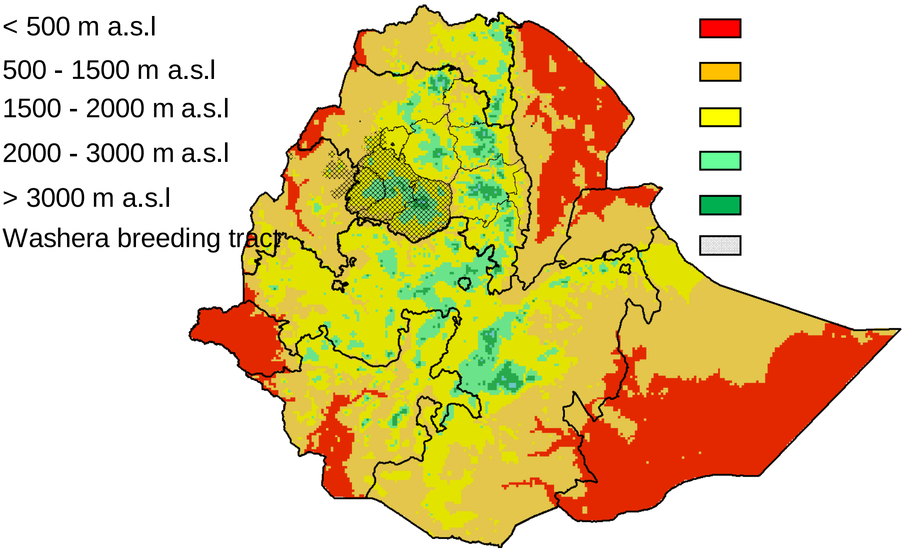


*Fig. 1. Ecological and geographical distribution of Washera sheep in Ethiopia.*

**Definition of breeding objectives**

*Definition of production and marketing systems*

Farmers' livestock breeding objectives can be defined through participatory approaches, in which farmers explicitly state their preferences for traits. In the current study, breeding objectives for Washera sheep were defined based on farmers' sheep production and marketing objectives (Mengiste, 2008; Personal observations), employing bio- economic models.

Washera sheep flocks are kept in communal grazing lands during the day time with little or no supplementary feeding. There is no planned breeding. Unintentional negative selection is practiced as ram lambs with good body conformation are sold at an early age of 3-6 months for immediate cash needs and inferior ones are maintained for breeding.

Based on the above production and marketing practices, Washera sheep production system can be classified as mainly subsistence. However, there are few market-oriented farmers who practice finishing. There is also an emerging export market where finished lambs are in good demand. Breeding objectives are normally defined based on current and anticipated future markets as livestock breeding programs are usually long-term investments. Therefore, in this study breeding objectives were defined for two production systems:

Subsistence: subsistence ewe-lamb system, producing 3-6 month lambs for sale

Market-oriented: subsistence ewe-lamb system, but integrated with finishing of 6-Month-old and culled rams for sale

*Identification of breeding- objective traits*

Breeding-objective traits should normally include traits that are known to influence profitability of a livestock farm as well as farmers' traits (color, tail, appearance, beauty traits, etc). In this study, only economic traits (except chest girth which could represent farmers trait 'general appearance') that influence profit of the farm are identified. The following biological component traits that influence revenue and costs associated with products of subsistence and market-oriented production systems were identified:

Subsistence: Six month weight (SWT), mature weight (MWT), number of lambs weaned represented by twinning rate (TWN) and pre-weaning lamb survival (PWS), chest girth representing general appearance (CG).

Market-oriented: mature weight (MWT), number of lambs weaned represented by twinning rate (TWN) and pre-weaning lamb survival (PWS), feedlot gain (ADG) and carcass dressing % (DP).

