TECHNICAL BULLETIN No.14
GENETIC IMPROVEMENT OF SHEEP AND GOATS AT VILLAGE LEVEL

ESGPIP

ETHIOPIA SHEEP AND GOAT PRODUCTIVITY IMPROVEMENT PROGRAM

FOREWORD
This fourteenth technical bulletin produced by the Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP) focuses on the underlying principles of the genetic improvement of sheep and goats and application of the principles at the village level under the realities of the smallholder producer in Ethiopia.

Even though improvement in the management (feeding, health care etc.) of sheep and goats is the first step that needs to be taken to improve productivity, more can be gained by also improving the genetic potential of the animals. Genetic improvement especially at village level requires longer term commitment and organization. It is, however, a step that needs to be taken. The process can be started by implementing simple measures like record keeping controlling mating etc. This technical bulletin shows what the Kebele Development Agent can do to help genetically improve the sheep and goats in their kebeles. The bulletin can also be used by others like commercial producers and also as a training tool at different levels.

At this juncture, I would like to thank all those involved in the preparation and review of this technical Bulletin.

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Chief of Party
ESGPIP
May, 2008

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GENETIC IMPROVEMENT OF SHEEP AND GOATS AT VILLAGE LEVEL

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1.   Introduction

The aim of sheep and goat farmers is to improve productivity for increased income & food availability. Productivity can be improved by two approaches:

- Improving the management of sheep and goats, so that their genetic potential can be expressed as fully as possible. Improving feeding, disease and parasites control or any other technical options.

- Improving the genetic potential by selecting the best animals for future mating, or by introducing new genotypes.
    o Professional animal breeders may be needed to design detailed breeding plans
    o And there are many simple improvements that extension staff can suggest, with or without the advice of animal breeders

2.   Principles of breed improvement

Characteristics that can be passed on to the next generation due to genetic factors such as fast growth rate, high milk yield, etc constitute the genotype (G). Other characteristics such as adaptability to a particular environment cannot be passed on and are due to the environmental effect (E). The two components (genotype and environment) together are known as the phenotype expression (P). This can be expressed in the form of an equation as follows:

$$P = G + E$$

It is necessary to determine the proportion of the total variation in a population that is of genetic origin. Generally, the effects of G and E are expressed as deviations from the flock average. P = Flock average + Genotypic deviation + Environmental deviation.

The genotype of an individual is determined by the genes, acting individually or in combination, passed on to it by its parents. Positive change or breed improvement occur through selection of superior individuals for mating. **Selection** and **mating** are the basic tools of breed improvement

2.1.   Variation in quantitative traits

Suppose the 12- month live weight of a population of individuals of a given breed ranges from 17 to 47 kg. Figure 1 shows the possible frequency of each live weight. The scale is given in terms of Standard Deviation (SD-σ) and in kg. The mean live weight for this population is 32 kg and the standard deviation (SD) as a measure of variation is 5 kg.

Variation is the raw material of breed improvement. The variation seen in Figure 1 (17 to 47 kg) shows that there is an opportunity to improve the 12-month live weight through selection of animals to be used as breeding stock.. This gives an opportunity to improve performance to the higher side of the weight range. The main tool used to make changes to this variation is selection. The objective is to improve the mean performance of a trait (traits) and reduce the degree of variation.
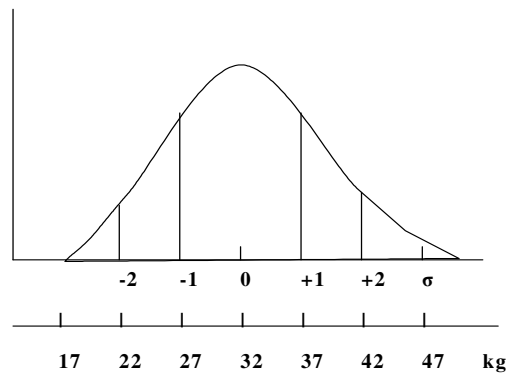

