Strategies for strengthening small ruminant breeding systems for a sustainable small ruminant livestock production in KSA

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Strengthening MoEWA's Capacity to implement its Sustainable Rural Agricultural Development Programme (2019-2025) (UTF/SAU/051/SAU)

Food and Agriculture Organization of the United Nations

Riyadh, Kingdom of Saudi Arabia

Contents

1. Introduction

Small ruminants under traditional productions systems as exists in KSA are not kept for single purpose, rather they are kept as multipurpose animals. They provide multiple roles such as source of income, food (meat and milk), wool, insurance functions and cultural values. The growing demands of meat products at the domestic as well as international markets also increase the importance of sheep and goat in the national economy. The small ruminant sector supports balanced rural and regional development, as livestock production is widely practised and distributed: 76% of livestock holdings are small-to-medium in size and owned by herders living in rural areas. In addition, the sector contributes to preserving sociocultural heritage, as Saudis prefer indigenous sheep and goat meat, and many animals are slaughtered annually for religious purposes. Around 23 million sheep and goat population contribute to this process. In spite of its significant socio-economic contribution, the income levels of the farmers of this small ruminant sector are very minimal. Some studies indicate that the income earned by 76% of sheep and the goat farmers are very poor (less than SR 5000 a month) owing to lower productivity levels of their animals.

Genetic quality of the animals contributes significantly to the productivity. Improving the genetic quality requires sustained and systematic genetic improvement of the sheep and goat population. The State of the World's Animal Genetic Resources for Food and Agriculture (FAO, 2007) indicates that the vast majority of developing countries have not been successful in sustaining genetic improvement in their livestock populations. The KSA has not even started any genetic improvement programme, and local breeds are not characterized, unlike the situation in high-income countries, they are not subject to structured genetic improvement programmes. Therefore, many countries, including the KSA, are failing to take advantage of the opportunities that such programmes offer to develop animals that better meet the needs of livestock-keeping communities and supply the products that consumers demand. Conversely, three quarters of breeds subject to structured genetic improvement programmes are located in developed countries (FAO, 2010). The KSA is a high-income country, but with low productivity, while technification of the small-ruminants sector is similar to what can be found in developing countries.

Sustained livestock genetic improvement activities that meet national needs without jeopardizing community needs make a vital contribution to food security and rural development. Lessons learned from countries that have sustained genetic improvement programmes provide a solid basis for effective use of animal genetic diversity. In developed countries, the number of breeds subject to genetic improvement has doubled or tripled and the KSA must aspire to follow this path. Around half of gains have resulted from genetic improvements, and the other half from non-genetic interventions. Both factors are important in the KSA, given serious problems in nutrition and health. The importance of this issue is further underlined by the fact that most genetic improvement is comparatively permanent. This emphasises the need for developing a breeding strategy for KSA that encompasses sustainability, adaptation to marginal environments and use of naïve genetic resources.

Several efforts have been made in the past especially in developing countries on the use of highly selected breeds of the western countries and creating crosses with the local breeds or maintaining them as pure stocks as a mean to replace the local breeds. In many instances, this has failed to yield any desirable results, since the farmers in less developed countries were not in a position to provide the similar environment and inputs that were provided to these animals in their country of origin. Further, the introduced breeds and their crosses are often exposed to intense stressors to which they are not well adapted (e.g., periodic feed and water shortages, diseases, climate extremes, and lower-capacity husbandry). In general, many small ruminants cross breeding programs in tropical country were not successful because of the incompatibility of the genotype with the farmers breeding objectives, management methods and the prevailing environment of the tropical low input production systems.

The ineffective experience of small ruminant crossbreeding program or breed replacement (with foreign breeds) across the tropical countries could be a convincing platform for the KSA to improve their own breeds that provide adaptation to local environments and possesses considerable levels of genetic potential for improvement, and therefore, hardly the production system requires introduction of any foreign breeds to improve the genetic qualities of the KSA' small ruminant population. The cultural context of KSA equally respects local breeds and they play an important role in the society' cultural heritage. Therefore, Straight Breeding i.e., selective pure breeding of the adapted indigenous breeds is the best possible option of genetic improvement in the KSA. Integrating selective breeding with a community-based breeding methods will add value to the KSA' small ruminant genetic improvement initiatives, because community-based breeding programs consider the indigenous knowledge of the communities on breeding practices and breeding objectives. This document provides a comprehensive framework and a strategy to design and implement a genetic improvement program for KSA sheep and goat population incorporating the elements of community participation and latest breeding technologies.

2. Important documented breeds of KSA sheep and goat

KSA so far submitted the local breed information in the FAO Domestic Animal Diversity Information System (DAD-IS), and hence the information provided below are mostly form the available local references of MoEWA and the information collected and observed through a field study by a FAO consultant undertaken with an objective to characterize small ruminant production system of KSA.

2.1. Heri/Harri/Hejazi sheep

The Harri breed seems to have originated from Hejaz and Asir mountains and now can be found in Jeddah, Mecca, and Medina. According to some sources, Harri breed origin is related to the Harat volcanoes of the northwestern Arabian Peninsula and now is common in different areas of KSA, mainly Qassim, Hejaz plains, Tehama, and Sarawat mountains (AL-Harbid, 2013). The Harri breed is mainly white in colour sometimes with dark spots (normally in the muzzle and eyes). It is destined for meat production, its average size is medium, its height is around 60-70 cm, and its weight 40-60 kg. It presents a cylindrical fat tail, middle sized ears, and medium size legs. The breed is adapted to high temperatures and to poor diet (MoEWA)

2.2. Rufidi/Rafidi

This breed could correspond with the Tihamah breed, from the Tihama region around Jizan. Rafidi is a mainly white, hairy, and medium/small sized sheep. Some animals may, however, have black markings on head, neck, and legs. The fat tail is short, and the most recognizable characteristic is the very small ears. Different phenotypes of this sheep were observed in with some variations in head and neck shape. It seems there is variation in size, with adult females weighing 25-40 kg. The breed seems to account for less than 5% of the KSA sheep population according to MoEWA (and probably less according to field observations).

2.3. Nu'amieh/Awassi

Awassi sheep are called Nu'amieh in the KSA where it is bred mainly in the north under desert conditions, and where the Naemi breed is also called the desert Awassi sheep. This breed is highly studied and described, as it is the most numerous and widespread breed of sheep in southwest Asia, where it has become fully adapted to semi-arid or arid regions. However, specific subpopulation variations in the KSA are not described. Awassi adult sheep height ranges 68-80 cm in rams and 65-70 cm in ewes, and body length is 62-72 cm in rams and 58-67 cm in ewes. The weight is 60-90 kg for rams, and 30-50 kg for ewes. The head of the Awassi is long and narrow, with a convex profile. The ears are pendulous, about 15 cm long and 9 cm broad. Rams are nearly always horned; horns are normally 40-60 cm long and strongly curved/wrinkled, curved backward and downward, with the tips directed outward. The neck is fairly long, lappets being frequent. The chest is also long but of only moderate depth and width, with a small, thin dewlap, and prominent brisket. The back is long and straight, the anterior part of the rump is relatively broad and nearly on a level with the back, but the rump is short with a slope to the fat tail. The barrel is deep and wide. The legs are of medium length and thickness. The fat tail is broad and relatively short, usually ending above the hocks, more rarely extending below them. Typically, the wool of the Awassi is white with a yellowish hue. The head, ears, and anterior part of the neck are brown, while the legs may be wholly or partly brown. Some animals have a white blaze on the head. The hoofs of the Awassi are dark brown. The mean birth weight of male lambs is 4.3 kg and of female lambs is 4.1 kg. The main local purpose of Nu'amieh sheep is meat, however as reported it possesses a high potential for milk and it is possible to find dairy products from Nu'amieh in different shops in the Arar region, such as butter, dry milk, milk, and cheese. It is also possible to find coarse wool products of Nu'amieh sheep.