**Derivation of economic weights**

*Bio-economic model*

Bio-economic models relating the different breeding-objective traits with components of production and marketing in subsistence and market-oriented Washera sheep production systems were constructed. The models were constructed using Excel spread sheet program. The model was designed so that effects of genetic improvement in breeding-objective traits could reveal changes in values of revenue and expenses in the different production systems. For instance, effect of improvement in dressing percentage was modeled in such a way that a 1% improvement in dressing percentage would result in a 1% increase in sale value of live sheep.

Marginal economic values for each trait were estimated as a change in profit resulting from an increase in one additive genetic standard deviation in the trait value due to selection. Additive genetic standard deviations were calculated as whe$\sqrt{\sigma_p^2 * h^2}$ $\sqrt{\sigma_p^2 * h^2}$ ance and $h^2 h^2$ is heritability estimate.

Phenotypic variances were obtained from a Washera sheep feedlot experiment for feedlot gain and dressing percentage, and from on-farm Washera sheep monitoring data (Mengistie, 2008) for the rest of the traits.

Economic weight for each trait is calculated as a product of its marginal economic value (which was calculated by a model developed in Excel spread sheet) and the respective discounted genetic expression coefficient (DGE). DGE and economic weights were internally calculated by ZPLAN (Willam et al., 2008) using the undiscounted economic values as inputs.

*Sources of revenue and costs*

Progeny structures for a 500 ewe flock were defined based on reproduction parameters for Wahera sheep (Table A1) to calculate the costs and revenues. Costs and revenues were calculated on per ewe basis. Profit was calculated as the difference between revenue and expenses per ewe joined and year.

Sources of revenue included both tangible (direct regular cash income from sale of surplus lambs, finished lambs, manure and skin) and financing and insurance benefits. Financing benefits result from inflow (investing capital/saving) and outflow (spending capital) of livestock providing the function of banking which is mostly not accessible in developing rural areas. Financing benefit was calculated as (Bosman et al. 1997)

$$B_f = b_f * V$$

where $b_f$ is average inflation rate in Ethiopia during three quarters in 2006 and 2007 (NBE, 2007). Outflow value in Ethiopian Birr (ETB), $V$, is expressed per ewe and year for each class of disposable animals as

$$V_i = N_i * W_i * P_{kg} \quad [1]$$

where $N_i$ is number of animals available for sale per ewe and year in class $i$ animals, $W_i$ average weight in class $i$ animals, $P_{kg}$ price per kg of live weight.

Sheep in most parts of Ethiopia have important function as insurance against crop failure and other social needs. Insurance benefits were calculated based on breeding ewes and rams which are assumed to remain in the flock and available as insurance and also to avoid double counting that results from considering the other classes of animals. Insurance benefit was calculated as

$B_i = b_i * V$

where $b_i$ is percentage of the value of an average flock required to meet the value of interest paid on money borrowed (at interest rate of 10.5%) to cover for crop failure in an average crop farm plus an assumed ETB 300 medical expense per year; *V* is calculated as above in [1] but considering only breeding stock. Input parameters for calculating revenue per ewe per year in subsistence sub-systems and per slaughter animal bough in per year are given in Table A1 and A2.

Three sources of variable expenses (feed, management and veterinary costs) were identified. Input parameters for calculating expenses per ewe per year are given in Table A1 and A2.

**Breeding plan**

Alternative breeding schemes for Washera sheep were designed and evaluated using the method developed for this purpose and incorporated in a computer program, ZPLAN (Willam, et al., 2008). ZPLAN uses gene flow methods and selection index procedures to simulate breeding plans. Based on genetic, biological and economic variables, the program calculates genetic gain for the aggregate breeding value, the annual response for each trait and the profit per female animal due to selection. Profit is calculated as a difference between costs and returns.

*Breeding scheme and Selection pathways*

A two-tier breeding scheme with a nucleus (breeding unit) and a village population (production unit) was simulated. Genetic gain is generated in the nucleus flock and disseminated via rams to the village population where no selection activity is assumed. There is no transfer of animals from the village to the nucleus flock, i.e. the scheme is a closed nucleus breeding unit.