Figure 1. Frequency of live weight in a flock

2.2.   Tools useful for breed improvement

Animal identification, record keeping, estimated genetic value and breeding value, which express the genetic worth of the animal, are important tools in any breed improvement effort. Breeding value is defined as the value of an individual as a parent. Parents transfer a random ample of their genes to their offspring. Estimated breeding value gives an estimate of the transmitting ability of the parent. The Breeding Value (BV) of an animal could be estimated as follows:

$$BV = \text{heritability } (h^2) \text{ of a particular trait X (individual average – average of contemporaries)}$$

or

$$BV = h^2 \text{ X (individual deviation)}$$

2.2.1. Identification:

Animals must be identified to differentiate performance and potential of individuals and make decisions to use them for genetic improvement. There are many forms of identification such as using names or phenotypic appearance (in the case of small flock size), ear tags (plastic or metal), ear notching, branding, and other means.
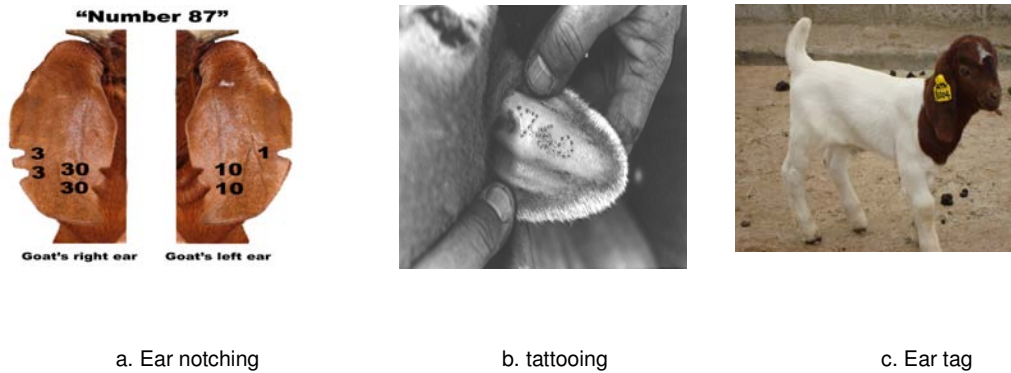
| a. Ear notching | b. tattooing | c. Ear tag |

Figure 4.13. Ear notching and pliers.

2.2.2. Record keeping:

Keeping simple records on individuals in the flock is a necessary activity to base selection judgments on actual information. Recorded information on reproduction, maternal ability, growth, carcass and lactation is necessary in making breeding and culling decisions. Accurate records are needed to identify the best and poorest performing animals on a farm. Performance recording is also an aid for making management decisions like provision of individual care.

2.3. Methods of genetic improvement

The methods used for genetic improvement are:
1. Selection within (or between) local breeds on which animals to keep as parents.
2. Crossbreeding with improved breeds.

2.3.1. Selection

2.3.1.1. Concepts of Selection

SELECTION IS CHOOSING! It is the business of making decisions about a particular animal based on the information available on that particular individual animal and its contemporaries. Selection can be natural or artificial. It is the process in which the best animals are chosen to be parents of the next generation. Unselected individuals are removed from the population through castration or removal from the flock by selling the males. This process continues from generation to generation. The main effort in selection should be directed towards males. This is because it is the male that can produce more offspring. Its impact on genetic improvement per generation is, thus, higher.

In order to reduce inbreeding, a ram/buck should never be allowed to mate with his full sisters, his daughters, his granddaughters or his dam. Additionally, the number of years a male serves should be limited to one. The male should then be replaced either through exchange with other flock owners or through purchase of a new sire.

Farmers within a certain area may reach agreements to exchange the best rams/bucks from their flocks with other farmers engaged in the exchange on a rotational basis. If exchange is not done, males at the end of their service can be sold immediately or can be

castrated for later marketing at good condition. In practice, farmers should be advised to exchange sires annually.