2.4. Arabi/Erb/Erbi sheep

This fat-tail sheep breed is normally born black in the KSA and tends to remains black (although in other countries they often turn white). It is not clear if it is originates in east KSA, Kuwait or Irak/Iran, but now can be found in all these countries. Arabi sheep is endowed with a fat tail and it is drought resistant and high temperature resistant. The Arabi breed is considered to have good milk production and good maternal qualities. According to MoEWA information it accounts for less than 5% of the sheep population in the KSA

2.5. Najdi sheep

Believed to originate from central KSA, it is now present also in eastern parts of the country especially along the border with Kuwait. It is usually black with a white head, and black and white rings around the legs, and white spots on the legs and tail, with coarse wool. Najdi sheep have long fat tails extending beyond the hock, long legs, a pronouncedly convex nose, and long and large pendulous ears. Females are polled and males are polled or scurred. This breed tolerates drinking water deficiency and drought, and are highly suited to living under desert conditions, although it is less drought tolerant than the Awassi breed. Wither height average is 86 cm for males and 76 cm for females. Average weight is 62 kg for males and 45.5 kg for females, although bigger animals exist, with some show breeders using size as a selection criterion. Birth weight average is 4.1 kg, wool is of coarse/carpet quality, milk yield per lactation is average 118 litres, and prolificacy is estimated at 1.24. According to the FAO, estimated population in 2006 was 10,000 animals, although, currently, according to different field and market inferences, numbers seem much higher. Najdi breed meat is consumed locally but traditionally it was especially valued for its milk and long, straight wool. Nowadays, the main interest for this breed lays in its meat production, as in the KSA sheep milk production is marginal.

2.6. Al Gose/Adham/Tihami goats

Al Gose, Adham and Tihami may be the same breed but, as often happens in the KSA, local names vary and breed subpopulations or mixed breeds (local or foreign) add more confusion. Al Gose/Adham/Tihami is white, medium/large, with medium length hair, and can be found at least in the Assir region. This breed is mainly destined for meat production, as other smaller breeds are preferred for milk. This breed could be the same as the Tohami (Al-Bishi) breed, that according to King Saudi University information, is bred on the southeastern coast of the Red Sea. It is considered a medium-sized breed. The average weight of males is about 51 kg and females 33 kg. It is predominately a full white colour, often with black rings around the nose and eyes and black eyelids; sometimes the legs and abdomen are tinged in red or spotted, and the tail is short and coiled. Males have large horns curved backwards and can reach 40-50 kg and sometimes 55 kg. This goat breeds throughout the year and may have 2 births per year provided good pasture is available. Males reach maturity at 10 months and females at approximately 12 months. The proportion of twins is high and the breed is considered dual-purpose, as its average milk production is about 0.7-2 litres/day. According to the MoEWA booklet this breed is distributed around the coastal plains of the Tihama region, from the Laith region in the north to the borders of Yemen in the south

2.7. Muhayil/Djebeli goats

Muhayil is the local name (toponym) provided by herders in Abha to denote the local reddish goat. Muhayil and Djebeli are probably the same, although Muhayil could be a specific type of the Djebeli breed that groups a variety of animals. This breed is small and red-brown in colour. Interviewed KSA herders in the Abha region said they use this goat for mixed purposes (dairy and meat). Milk of this breed is sold fresh, also often butter produced in a traditional manner. It is not clear what is the origin of this breed, as it could be international (according to FAO DAD-IS information), brought to the KSA and mixed with local breeds. According to the MoEWA booklet this breed is found in the mountainous regions of the south, and colours vary from black, grey, brown and multi-coloured. It is the smallest goat breed in the KSA (15-20 kg for females and 18-25 kg for males). The ears are short, usually erect and sometimes horizontal, and the body is small and compact. This breed is characterized by its adaptability to grazing in rugged areas and the slopes of mountains and valleys and feeding on local poor-quality grazing. Puberty is reached at 6-7 months and twins are rare (no more than 5-7%). It is not sure what its relationship with another breed called Southern Mountain, described by King Saud University as follows: "Breeding is spread in the southern mountainous areas of the Sarawat Mountains. It is multicoloured, of medium size, and medium dagger-shaped horns for both sexes. Its bodies are covered with short hair, and it has a good milk yield and a high percentage of twins."

2.8. Levantine goat

According to King Saud University this breed corresponds to the central, eastern and northern regions of the KSA and has several colours: red and black most commonly, then white. This breed is characterized by its large size and symmetry in its members. It is considered a milk-producing breed, with an average milk production of 2.5 litres/day. Females can be vaccinated at the age of 9 months. The proportion of twins is high

2.9. Ardi (Najdi) goat

This breed originates from the middle and north, and nowadays can also be found along the east coast and in Assir and Taif. Ardi is a dual purpose, medium/large, black-grey coloured goat, well adapted to arid conditions. The average body weight of the male and female is 51 kg and 40 kg, respectively, although some animals observed in the field may exceed this weight. Horns are present in both sexes; the female horn is semi-circular, while the male horn is spiral. Ardi has elongated and normally white/grey drooping ears with coarse hairs. Field observations confirm other colours (e.g., brown) and different hair lengths to what owners and veterinarians called Ardi breeds, although, size, conformation, head shape, and ears were all quite similar. The mean birth weight of males and females is 4.29 kg and 3.63 kg, respectively. Ardi goats are considered dual-purpose and have an average milk production of about 0.75-1.5 litres/day. Puberty is at the age of 7 months for males and 6 months for females and the proportion of twins is high. No studies exist regarding the genotypic variability of the Ardi goat population in the KSA.

2.10. Hijazi/Habsi goat

This breed is raised in the Hijaz and Asir regions. It is characterized by its small size, with an average animal weight of about 22 kg for males and 19 kg for females. According to MOEWA booklet It is characterized as mostly black, sometimes light brown and rarely white in colour, although the white is sometimes tinged with another colour. It has the ability to withstand drought and heat and is mostly bred to produce meat.

2.11. Shami goat

It is difficult to pinpoint an exact geographical origin for the breed, but both large and small herds of Shami goats have been found in the Middle East throughout the centuries, where it is native. Large herds of Shami goats have been historically found in Syria, Turkey, Lebanon, Jordan, Israel, and the Palestinian territories. Detailed descriptions of the Shami appear in classic Arabic literature, religious texts, and folklore. Nowadays in the KSA, it is raised in the central, eastern, and northern regions. It is considered a milk-producing breed and the proportion of twins is high. It seems Shami goats are often bred for showing purposes; however, selecting for extreme head characteristics is becoming a health and welfare problem.

2.12. Aswad goat

This breed (whose name means black) is named in the FAO DAD-IS website. However, it was not possible to retrieve information from the DAD-IS. According to the MoEWA, this breed is present in all regions except the southern region, the Tihama plain, and the highlands. The goat is considered dual purpose (milk and meat), although predominantly raised for milk. Adapted to harsh climates, it is medium in size, with a compact body, medium leg length, with a long neck and small head. Black is the predominant colour, with brown and spotted red on the face, legs, and lower abdomen. Ears are long and both males and females normally have horns.