Two closed nucleus breeding schemes (regional or zonal) were considered. A regional scheme simulates a selection program addressing the entire Washera sheep population. The population of Washera sheep is estimated to be 1227700 (Solomon et al, 2009) based on distribution of sheep populations by administrative regions and zones (CSA, 2005). The number of breedable females in the population can be calculated based on flock structure in the population. Breedable females constitute about 58.8% of the flock in Washera sheep (Mengiste, 2008). Thus there are some 723000 breedable ewes in the population. The regional scheme is designed to serve 25% of the population in the first phase of the breeding program. This is because of resource limitations and not all the Washera sheep farmers may participate in the breeding program. Besides, genetic gain achieved in the nucleus and the participating farmers' flocks could be transmitted to non-participants through purchase, loan and communal use of rams. The regional program can designed with a single nucleus flock or multiple genetically linked nucleus flocks which operate as one big nucleus. If such a scheme is not feasible, independent smaller nucleus flocks can be established each to address 10% of the population in contiguous districts (Zonal breeding scheme). The nucleus is 5% of the base population.

Six selection groups are defined to indicate the selection pathways. A selection group is defined by both, type of parents (one sex) passing genes and type of offspring receiving their genes. Rams born in the nucleus are selected to breed rams (sires to breed sires, RB>RB) and ewes (sires to breed dams, RB>EB) for the nucleus. Females are also selected in the breeding unit to breed rams (dam to breed sires, EB>RB) and ewes (dams to breed dams, EB>EB) for the nucleus. Rams selected in the nucleus are also transferred to commercial flocks to improve the ewes (sire to breed dams, RB>EC). The top best rams are first selected for the nucleus. Ewes in the production unit are used to breed ewes for the production unit(EC>EC).

*Selection criteria and genetic parameters*

Three selection indexes were constructed. Index 1, assumed to reflect the breeding objective of subsistent farmers, included SWT, TWN and PWS. Index 2 (SWT, TWN, PWS, ADG, DP) and Index 3 (SWT, TWN, PWS, ADG) are alternative indexes reflecting the objectives of market-oriented farmers. Sources of information for the traits include own performance, sires, dams and paternal half sibs. ADG and DP were evaluated on 10% of half sibs of the candidate animals, which are to be finished and slaughtered for carcass evaluation. Genetic parameters used are presented in Table 1. Since estimates for Washera sheep are not available, available estimates for other local and exotic breeds were used.

Table 1. Phenotypic standard deviations ($\sigma_p$), heritabilities along diagonal, and genetic (above diagonal), phenotypic (below diagonal) correlations used in the simulated selection

| Traits | σp | SWT | MWT | ADG | DP | TWN | PWS | CG |
|---|---|---|---|---|---|---|---|---|
| SWT | 1.20 | 0.35 | 0.93 | 0.62 | -0.22 | 0.09 | 0.10 | 0.98 |
| MWT | 2.31 | 0.42 | 0.30 | 0.78 | -0.06 | 0.08 | 0.09 | 0.80 |
| ADG | 4.51 | 0.44 | 0.34 | 0.25 | -0.17 | 0.08 | 0.09 | 0.50 |
| DP | 2.45 | -0.07 | -0.05 | -0.09 | 0.42 | 0.00 | 0.00 | -0.05 |
| TWN | 0.25 | 0.09 | 0.O8 | 0.09 | 0.00 | 0.10 | - 0.02 | 0.60 |
| PWS | 0.18 | 0.10 | 0.09 | 0.09 | 0.00 | 0.00 | 0.09 | 0.10 |
| CG | 7.37 | 0.77 | 0.74 | 0.40 | -0.05 | 0.50 | 0.06 | 0.31 |

$\sigma_p$ Phenotypic standard deviation. SWT Six month weight; MWT Mature weight; ADG Feedlot gain (g/ head/day);
DP dressing out percentage; TWN Twinning rate; PWS Pre-weaning survival; CG Chest girth.
Source: Abegaz et al. (2002); Rege et al. (2002); Solomon (2002); Snowder and Van Vleck (2003); Safari and Fogarty (2003); Safari et al. (2005); Solomon et al. (2007; 2008b).