Table 1. Qualitative and quantitative traits

Qualitative	Quantitative
Influenced by a few identifiable genes	Many genes that can not be identified
Little or no influences by E	Moderately to highly influenced by E
Discontinuous distribution with discrete phenotypic classes	Continuous distribution with phenotypes measurable on a continuous scale
Description and analysis in terms of individual animals and frequencies	Description and analysis in terms of populations of animals (e.g. population mean and variance)

Animals for breeding are chosen on the basis of external examination and quantitative criteria. Table 2 presents some quantitative traits upon which selection can be based

Table 2.   Some quantitative traits upon which selection can be based

Reproduction	Growth	Milk yield	Slaughter
Age at 1st lambing Fertility rate Lambing rate Number of lambs weaned	Birth weight Weaning weight (WW) Weight gain to weaning Yearling weight (YW) Adult weight Body conformation Feed conversion efficiency	Lactation length Milk yield Fat content Protein content	Dressing percentage Carcass conformation Leg length

Genetic progress depends on the heritability of the trait to be improved and the number of animals kept back for breeding.. The proportion of the phenotypic variance that is due to genotypic variance is called heritability (h^2). It determines the likelihood of passing on a characteristic from parents to offspring.

Table 3. Heritabilities of some traits important in the genetic improvement of sheep and goats

Trait	Heritability
Weaning weight	0.30- 0.50 (high)
Milk yield/lactation	0.20- 0.30 (medium)
Multiple birth	0.15- 0.25 (low)

The higher the heritability, the greater is the rate of improvement through selection. The heritability of a trait can be classified as high ($h^2 > 0.50$), medium ($0.30 < h^2 < 0.50$) or low ($h^2 < 0.30$).

- **Selection differential:** degree of superiority of the selected parents over the rest of their generation.

- **Generation interval:** time interval between generations. In some cases, it is the average age of the parents when their first offspring are born. In other cases, it is the average age of the parents when their offspring have been selected to replace them.

- **Relationships between traits:** Different traits can have different relationships. The relationship (correlation) can be positive or negative. There is, for example, a positive correlation (relationship) between weaning weight and weight at 12 months which means animals with higher weaning weight will have higher weights at 12 months of age. There is negative correlation e.g. between increased birth weight and ease of birth.

2.3.1.2.   Methods of selection

Identification of superior animals to be selected to be parents of the next generation can be accomplished through the following methods:
- **Performance testing (individual):** an animal is selected based on its own performance.
- **Progeny testing:** an animal is selected based on the performance of its offspring.
- **Pedigree selection:** an individual is selected based on the performance of its parents. This method is useful in selecting animals before they reach the age where they can express their performance, e.g., milk production and litter size.
- **Family selection:** selection based on information from relatives other than ancestors and progenies. This method is generally used to supplement the information from the other methods and thereby improve accuracy.

2.3.1.3.   Selection criteria

Criteria to be used in selection depend on the goal for selection. If for example, the goal is to select for higher meat production, such criteria like weaning weight, yearling weight etc could be used as criteria. Other criteria may be used for other selection goals. Some such criteria are listed in table 2.

2.3.2. Mating system

There are generally two broad categories of mating systems: pure breeding and cross breeding.

2.3.2.1.   Pure breeding

Involves mating of individuals within a breed and can be divided into two methods.
- **Outbreeding:** the continuous use of unrelated rams in purebred flocks; it maintains the greatest possible amount of heterozygosity
- **Inbreeding**: the mating of a ram/buck and ewe/doe that are related to each other by having one or more ancestors in common. Inbreeding can have the following consequences:

- o **Inbreeding depression:** decrease in growth rate, disease resistance, reproductive performance and viability in subsequent generations.
- o Occasional physical deformities in offspring (e.g. undershot jaw-Refer to technical bulletin No.4 for details).