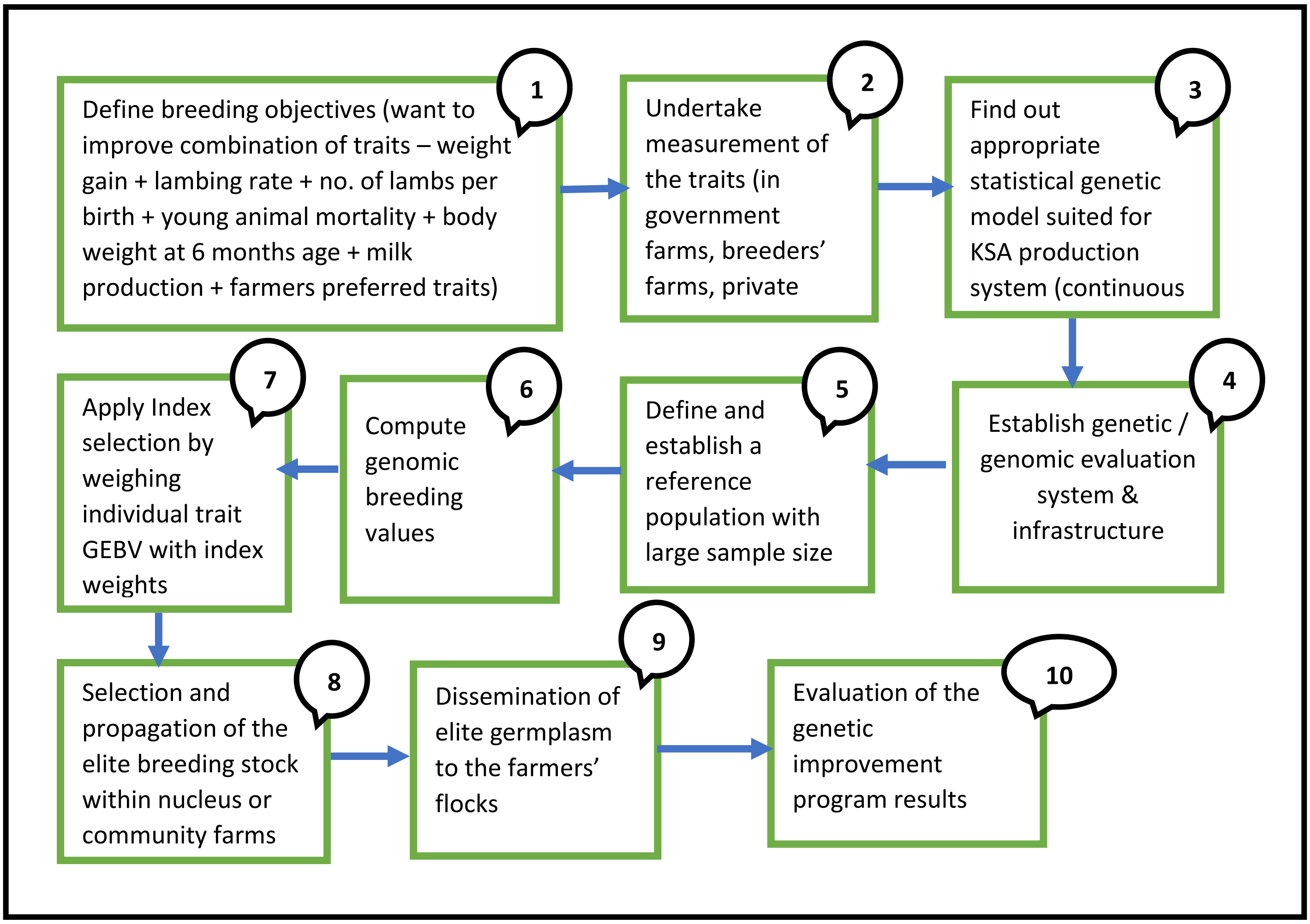
3. Community based breeding program

Community-based breeding programs take into account the indigenous knowledge of the communities on breeding practices and breeding objectives. because community-based breeding programs consider the indigenous knowledge of the communities on breeding practices and breeding objectives. Community based breeding programs consider the needs, views, decisions, and active participation of farmers from inception through to implementation. Their success is based upon proper consideration of farmers' breeding objectives, available infrastructure, participation, and ownership.

Improvement in performance of the populations of small ruminants can be achieved overtime through improvement in management and feeding conditions, and through genetic improvement by use of genetically superior animals. Genetic improvement results in small but cumulative effects, making it a powerful way of increasing efficiency of animals. To implement a successful breeding program for the sheep and goats, one need to follow these steps

- A good understanding of the production systems and the relative importance of the different constraints in these systems, and undertake characterization of the sheep and goat population exists in the KSA
- Organize community sheep and goat breeders into a group whose herds will become the source of selecting high genetic merit breeding stock, especially the males
- Clear definition of the selected breeding objectives supported by farmers
- Collection of information for those selected traits with farmers participation
- Accurate methods of identifying superior genotypes – like application of genomic selection in selection of high genetic merit males for breeding larger flocks
- Practical schemes which allow the superior genetic material to be used advantageously – e.g., establishment of artificial insemination program for sheep and goats
- Knowing what happened with the breeding program (impacts in terms of genetic improvement, genetic diversity) – monitoring the genetic progress in the population
- The above components are of interactive in nature, and helps to define the various aspects such as description of production environment and production system, characterization of the available local genotype, definition of breeding objectives, identification of traits to be selected, decision about breeding methods and breeding population and understanding of structure and organization of people involved.

Steps for implementing a systematic genetic improvement program for sheep and goats under a specific production system and specific breeds for genetic improvement



3.1. Step 1: KSA small ruminant production system characterization

Four type of small ruminant production system commonly found in the KSA. Those are

(1) Grassland based arid and semi-arid production – this was the traditional system in KSA, a land-based system in arid and semi-arid regions, featured by growing periods of less than 180 days, with grazing by ruminants as the predominant form of land use. This kind of enterprise generates around 90% of the total value of production, while the remaining 10% of dry matter consumed by animals is provided by crop production. However, the systems are getting converted into a transhumance system, where in extra feed is substituted through external purchase.

(2) Landless ruminant production - Ruminant feed is mainly introduced from outside the farm system, thus separating feed decisions from feed production decisions, and particularly manure utilization on fields to produce feed and/or cash crops. An LLR system can be based on zero grazing or opportunistic grazing, depending on season and location. These systems are getting prominence in the country as a way of system intensification.

(3) Mixed rainfed arid / semi-arid production and mixed irrigated arid / semi-arid production – these are not prominent systems in KSA, but a smaller proportion of farmers in selected regions use crop by-products from the crop cultivation to feed their animals.

Considering the above production system classification, the animal breeding strategy for KSA should aim meeting the breeding requirements of extensive transhumance system of production and intensive landless production system. Involving communities in both of these systems will be an optimal breeding strategy. KSA does not have any well-planned breeding program for sheep and goats at present. To systematize the breeding program for small ruminants in the country, a dedicated body that can oversee the entire spectrum of breeding is required.