*Biological, technical and economic parameters*

Gene flow between populations and groups of animals is defined by constructing transmission matrix. The transmission matrix is constructed based on estimates of productive lifetime, survival rate and age at first lambing of animals in each selection group. Other reproductive parameters such as lambing frequency and twinning rate are required to calculate the proportion of selected animals and selection intensities. These biological and technical parameters are given in Table 2.

Table 2. Biological and technical parameters for the nucleus and commercial populations

| | Nucleus | Base |
|---|---|---|
| Simulated population size (breedable females) | | |
| Regional breeding scheme | 8900 | 178016 |
| Zonal breeding scheme | 516 | 10325 |
| Transfer of animals between nucleus and commercial | | |
| Fraction of nucleus dams born in commercial | 0.0 | |
| Fraction of commercial dams born in nucleus | | 0.0 |
| Fraction of nucleus sires born in commercial | 0.0 | |
| Fraction of commercial sires born in nucleus | | 1.0 |
| Productive lifetime (years) | | |
| Sires | 0.67 | 1.33 |
| Dams | 4.0 | 7.0 |
| Number of lambings per year | 0.67 | 1.37 |
| Reproductive parameters | | |
| Mating ration (female to male) | 50 | 100† |
| Lambing interval (years) | 0.73 | 0.73 |
| Conception rate | 0.90 | 0.90 |
| Age at first lambing (years) | 1.5 | 1.5 |
| Twinning rate | 1.11 | 1.11 |
| Survival of Rams | 0.95 | 0.93 |
| Survival of Ewes | 0.95 | 0.93 |
| Preweaning lamb survival | 0.90 | 0.85 |
| Male lambs suitable for breeding | 0.90 | 0.90 |
| Female lambs suitable for breeding | 0.90 | 0.90 |

† Mating ratio in base population is doubled to 100 ewes to 1 ram since mating is year-round in villages.

*Selection costs*

Overhead (fixed) and variable costs incurred in running the proposed breeding program are given in Tables 3. Overhead costs were calculated for the zonal and regional schemes separately. Costs were internally discounted by ZPlan over the investment period. The breeding program is planned for an investment period of 15 years. Time units for discounting were mean generation interval for fixed costs (2.03 years) and mean age of animals when costs occur for variable costs. The costs are not those incurred in running the farm, but extra costs incurred as a result of introducing selection activities. Similarly the returns do not include the whole return obtained from farm output, but the extra return obtained as a result of genetic gain.

Table 3. Fixed over head costs and variable costs before discounting per ewe per year in the breeding unit under zonal and regional scheme and the average time of cost occurrences in years

| Cost element | Costs (Birr) | | Years |
|---|---|---|---|
| | Zonal scheme | Regional scheme | |
| Over head costs (per ewe) | | | |
| Animal breeding expert (genetic evaluation) | 4.36 | 4.04 | 2.4 |
| Technical field assistant/ data encoder | 23.25 | 5.39 | 2.4 |
| Data processing facilities and supplies and communications | 8.72 | 2.81 | 2.4 |
| Variable costs (per ewe) | | | |
| Identification | 6.33 | 6.33 | 0 |
| Measuring 6 month weight (labor, weighing balance) | 1.02 | 0.17 | 0.5 |
| Recording litter size | 0.05 | 0.10 | 1.42 |
| Recording pre-weaning survival | 0.05 | 0.10 | 0.25 |
| Feedlot test (ADG; feeding and weighing labor) | 2.67 | 1.22 | 0.75 |
| Carcass analysis (carcass kit, weighing scale, labor, carcass analysis expert ) | 2.61 | 1.94 | 0.75 |

## Results

### Breeding objectives

Table 4 gives marginal economic values of traits for the subsistence and market-oriented Washera sheep production systems. Twinning rate, sale weight (at six months of age) and pre-weaning survival are the main objective traits in order of importance for the subsistence system. For the market-oriented producer, twinning rate, pre-weaning survival and six month weight are important traits.