2.3.2.2.   Crossbreeding

Crossbreeding Involves the mating of animals of different breeds. It aims at:

- Exploiting the fact that progeny perform better than each of the parents (hybrid vigor or heterosis). Here there is a need to have a good evaluation of the existing breeds to know which breeds excel for specific traits
- Combining desirable characteristics of two or more breeds - breed complementarities
  - o Upgrading stocks, with continuous back-crossing with males (or females) of the desired breed thereby progressively increasing its blood level in the offspring
  - o Creation of new synthetic breeds by combining the desirable qualities in crossbred foundation stocks

Crossing can be done between indigenous x indigenous e.g. *Washera x Menz* sheep; *Bonga x Horo* sheep, etc. exotic x indigenous e.g. Awassi x *Menz*; Boer x *Afar*

The following are some of the advantages and disadvantages of Crossbreeding
Advantages:

- Fast improvements can be attained;
- Effect on extension program: Farmers accept it faster as there is potential to see noticeable improvements in a shorter period.

Disadvantages:

- It requires more management than pure breeding;
- Flocks of pure breeds should be maintained in order for crossbreeding to continue at its maximum effect.

The use of crossbreeding under tropical conditions requires caution in two respects:

1. The breed that is to provide the improved characteristics must be chosen very carefully, taking into account the characteristics of local breeds and their environment
2. Care must be taken in deciding on the optimal exotic blood level in the resulting crossbred animals. This may depend upon the extent to which environmental conditions (management) can be improved. Hence, Animal improvement should be complimented or supported by improved environmental conditions (feeding, housing, health care etc.).

There are different types of Crossing. The following are the major ones:

- **Terminal crossing:** Production of crossbred animals for slaughter. Sires of one breed are mated to females of another breed to produce superior commercial

progeny, not used for breeding. For example, a prolific sire breed is mated with hardy local ewes/does to produce fat lambs/kids for the meat market.
- **Rotational crossing (criss-crossing):** rams/bucks of two different breeds are used alternatively
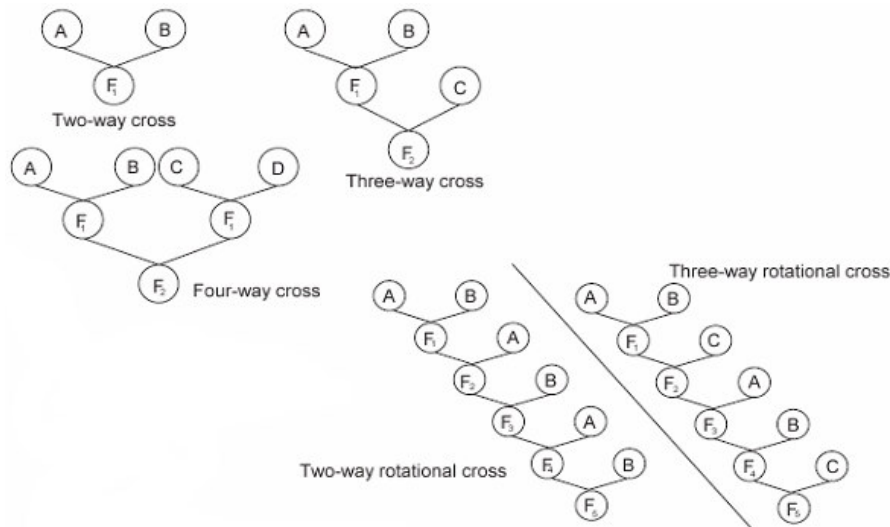

Figure 2. Different types of crossing (Ibrahim, 1998)