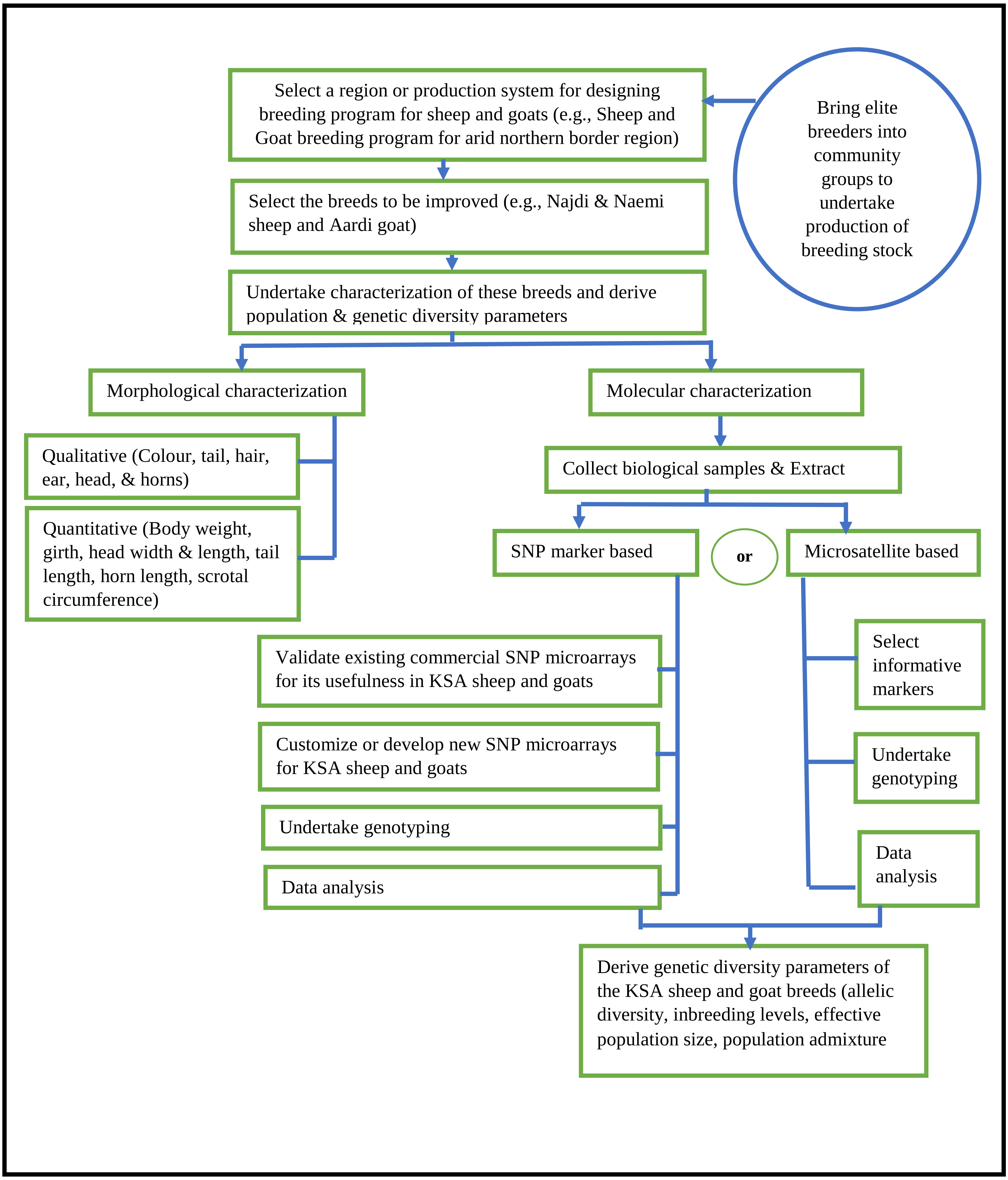
3.2. Step 2: Characterization of breeds

Breed characterization is an important element in breeding program design, and facilitate decision making process in animal breeding. This involves documenting several aspects such as breed origin, development, structure, population parameters related to its diversity and relatedness, qualitative and quantitative characteristics, and the underlying production systems where the breed exists. Two types of characterization usually followed: (1) Morphological (Phenotype) (2) Molecular characterization.

Phenotypic characterization follows the process of identifying distinct breed populations and describing their external and production characteristics in a given environment and under given management, taking into consideration the social and economic factors that affect them. Phenotypic characterization is a way to describe breeds in terms of external characteristics, such as coat colour, ear type and shape, horn shape and type, linear body measurements (heart girth, body length, ear length), production traits (body weight, growth rate) and reproductive traits (age at first lambing, litter size). Comparatively morphological characterization is a cheap tool. However, the phenotypic characters are highly influenced by environmental effects and there exists strong environmental correlations and interaction. Under this circumstance, molecular characterization helps to provide additional information.

Molecular characterization involves describing breeds at molecular level. This process provides measures of population parameters such as frequencies of specific genotypes and alleles, polymorphisms, heterozygosity, allelic diversity measures, genetic distances, relatedness in terms of inbreeding parameters, effective population size, relatedness to other breeds, etc., These parameters are important to define breed conservation, breeding and designing genetic improvement program. Mostly microsatellite based and Single Nucleotide Polymorphism (SNP) based molecular characterization are in practice. Until now microsatellite was commonly used to characterize populations, but due to certain limitations (like interpretation difficulties in calling rates) it is getting replaced by SNP based characterization. SNP markers have promising advantages over microsatellite markers such as being prevalent and providing potential markers near or in any locus of interest. Some SNPs are located in coding regions and directly affect protein function. SNPs have lower mutation rates than microsatellites, making them more suited as long term selection markers and SNPs are more suitable for different genotyping techniques and have strong potential for automation. Commercial SNP arrays are available almost for all of the farm animal species, but their informative content specific to the population understudy need to be evaluated before undertaking large scale application. However, large numbers of SNPs are required for genetic diversity analysis to get the accurate results. Under the KSA context, both morphological and molecular characterization of important breeds are not carried out in a systematic way and not reported to global AnGR data base. Therefore, an immediate action is needed to characterize the population of KSA' sheep and goats in a systematic way, for designing an efficient breeding program and further to report to the global community about the uniqueness of KSA' sheep and goat AnGR

Framework for breed characterization involving communities & genomic technologies



3.3. Step 3: Defining breeding objectives / breeding goals

Breeding goal definition is the first step to be made in designing of breeding program. Breeding goal is the specification of the traits to be improved including the emphasis given to each trait. It gives the direction in which we want to improve the population, clear understanding of production objective and breeding goal of the farmers (beneficiaries) is an important component of planning of breeding programs. The breeding goal identifies the animal traits that farmers would like to be improved. Breeding objectives must to be set at national (macro), regional or local level by stakeholders (and not by outsiders) to truly reflect the real needs of the area; farmers must support the direction of change. The ultimate goals of a breed at the macro-level should be expressed by the agricultural development policy, market, production system of the country, region or locality. At the micro level the definition of breeding objectives means that for the given production environment the relative importance of improvement of different traits of the breed must be identified.

The breeding objective and the selection criteria (traits), on which the livestock keepers wish to improve and base their selection should be identified through the full participation of smallholder farmers. To elucidate the desired breeding objectives of the farmers methods like choice experiments, interviews, focus group discussions, ranking experiments, etc., could be followed. The breeding goal usually involves the improvement of multiple traits simultaneously. The breeding goal should be formulated carefully and should hold consequently for many generations to become successful as a breeder. Breeding goals involving multiple traits can be expressed in term of weighing factors for traits based on its economic value or based on the desired genetic improvements for each trait. The outcome of a breeding program is often realized many years after selection decisions are made. This underlines the need to anticipate future demands when defining breeding goals and requires attention towards returns on investments. And most breeding goals are only reached after several generations of selection. This requires tenacity of the breeders involved. Frequent changes in breeding goals impedes the generation of progress in breeding programs.

Weighing the different traits of the breeding goal

Breeding goals can be simple or complex. In case of commercial breeding programs many traits are recorded and have an influence on the profit of animals produced by these commercial breeding programs. In extensive production conditions or in case of hobby breeding only a few important traits are recorded and simple breeding goals consisting of a few traits are used. In order to rank the individual selection candidates for the breeding goal traits it is necessary to comprise the values for the respective traits into one single selection criterion. The value of this criterion can be obtained by summing up the breeding value for each trait multiplied by a weighing factor based on the relevance of that trait in the breeding goal. The relevance might be based on the relative economic value of the trait. The methodology to weigh the traits with respect to resource efficiency and economy is well developed.

Breeding goal as a single criterion can be expressed as:

Breeding goal (H) = v1 (economic value of trait 1) * A1 (trait1 breeding value) + v2 * A2 + v3 * A3

Breeding value is an estimate of an animal's genetic merit (as a parent) for a particular trait. It is estimated as twice the average superiority of the individual's progeny relative to all other progeny under conditions of random mating.