Table 4. Undiscounted† economic values per unit increase in genetic merit for traits in the subsistence and market-oriented systems

| Economic values | | |
|---|---|---|
| Breeding objective traits | Subsistence breeding objective | Market-oriented breeding objective |
| SWT | 16.93 | 24.56 |
| MWT | 7.63 | 7.63 |
| ADG | 0.00 | 4.25 |
| CG | 0.00 | 0.00 |
| TWN | 19.80 | 39.79 |
| PWS | 14.61 | 29.37 |
| DP | 0.00 | 10.69 |

SWT Six month weight; MWT Mature weight; ADG Feedlot gain (g/head/day); DP dressing out percentage; TWN Twinning rate; PWS Pre-weaning survival; CG Chest girth.

† ZPLAN requires values being calculated before discounting.

**Genetic responses**

Table 5 presents expected annual genetic responses in breeding-objective traits in the subsistence and market-oriented production systems under the regional and zonal breeding schemes. Responses were generally very similar. Genetic responses in individual traits were slightly higher in the market-oriented system and under the regional scheme. Responses to the overall breeding objective (monetary genetic gain) were higher for the market-oriented system and under regional scheme. There was also a small difference in responses when selection was based on the two alternative indexes constructed for the market-oriented system. All responses were positive except for dressing percentage.

Table 5. Annual genetic responses to selection based on indexes reflecting subsistence and market oriented breeding objectives under regional and zonal breeding schemes

| Breeding objective traits | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| † Breeding scheme/ objective | Selection criteria | SWT (kg) | MWT (kg) | ADG (kg) | CG (cm) | TWN | PWS (%) | DP (%) | Breeding objective (Birr) |
| Zonal Scheme | | | | | | | | | |
| Subsistence | Index 1 | 0.30 | 0.42 | 0.44 | 1.43 | 0.003 | 0.002 | -0.13 | 8.52 |
| Market oriented | Index 2 | 0.30 | 0.42 | 0.45 | 1.42 | 0.004 | 0.003 | -0.09 | 11.57 |
| | Index 3 | 0.30 | 0.42 | 0.56 | 1.43 | 0.004 | 0.003 | -0.14 | 11.73 |
| Regional Scheme | | | | | | | | | |
| Subsistence | Index 1 | 0.31 | 0.43 | 0.44 | 1.44 | 0.003 | 0.003 | -0.14 | 8.57 |
| Market oriented | Index 2 | 0.30 | 0.42 | 0.46 | 1.43 | 0.004 | 0.003 | -0.11 | 11.64 |
| | Index 3 | 0.30 | 0.42 | 0.57 | 1.44 | 0.004 | 0.003 | -0.09 | 11.79 |

† See text for description.

Index 1: SWT, TWN, PWS; Index 2: SWT, TWN, PWS, ADG, DP ; Index 3: SWT, TWN, PWS, ADG

SWT Six month weight; MWT Mature weight; ADG Feedlot gain (g/head/day); DP dressing out percentage; TWN Twinning rate; PWS Pre-weaning survival; CG Chest girth.

The genetic superiority of selected animals which flows into the base population from the different selection pathways (responses per generation for the breeding objectives) in the different selection groups ranged from Birr 14.58 to 33.71. The responses were higher in sire selection groups (RB>RB and RB>EB; see text for notations) than dam selection groups (EB>RB and EB>EB). This was due to the higher selection intensity in sire selection groups (2.19) than in dam groups (0.87). The accuracy of selection, which is the correlation between the selection index and the breeding objective (aggregate genotype), was 0.63 in subsistence and 0.53 in market-oriented breeding objective.