3. Genetic improvement programs

An increase in production is usually brought about by simultaneous improvements in the environment and genotype. Genetic improvement is part of an improvement package for increased livestock productivity. The whole package of genetic improvement should include the following:
- The first step in a breeding program is to define realistic and attainable objectives or decision on what we want to improve
- Choice of selection criteria, and decisions on measurement techniques
- Decisions on the techniques for genetic improvement
- Establishment or improvement of marketing systems to create an incentive for the efforts of genetic improvement
- Improved management (including veterinary care) to ensure realization of genetic potential
- Development or improvement of the extension service, which will involve the training of extension officers to assist producers in implementing improvement plans

Figure 3. Hierarchical structure of gene flow
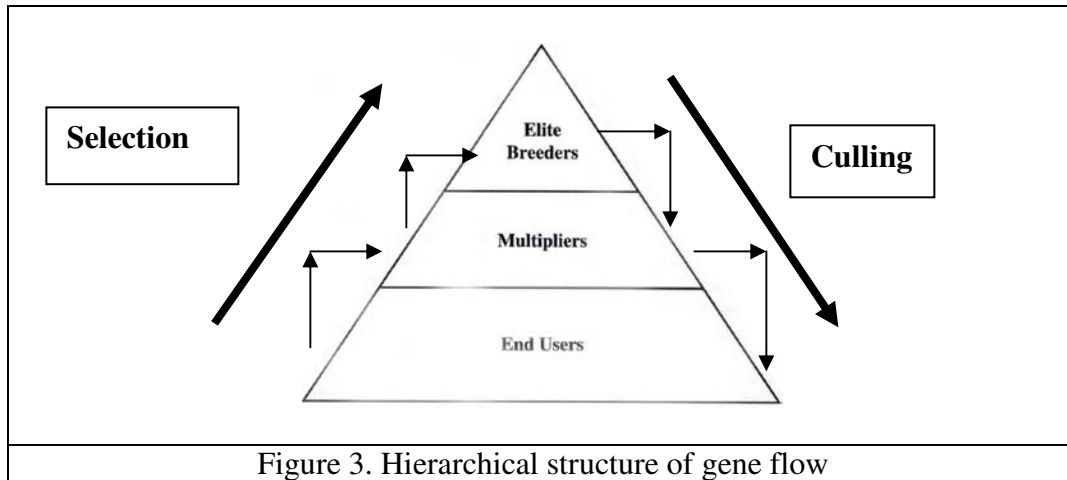
3.1. Nucleus breeding schemes

A nucleus breeding program is a centralized improvement program in which very superior animals are brought together from supply farms to form an elite nucleus flock. Farmers have to agree to put their superior animals together. The nucleus or base may remain open to the best animals from the supply flocks. This system is, therefore, called the **open nucleus breeding scheme**. Once the nucleus is established, an efficient recording and selection program can be implemented.

Farmers in an area using the same communal grazing area can be organized to undertake a breed improvement program together. They can, for example, select about 200 elite animals among their total flock to form a nucleus flock of breeding females. These will be mated to selected males to produce the next generation. This is coupled with continuous culling of inferior animals. Records on the performance of the nucleus flocks and their offspring will be kept. Rigorous selection and culling will be done continuously. The best animals will be retained and the least performing ones eliminated from the nucleus herd. High performing animals that have performances better than those culled from the nucleus herd selected from the annual round of inspections and selection among the village flocks will be promoted to membership of the nucleus flock. This process will continue resulting in a progressive increment of the average performance of the nucleus herd from generation to generation. Figures 3 and 4 show the nucleus breeding scheme.