An example of a research on community breeding program approaches and development of index values for Abergelle goat breed in Ethiopia involving communities (Guangul, et al, 2014)

Traits used for the selection of female goats	Index value	Traits used for the selection of male goats	Index value
1. Body size	0.211	1. Body size	0.310
2. Twinning	0.124	2. Colour of the animal	0.250
3. Milk yield	0.317	3. Libido	0.232
4. Mothering ability	0.063	4. Growth rate	0.092
5. Kidding interval	0.086	5. Pedigree information	0.070
6. Young animal growth rate	0.072	6. Horn presence	0.016
7. Colour of the animal	0.057	7. Drought resistance	0.030
8. Age at first kidding	0.014		
9. Drought resistance	0.045		
10. Pedigree information	0.011		

If we undertake measurements for these traits, we can have estimated the breeding value (genetic merit) for specific traits. Hypothetically (in reality the methods are complex and requires appropriate statistical models) we have the following breeding values (for ease let us consider these values as standardized values between -3 to +3) for the different traits in 6 females that we use it for selecting the top ones.

Combined trait value weighted by the index weights for Animal A will be

Animal A = [(0.211*2.2) +(0.124*1.3) +(0.317*1.7) +(0.063*-1) +(0.086*2.2) +

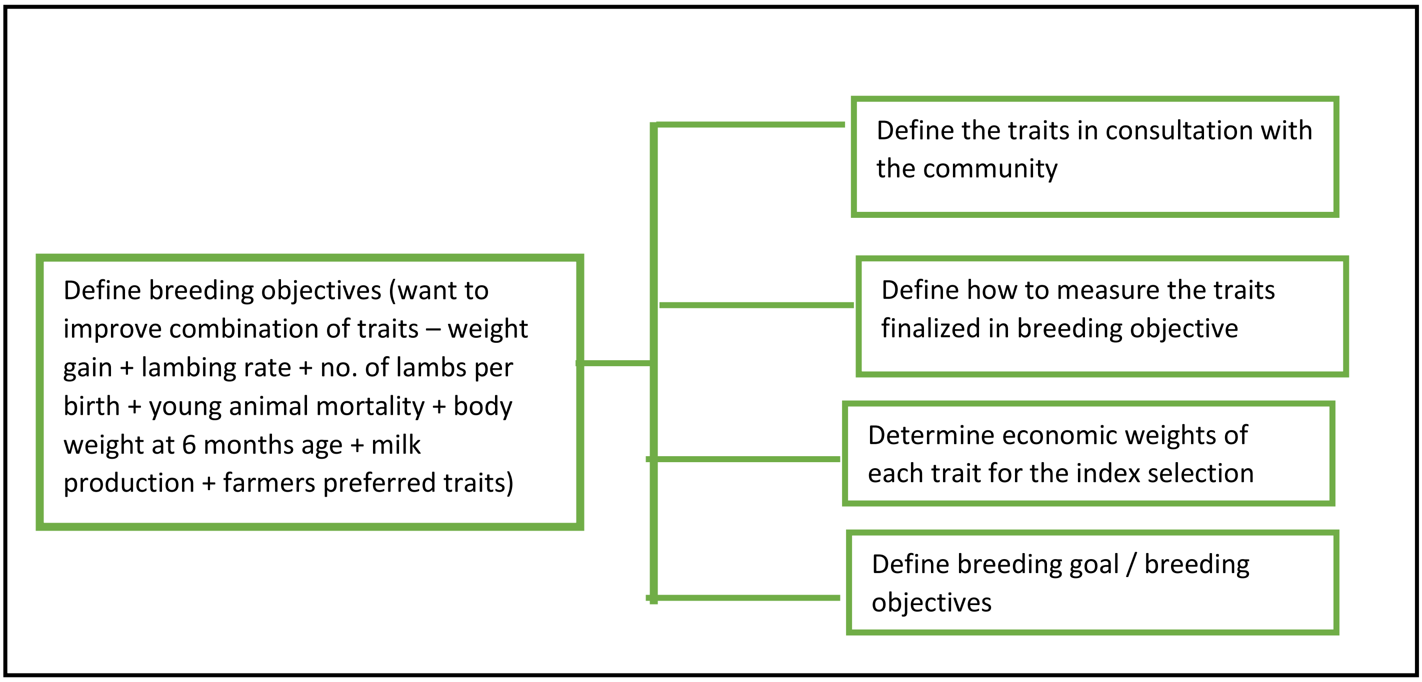
(0.072*1.6) +(0.057*1) +(0.014*2.4) +(0.045*1) +(0.011*1)] = **1.5523**

The combined trait values for the ranking and selection of the 6 female animals in this example are:

Particulars	Animal A	Animal B	Animal C	Animal D	Animal E	Animal F
Combined index value	1.5523	0.5578	1.8916	1.6308	-0.1866	1.5669
Rank	4	5	1	2	6	3

From the above example, if we want to select top ranking 3 animals, we will be selecting Animal C, D and F, as future breeding animals. We can do the same for the males also. Only thing we need to consider is what traits we want to include in the breeding objectives.

Similar exercise could be taken up for the KSA livestock sector in defining breeding goal, and accordingly defining what traits to be recorded and **applying appropriate econometric methods to derive index weights for different traits.**



3.4. Step 4: Measuring the traits (Phenotype information)

Once we define the breeding goal, relevant information should be collected. Relevant in this respect are traits of animals (called phenotypes) that can help to establish the value of an animal with respect to the breeding goal. When growth rate in sheep and number of lambs produced by ewe in a year are the traits we want to improve, then we need to collect the performance data related to the traits, for e.g., young animal weight gain per day and number of lambs every ewe produces in a year. Other relevant information is the pedigree of the animals. Animal breeding is all about passing genetic abilities from one generation to the next. When you want to trace or influence this process of passing heritable traits, a registration of the parent-offspring relationships, the pedigree of an animal, is crucial. And nowadays, DNA-analysis is possible and practised in animals and can also be used to trace or influence the passing process of genetic abilities for traits.

When we collect trait data (phenotype data) the following points

- When we collect trait data (phenotype data) the following points to be considered.
- What can be measured?
- How often can or should the trait be measured?
- Who or what is measuring the trait?
- What animals can or should be involved?
- At what age?
- How detailed?
- What is the accuracy of the measurement?
- Do systematic effects (season, herd, etc.,) play a role on the outcome of the measurement?