**Costs, returns and profit**

Returns per trait, overall returns and profit per ewe and year are presented in Table 6. All returns are positive except returns from dressing percentage. The highest returns were obtained from improving SWT. Returns per trait, overall returns and profits were higher for the market-oriented breeding objectives and for the regional breeding schemes. However, the two selection indexes gave similar results.

Table 6. Returns and profits per ewe per year (Birr) for subsistence and market-oriented systems under regional and zonal breeding schemes

| | Zonal Scheme | | | Regional Scheme | | |
|---|---|---|---|---|---|---|
| | subsistence | Market oriented | | subsistence | Market oriented | |
| | Index 1 | Index 2 | Index 3 | Index 1 | Index 2 | Index 3 |
| Overall return | 63.08 | 85.51 | 86.63 | 63.41 | 85.95 | 87.07 |
| Return / trait | | | | | | |
| SWT | 38.49 | 54.96 | 54.96 | 38.69 | 55.25 | 55.25 |
| MWT | 24.03 | 23.81 | 23.75 | 24.16 | 23.94 | 23.87 |
| ADG | | 14.34 | 17.78 | | 14.41 | 17.87 |
| TWN | 0.36 | 0.76 | 0.79 | 0.37 | 0.77 | 0.80 |
| PWS | 0.19 | 0.43 | 0.44 | 0.19 | 0.43 | 0.44 |
| DP | | - 8.79 | -11.11 | | - 8.84 | -11.17 |
| Profit /ewe/year | 21.74 | 39.04 | 42.70 | 45.41 | 64.86 | 67.89 |

## Discussion

### Breeding objectives

In this study, we defined breeding objectives and planned a closed nucleus breeding program for genetic improvement of Washera sheep in Ethiopia. The production and marketing objectives and the breeding objectives defined here for Washera sheep are similar to those defined by Solomon et al. (2010) for traditional sheep production in Ethiopia employing a farmer participatory approach. The results indicate that twinning rates is economically most important trait under both subsistence and market-oriented systems. Dressing percentage is an important breeding objective trait for market-oriented farmers. The trait reflects the objectives of market-oriented farmers, feedlot operators, who may not keep breeding flock, and consumers. Pre-weaning survival of lambs and twinning rates are also important traits.

Differences in production strategies and breeding objectives between groups of farmers within a traditional management system are often much greater than commonly understood (Sölkner et al. 1998; Solomon et al., 2010). In our study, two sheep production systems (subsistence and market-oriented) with two separate breeding objectives were defined for Washera sheep. This underscores the idea that differences in production systems in which a breed is used and the breeding objectives needs to be considered when developing breeding programs (Phocas et al., 1998; Hirooka and Groen, 1999; Vargas and van Arendonk, 2004; Barwick and Henzel, 2005; Wolfová et al., 2005). The rationale is that a single breeding program may not satisfactorily meet the different objectives under different production systems. Responses in trait units in the subsistence and market-oriented systems in the current study are similar (especially when the response values are rounded). However, the market-oriented objective yields more responses for the overall breeding objective (37.8%) and profit (96.1.8%) than the subsistence systemobjective.

**Selection index**

Three selection indices, one reflecting the subsistence breeding objective and two alternative indexes reflecting the market-oriented objective were constructed and evaluated. The two alternative indices for the market oriented breeding objective gave similar responses in trait units. However, dressing percentage (DP) gave negative returns to investment because of the negative genetic gain in DP and the extra cost of carcass analysis. The negative genetic gain could be due to its antagonistic relations with the other traits in the selection indexes constructed in this study. The index excluding DP gave 9.4% more profit over the index including DP. This trait may not therefore be included in the selection indexes. Besides to returns to investment, the decision as to which of the indexes to use depends on the expertise and ease of measurement of carcass dressing percentage. Using DP as a selection criterion also entails that 10% of the animals in each halfsib group will not be available for breeding as they are slaughtered for measuring DP according to the breeding plan designed in this study. The patterns of genetic responses in trait units are generally very similar for all breeding objective traits when any of the indexes were used.