Open nucleus schemes have the following advantages:
- Animals entering the nucleus are tested under farm conditions;
- Selection is based on records for traits of economic value;
- The improvements are quickly spread as farmers participating in the schemes receive their replacement sires from the nucleus;
- A rapid generation turnover can be maintained;
- Inbreeding is avoided;
- Objectives are maintained for many years; and
- Small farmers benefit from coordinated effort, policy, pooled experience and shared facilities.
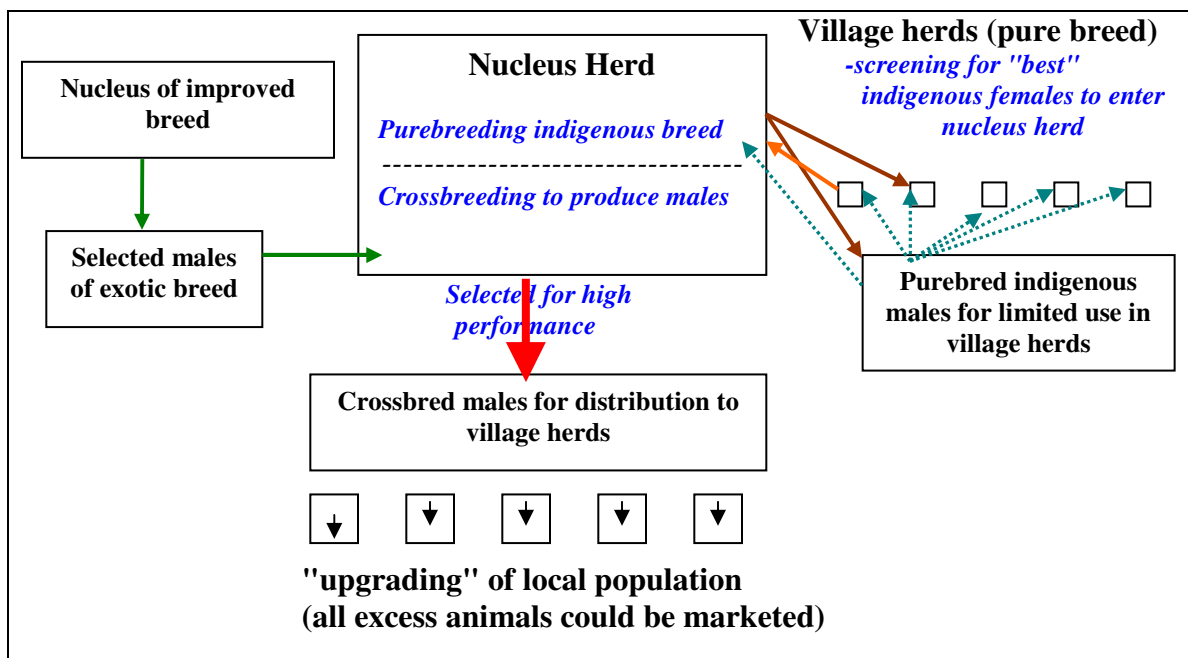
Figure 4. Open Nucleus breeding scheme for conservation and improvement

3.2. Practical methods of breed improvement

Breed improvement in sheep/goat populations can take place at the level of individual flocks, village flocks and/or district/national level.

3.2.1. Individual flocks

Possibilities of genetic improvement depend on the size of the flock owned. In flocks larger than 100 sheep/goats, an owner would be able to make genetic improvements through selection within his own flock. In the case of small flocks, there is little scope for selection due to inadequate variability. Up-grading through crossbreeding is an option in this case. Clear guidelines for breeding and culling should be in place to ensure that inbreeding does not increase. The following steps and procedures should be followed in an individual flock selection program:

- Put down a clear objective/goal of the selection program
- Implement animal identification and record keeping
- Measure the traits
- Select sheep/goats for mating based on concrete information relating to the objective/goal. Farmers have their own criteria and due consideration should be given to these
- Cull low performing animals
- Measure progress
- The best rams/bucks in the flock should be selected and retained for 1 to 3 years
- A ram/buck should never be allowed to mate with his dam, full sisters, his daughters or his grand-daughters

If new rams/bucks can not be bought i.e. in case of a "closed flock" the following can be done:
- One ram/buck should be selected each year to be the breeding ram/buck for the year
- After serving one year, the ram/buck should be culled, or a breeding control device applied. Exchange or rotate breeding males every 1 or 2 years regularly among a small group

A superior ram/buck can be used for more than 1 year if the owner separates the flock into groups.