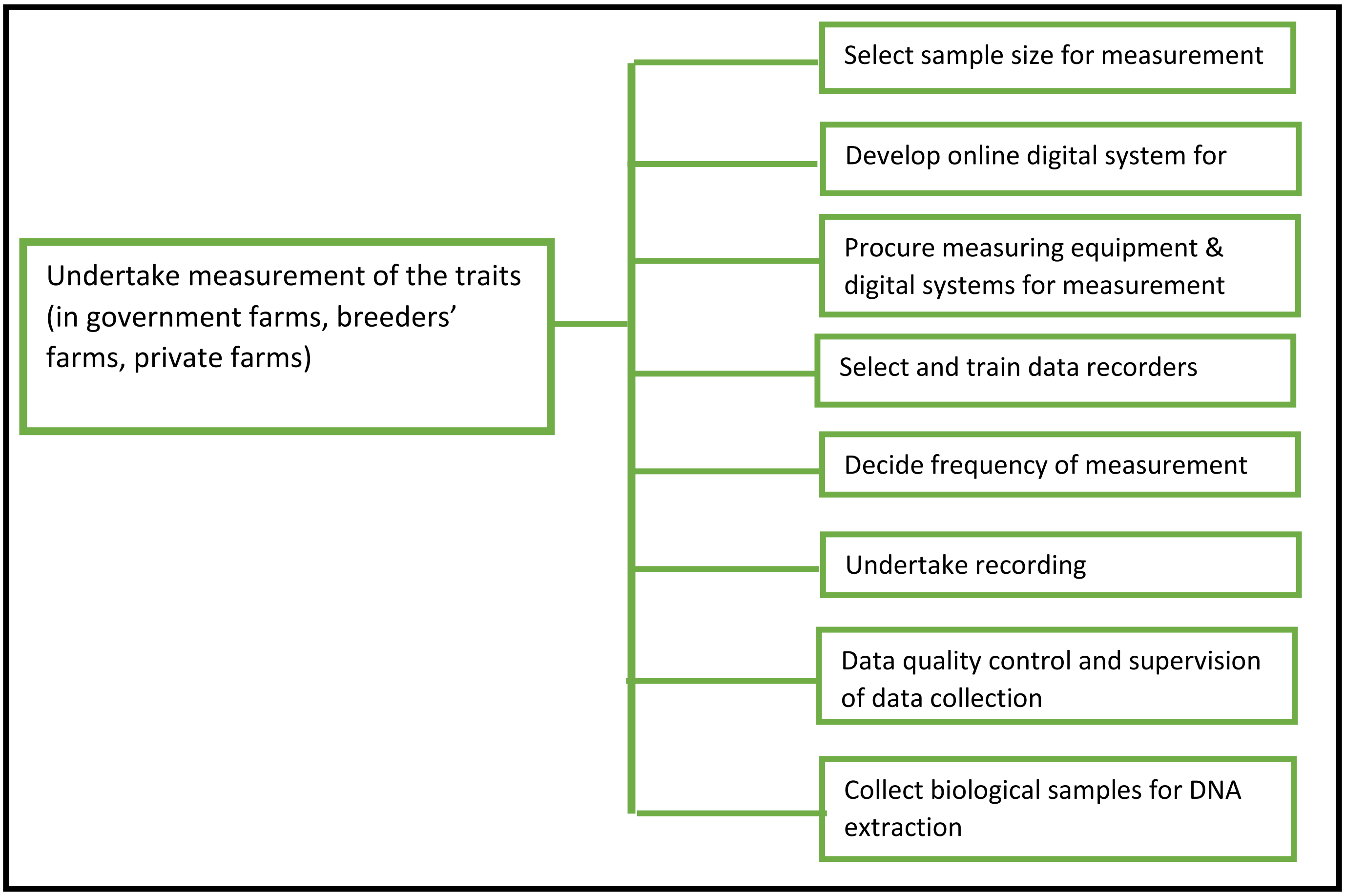
For the small ruminant breeding program in KSA the breeding objective could focus on a combination of traits such as

- Age at first breeding
- Number of lambs / years

- Twinning rate
- Weight at weaning
- Weight at 6 months
- Milk yield
- Young animal mortality rate
- Lambing interval
- Selected conformation traits (feet and legs, udder shape, etc.,)

In addition, farmer's preferred traits such as colour, body size, milking ease, etc.,) also could be added. **The trait measurement in KSA** preferably should be carried out through a dedicated body (having trained personnel) whose major activity includes establishing recording system, getting required measuring equipment, training manpower to record the traits, monitor the quality of data collected, summarize and run preliminary data checks for quality and other parameters, storage and distribution of the data for genetic analysis and downstream genetic evaluation process.

KSA' small ruminant development strategy has a strong focus on application of latest breeding technologies such as genomics based genetic improvement program for the sheep and goat population of KSA. In consideration of this aspect, it will be wise to collect biological samples (blood or hair or tissue) from the phenotype recorded animals, that will assist in DNA extraction and downstream genomic analysis.



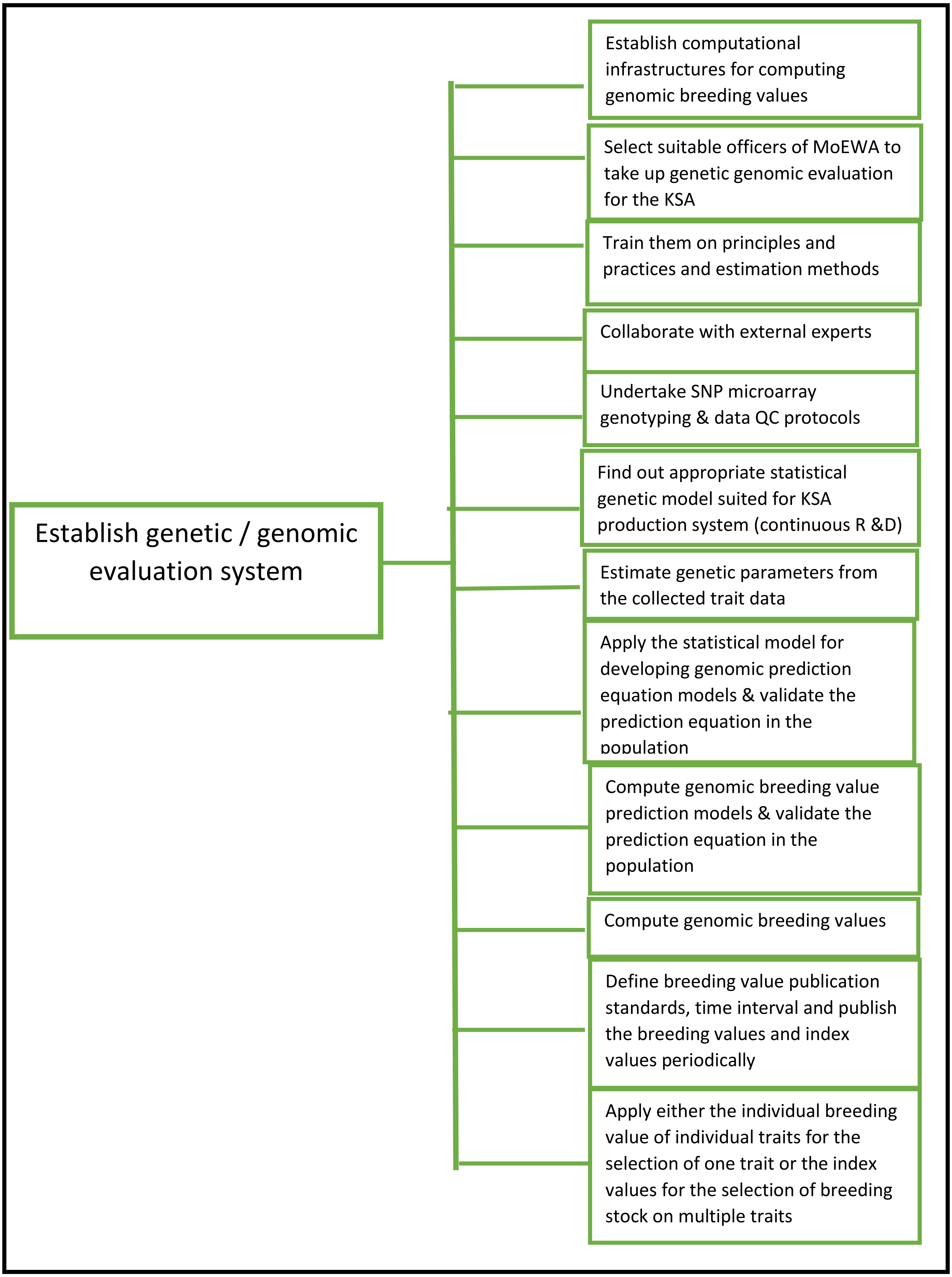
3.5. Step 5: Genetic analysis, breeding value estimation and selection criteria for the selection of elite animals

Many developed countries have dedicated genetic evaluation system for sheep and goats (for example LAMBPLAN, a dedicated genetic evaluation system for sheep in Australia), and undertake regularly evaluating the genetic merit of the livestock species for selection and culling decisions. Genetic evaluation is an important step in the whole process of breeding program which helps to determine and make a decision about the choice to make which animals will indeed be selected as parents and which animals are excluded for reproduction. Deriving genetic parameters such as heritability from the collected data, incorporating parent and genetic information, deciding an appropriate statistical or genetic model that is relevant for the given production system are critical components in genetic analysis and breeding value estimation***. Important point to consider in the whole process is the relatedness of the animals used in the genetic evaluation, and the environment on which the measurements are carried out. This necessitates, development of country specific or region specific or production system specific statistical genetic models that can estimate the breeding merit more accurately. This limits the use of genetic evaluation system developed in another country. For example, the genetic evaluation models developed in Australia cannot be used as such in KSA to estimate breeding values of KSA' sheep and goats. Therefore, it is imperative for KSA to establish its own genetic evaluation system.***

The estimated breeding value indicates the value of the animal with respect to the breeding goal: the lowest ones will have a negative effect on the breeding goal traits and the highest ones will improve breeding goal traits. Nowadays, when DNA information of animals is available, it can also be used to estimate breeding values. This provides an opportunity to undertake certain levels of research to build up a reference population base for sheep and goats, and establish a genomic evaluation system that will hasten the entire process of selecting high genetic merit germplasm in a cost effective and time bound manner.