**Breeding program**

The breeding program proposed in this study is a nucleus breeding program. Livestock breeding schemes designed to suit the breeding structures in developing regions broadly include village (or community-based) breeding schemes (Solkner, 1998; Wurzinger et al., 2008; Solomon et al., 2009) and station-based nucleus breeding schemes (Ponzoni, 1992; Kosgey, 2004). Both schemes have their merits and demerits. Genetic progress could be slow under village programs because of inaccurate genetic evaluation due to the difficulties of implementing advanced selection tools such as selection on Best Linear Unbiased Prediction of breeding values and inefficient utilization of selected animals due to uncontrolled village breeding practices. On the other hand, nucleus breeding programs entail overhead selection costs in nucleus flocks (though cost of establishment and maintenance of the flocks may not be considered as the flocks could serve other purpose, particularly in research farms) to fulfill the continuous supply of improved rams to village flocks. Besides, farmers breeding objectives may not be fully addressed by breeding objectives and selection criteria defined by project experts in nucleus centers. This has great implications in the success of livestock projects since breeding strategies that base on farmers' indigenous knowledge and preferences are more suitable and sustainable than exotic technologies. To cater for farmers preferences, a new pilot station-cum-village based sheep breeding scheme has been designed and implemented for Menz sheep (unpublished). The design integrates the merits of station-based and village-based breeding schemes. Such a design could be adopted for the already ongoing and new nucleus breeding programs including Washera sheep selection program.

Alternative designs of nucleus breeding programs relating to the nucleus size, operation of breeding tiers (open vs. closed schemes), etc. have been evaluated elsewhere (e.g. Kosgey 2004; Gicheha et al. 2006)). In this study we opted to develop a breeding program specific to Washera sheep. Two alternative breeding schemes were designed (a regional and zonal scheme). The regional scheme is designed to address the entire Washera sheep population (estimated 1.2 million), while the zonal scheme will serve part of the population. Both schemes yielded similar responses to selection in terms of trait units. The regional scheme gives 58.9% more returns to investment over the zonal scheme. However, the regional scheme seems to be operationally difficult. The nucleus size is too large to operate as a single flock. Thus the nucleus needs to be split into many smaller flocks which need to be genetically linked to operate as one big nucleus. This can be achieved by designing across-flock genetic evaluation and exchange of rams. This obviously poses a huge operational difficulty. The zonal scheme could be easily adopted as it involves setting up an independent nucleus for each zone with approximately 10% of the population. Such nucleus flocks could be established for other zones as required and depending on resource availability.

Operational considerations in running such a scheme includes that farmers participating in the breeding program need to practice controlled breeding as the scheme assumes that all rams in the target base population use rams from the nucleus. To this end, it is recommended to distribute rams to organized villages using communal grazing and thus communal rams. Use of improved rams in common will also increase the mating ratio more than assumed in this study. This will increase genetic progress and profit from investment more than estimated here.

The breeding scheme designed in this study is a closed nucleus scheme. Open nucleus schemes are superior to closed nucleus schemes in terms of genetic and economic efficiencies because of a higher expected mean genetic value of nucleus replacements and because such a system will integrate farmers' resources, reduce overhead costs and encourage more farmer participation (Bondoc & Smith 1993; Kinghorn 2000). However, open nucleus schemes are operationally rather difficult, particularly in developing regions. The closed nucleus flock proposed in this study could develop into an open scheme as experience buildup in the breeding program. Supply of nucleus rams to cooperative villagers could facilitate the adoption of open schemes. Furthermore, the level of inbreeding could build up faster in closed flocks compared to open flocks, particularly in small nucleus flocks. Thus it is important to consider large flocks and planned mating in closed nucleus programs.