3.2.2. Group flocks
Under circumstances where flock sizes are small there will be a need to form an owners group to exert selection pressure on their larger, combined flock. This also provides the possibility to make use of a superior ram/buck by sharing the cost of an improved male among many members. Government and NGOs can play an important role in assisting sheep/goat keepers to organize breed improvement, or developing improved stock on breeding stations.

3.2.2.1.   Selection in group breeding schemes
In group or cooperative breeding schemes, members agree to set up a nucleus flock of their best goats/sheep to produce their replacement breeding males.

Steps:
1. Members meet and agree on the objectives of the breeding scheme, its structure and organization.
2. Terms of membership of the scheme are clearly set out
3. Group members contribute the foundation stock for the nucleus flock
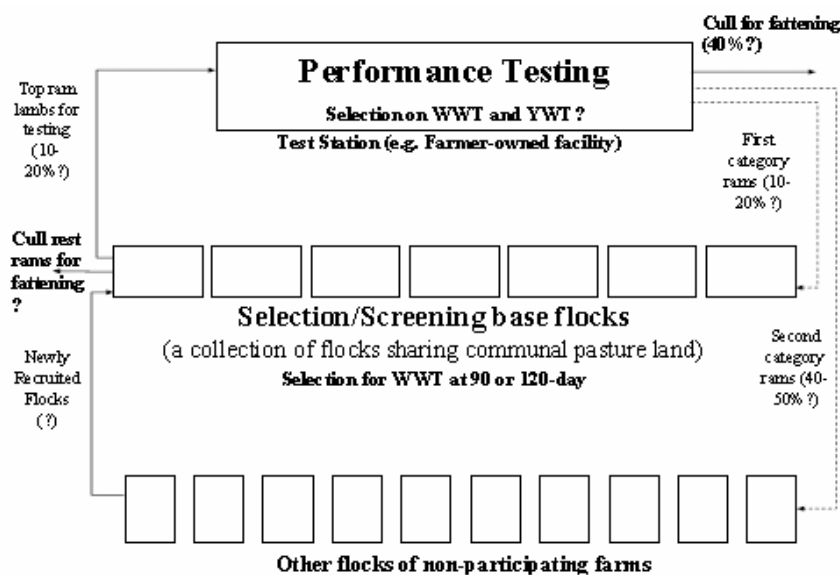4. Rigorous selection procedures are applied to this central flock

Figure 5. Outline structure for a possible sheep selection program

Guiding principles
- Start small, e.g., with a community grazing sheep together, members of which know each other well.
- Catalyze the formation of a 'self-help' type cooperative and ensure the advantages of forming a coop.
- Ensure the running of the activities of the cooperative, including decision-making and actual work is in the hands of members.
- A revolving fund which is eventually paid back and used elsewhere to start a similar scheme is the best way to achieve and to build self confidence. The source of the fund may be contributions by members and/or contributions from the government/NGOs.

Structure and operations:
- Use the breeding scheme as the organizing unit around which to build overall improvement; the scheme should NOT just be about breeding.
- The management package has to include husbandry, including health and nutrition – this has to be built into the scheme, including capacity building to empower farmers to do much of these on their own.
- Culling has to be associated with value-adding activities – e.g., fattening and innovative marketing to ensure that the culled animals fetch competitive prices (through forming farmers' coops, linking them up with markets, etc) and form a basis for capital formation for participating farmers.
- Farmers should make the selection/culling decisions possibly through a panel they are assisted in forming.
- Key activities such as weighing should, over time (but as soon as possible) be done by farmers themselves.
- Initial training will be required, but the idea is to make farmers OWN the processes and the eventual outcome – including success!
- Include serious considerations of input supplies and output markets; for example, facilitating contracts to supply products to whole-sellers, abattoirs, etc.
- The scheme could be used for pure-breeding (selection within breeds), for delivering crossbreds to farmers, or to facilitate formation of a synthetic breed.
- There have to be products going to market at any stage (i.e. throughout the year). It is the additional income that is the driving force for sustained implementation of genetic improvement measures.