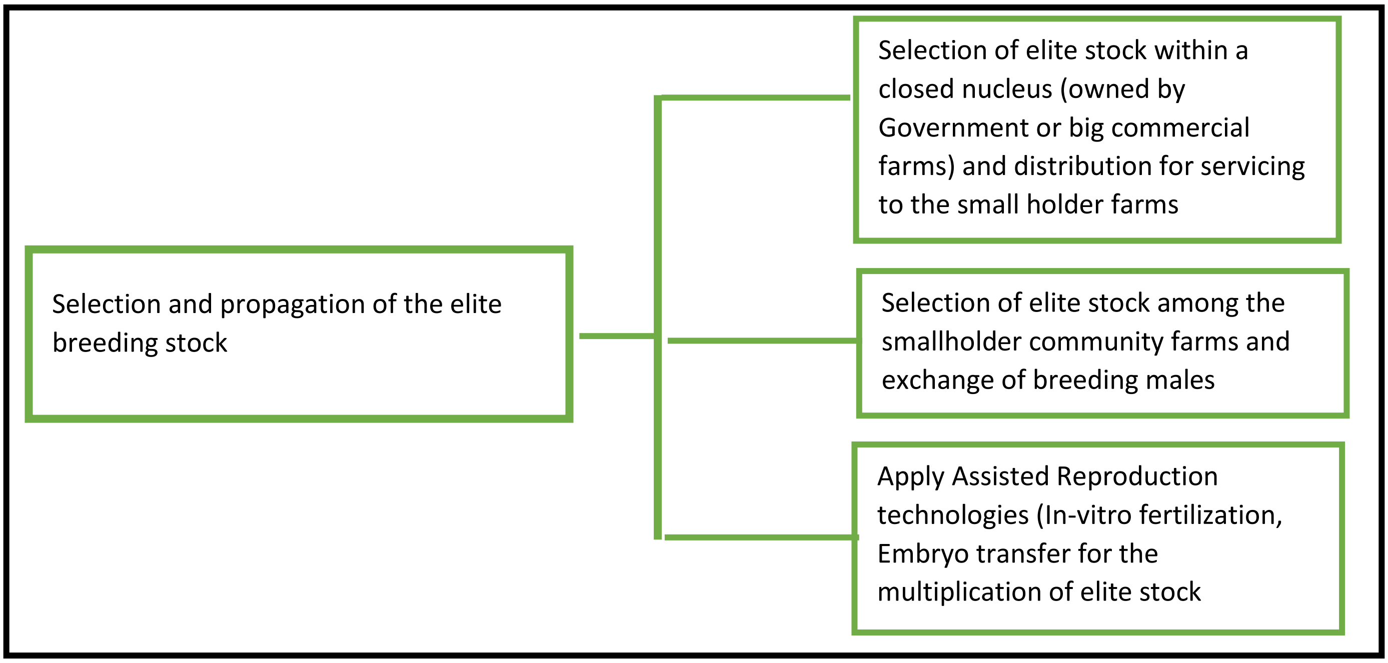
3.6. Step 6: Selection and Mating

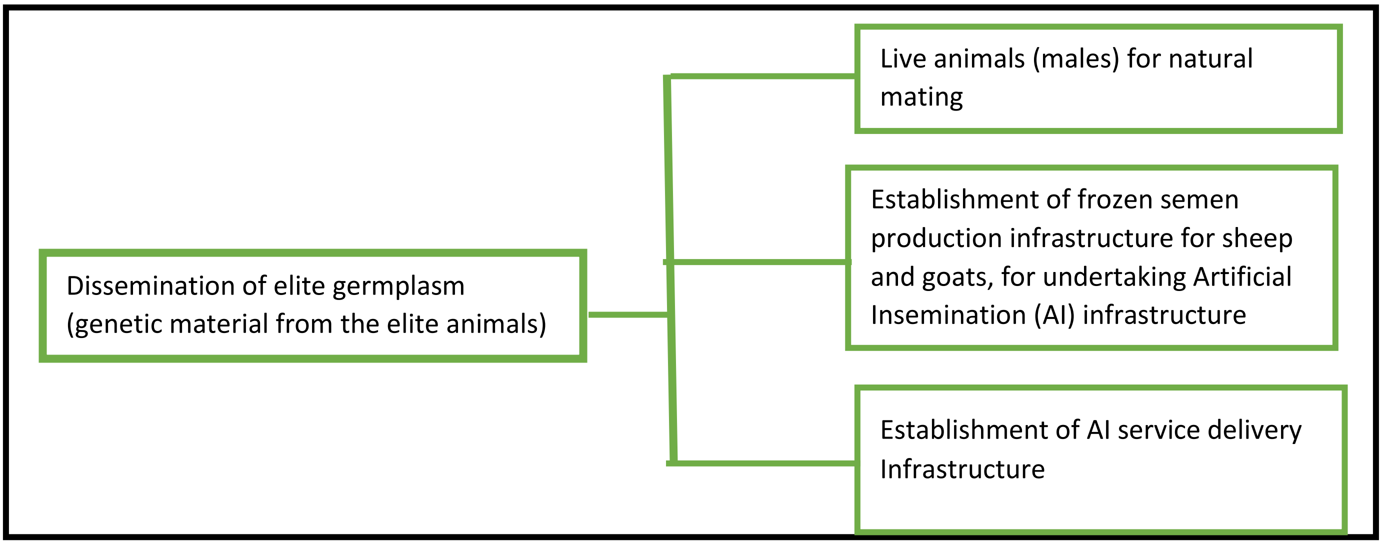
Once we derive the estimated breeding values (genetic merit of the animals, the actual selection of parents needs to take place. The parents with a higher-than-average estimated breeding value will improve the breeding goal traits in the next generation. For example, a ram having a higher breeding value (than the average of the population) for higher weigh gain or higher growth rate is expected to produce heavier lambs in the next generation. Proper selection of parents will give a positive selection response in the next generations. Selection creates progress in breeding goal traits. After the selection of the parents another choice has to be made: which ram should be mated to which ewe? This could be achieved using pedigree information or the breeding values of the traits desired for improvement in the population. This is termed as mating plan (sire and dam combinations)


Establish genetic / genomic evaluation system
Establish computational infrastructures for computing genomic breeding values
Select suitable officers of MoEWA to take up genetic genomic evaluation for the KSA
Train them on principles and practices and estimation methods
Collaborate with external experts
Undertake SNP microarray genotyping & data QC protocols
Find out appropriate statistical genetic model suited for KSA production system (continuous R &D)
Estimate genetic parameters from the collected trait data
Apply the statistical model for developing genomic prediction equation models & validate the prediction equation in the population
Compute genomic breeding value prediction models & validate the prediction equation in the population
Compute genomic breeding values
Define breeding value publication standards, time interval and publish the breeding values and index values periodically
Apply either the individual breeding value of individual traits for the selection of one trait or the index values for the selection of breeding stock on multiple traits