## Conclusion

Setting up a regional breeding program would be more profitable. However, operationally feasible breeding program for Washera sheep could be developed by setting up multiple independent nucleus flocks for each zone with approximately 10% of the population. Such nuclei could be established gradually as resources allow. Such scheme with 500 breeding ewes in the nucleus could serve 10 000 breeding ewes in the base population.

Our results demonstrate that twinning rate is economically most important trait under all systems of production. The results also indicate that an appropriately constructed single selection index and hence a single breeding program could serve the subsistence and market-oriented breeding objectives defined in this study. An index containing six month weight, twining rate and survival rate (or combined as number of lambs weaned) and feedlot performance (fattening gain) could be used in Washera sheep improvement.

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# Appendix

Table A1. Production parameters used for defining breeding objectives

| Production parameters | Subsistence | Market oriented |
|---|---|---|
| Nr. of lambings per year | 1.37 | 1.37 |
| Conception rate | 0.90 | 0.90 |
| Litter size | 1.11 | 1.11 |
| Lamb survival 0-3 months | 0.85 | 0.85 |
| Lamb survival 3-6 months | 0.90 | 0.90 |
| Ewe replacement rate | 0.10 | 0.10 |
| Ram replacement rate | 1.00 | 1.00 |
| Mature ewe weight (kg) | 28.5 | 28.5 |
| Mature ram weight (kg) | 32.3 | 32.3 |
| Six month weight (kg) | 16.2 | 16.2 |
| | | |
| Finishing duration (days) | | 90.00 |
| Finishing ADG of lambs (kg/d) | | 0.13 |
| Finishing ADG of culled rams (kg/d) | | 0.12 |
| Sale weight of finished lambs | | Variable* |
| Sale weight of finished culled rams | | variable |
| | | |
| Carcass dressing % | | 48.1 |
| Finishing feed intake of lambs (kg/d) | | 0.50 |
| Finishing feed intake of culled rams (kg/d) | | 0.50 |
| | | |
| Manure (kg/head/night) | | 0.19 |

* Varies with weight at six month and ADG during finishing which vary with selection.

Sources: Amha (1995); Abebe (1999); Solomon (2002); Mengiste (2008).

Table A2. Sources of revenue and expenses and values used for defining breeding objectives

| Sources of revenue | Subsistence | Market-oriented |
|---|---|---|
| Male lambs, 6 month old (ETB/kg live weight) | 15.00 | |
| Female lambs, 6 month old (ETB/kg live weight) | 13.00 | |
| Finished lambs, 9 months (ETB/kg live weight) | | Variable* |
| Culled ewe 7 years old (ETB/kg live weight) | 5.78 | 5.78 |
| Culled ram (ETB/kg live weight) | 7.84 | |
| Culled ram finished (ETB/kg live weight) | | 14.49 |
| Culled ewes 7 yrs old (ETB/kg) | 5.78 | 5.78 |
| Skin (ETB/pc) | 30.00 | 30.00 |
| Manure (opportunity cost of commercial fertilizer, ETB/kg) | 0.18 | 0.18 |
| Financing benefit (Bf = inflation rate) | 0.06 | 0.06 |
| Insurance benefit (Bi = ETB/ewe or ram/year) | 0.09 | 0.09 |
| | | |
| Sources of expenses | | |
| Feed cost | | |
| Grazing opportunity cost (ETB/head/d) | 0.01 | 0.01 |
| concentrate for finishers (ETB/kg) | | 0.60 |
| Management cost | | |
| labor for herding and feeding (ETB per head/d) | 0.03 | 0.05 |
| transport and marketing tariff (ETB/head) | 3.50 | 3.50 |
| Veterinary cost | | |
| Dewormimg (ETB per head/yr) | 1.12 | 1.12 |
| Vaccination (ETB per head/year) | | 0.20 |
| Fxed costs (ETB per head per year) | 0.50 | 0.50 |