What can the Kebele Development Agent do?

Animal identification:
- train your farmers on the importance of animal identification for breed improvement and management and convince them to take steps.
- Demonstrate use of appropriate methods. Discuss alternative means of identification and agree upon an applicable method.
- Record keeping:
- Develop a simple record and train a member of the farming household on how to keep records;
- At intervals, inspect the records that are kept and take corrective measures if you identify problems in record keeping;
- Demonstrate the usefulness of the records by showing the use of the information in the records for improvement.

Selection:
- train farmers on the value of selection and culling in breed improvement; Selection tools and methods. Refer to technical bulletin No. 4 "Selecting breeding stock for sheep production" for the purpose.
- Discuss with farmers the selection criteria they use and additional criteria enumerated in this bulletin they should use.
- Progress can be achieved by advising farmers not to sell (with the intention of getting more money from the sale) their best animals and not to sell indiscriminately. Rather, farmers should keep superior males for breeding and superior females for replacement.
- train farmers on the removal of males undesirable for breeding by castration and other means.

Promoting genetic improvement:
- **Individual flocks:**
  o Train farmers who have flock sizes of more than 100 to take steps outlined in section 3.3.1 of this bulletin.
- **Group flocks:**
  o Train farmers who have small flock sizes and using the same communal grazing area will have to be organized in groups. The KDA can take the lead to convince farmers of breed improvement and concrete steps of organizing the farmers and other steps as outlined in section 3.2.2 of this bulletin.

4. SUMMARY
The general principles of genetic improvement of sheep and goats are outlined. The applications of these principles at village level in Ethiopian farms and village flocks using common grazing areas is also shown. The role of kebele development agents in training farmers and organize them to work towards a common goal of genetically improving their flocks is highlighted.

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6. Annex. Definition of technical terms

Breed: Is either a sub-specific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species, or a group for which geographical and/or cultural separation from phenotypically similar groups has led to acceptance of its separate identity.

Breeding value: The value of genes to progeny

Conservation: All human activities, including strategies, plans, policies and actions undertaken to ensure that the diversity of farm animal genetic resources is being maintained to contribute to food and agriculture production and productivity, now and in the future.

Crossbreeding: A mating scheme utilizing two or more breeds.

Full-sibs: Animals having the same dam and sire.

Gene: Basic unit of heredity that is located on chromosomes and affects a specific trait.

Generation interval: Average time between birth of an animal and birth of its replacement.

Genetic value: The value of genes to self; it includes non-additive effects (such as dominance) which cannot be passed on to progeny.

Genotype: The genetic make-up of an animal.

Grading-up: Repeated mating of females and their female offspring with sires of a particular breed to produce a crossbred animal indistinguishable from the desired sire breed.

Half-sibs: Animals having one parent in common.

Heritability: The amount of variation in a trait which is due to genetic differences.

Heterosis: The increase in performance associated with the crossbred animal when compared to the average of the purebred parents.

Heterozygous: A gene pair with different genes for the same trait.

Homozygous: A gene pair where both genes are identical.

Inbreeding: Mating of individual animals that have common ancestry and are closely related, e.g., dam and son, siblings, etc.

Inbreeding depression: Reduction in performance due to inbreeding.

Nucleus flock: A flock or herd of the best animals available for the purpose of developing superior stock. A breeding scheme used by a group of producers to pool their best animals into one flock for the purpose of developing superior animals.

Open nucleus: Nucleus flock that continually allows introduction of superior animals from cooperator flocks.

Phenotype: The expression of genetic traits.

Selection: Any natural or artificial process that permits an increase in the proportion of certain genotypes or groups of genotypes in succeeding generations in relation to others.