3.7.Step 7: Dissemination of elite germplasm

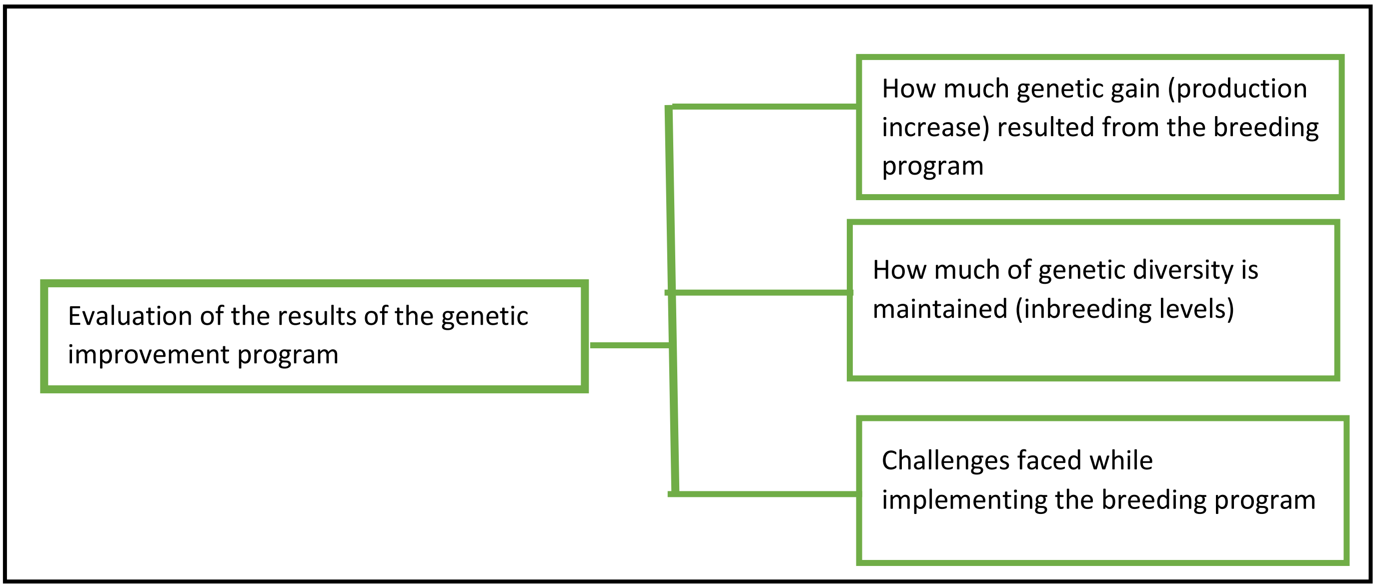
Once the selection and mating decisions are finalized, the next step is to decide how the selected germplasm will be disseminated. For example, top 20 rams from the recording and genetic evaluation systems are selected as top germplasm for propagation. How the selected elite rams will be distributed? – either as live animals to farmers or by establishing artificial insemination program to distribute the selected breeding stock to large number of breeding population of sheep and goats. For the KSA, the option could be to set up artificial insemination infrastructure (frozen semen production, semen and liquid nitrogen delivery mechanism, etc) that would aid selection of top germplasm of local breeds available in the country and disseminate them to large number of sheep and goat population. Production and distribution of large number of males for natural mating has limitations in terms of recording logistics, production and rearing costs, and transmission of diseases during natural servicing. Many countries adopted AI in goats very successfully, incorporating as an important tool in sheep and goat development.





3.8. Step 8: Evaluating the results of the breeding program

The final step in the whole process is to know whether we have achieved the desired results? And if not, what are the impediments? Besides looking at whether the new generation progenies are better than their parents, we also need to understand are there any unwanted effects? For example, we got a good response in weight gain in young progenies, but at the same time there is an increasing problem with the foot problem. In that case we need to revisit our breeding strategy and redefine our breeding goals. Another criterion requires to be evaluated is what has happened with the relatedness among the animals of the new generation. Are they more related to each other than their parents, due to the fact that we have selected only a few heavily related animals as parents for this generation? If so, there will be larger inbreeding effect in the population that might affect the fitness of the animals. In brief, achieving genetic improvement along with minimal levels of inbreeding are the two important aspects of any animal breeding program.



4. Infrastructure strengthening and capacity building

For the successful implementation of the genetic improvement program in small ruminants, establishing or strengthening the existing breeding centres should be considered having the following components

1. Satellite breeder farms (owned by the farmers) that serve as a source of elite male stock for breeding
2. Organization of Breeder Society for specific breeds or group of breeds
3. A nucleus farm to propagate the elite males for breeding in the farmer's flocks – application of advanced reproductive technologies like ovum pick up, in-vitro fertilization and embryo transfer could be adopted. Also making sure the breeding stock is free from any contagious diseases and known genetic disorders
4. Artificial insemination (AI) infrastructure – frozen semen production centre, artificial insemination service delivery system

5. Advanced computational system to handle large data (phenotype & genotype data), its storage, retrieval, genetic analysis and estimation of genomic breeding values – may be advisable to use the existing computational infrastructures available with universities (such as KAUST) for this purpose
6. Official performance recording system (for the collection of phenotype data and biological samples for genotyping)
7. Laboratory infrastructure to extract DNA, genotype and or sequence the animal DNA for genetic analysis and estimation of breeding values (use of existing facilities at KAUST could be considered)
8. Research & Development in the areas of (through International Collaboration)
    a. Designing of SNP microarrays or validating the existing SNP microarrays adapted for KSA sheep and goat population
    b. Molecular breed characterization and estimation of population parameters
    c. Estimation of genetic parameters for genetic analysis
    d. Deriving economic weights for traits under breeding objectives for multiple index-based selection of elite breeding stock
    e. Elucidating an appropriate statistical genetic model for genomic breeding value estimation
    f. Evaluation of the impacts of genetic improvement in the animal population
    g. Incorporation of other modern technologies such as "OMICS" technologies in the selection program
9. Building a dedicated team with qualified personnel and continuous capacity and building program for the team to undertake genomic evaluation and genetic improvement program for the small ruminant population of KSA.

5. Policies for implementing a systematic genetic improvement program

Enabling policies and framework need to be defined for the successful implementation of the breeding program, with consideration for the following aspects

1. Country level and regional level breeding policies for sheep and goat program with an emphasis on conservation of local breeds, and its utilization through appropriate genetic improvement platform, and at the same time maintain genetic diversity and control of inbreeding levels
2. Reinforcing policies to strengthen animal identification system
3. Standards and methods to operate genomic evaluation system in the country to select
4. Certification system for the selection of male breeding stock
5. Certification system for the artificial insemination system organizations
6. Bench mark standards in respect to farm level breeding (e.g. ram to ewe ratio, rotation of rams, outcrossing, etc.,)

6. Private sector engagement

KSA have a long history of stimulating private sector growth in many of the economic spheres of the country. The same logic could be applied to stimulate growth in the animal breeding sector. Some of the approaches could be: (a) breeding of elite males (b) artificial insemination - production of frozen semen and delivery system (c) field performance recording (d) data collection, sample collection and genotyping laboratory facilities and provision of such services

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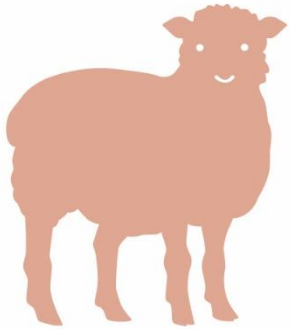

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