Breeding objectives and breeding strategies for small ruminants in the tropics

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Abstract

Small ruminants (i.e., sheep and goats) are widespread in the tropics and are important to the subsistence, economic and social livelihoods of a large human population in these areas. The aim of this thesis was to identify the breeding objectives for tropical small ruminants, and to develop appropriate breeding strategies for their improvement. The results indicated that breed substitution and crossbreeding programmes involving temperate breeds are rarely successful due to incompatibility of the genotypes with the farmers' breeding objectives and the production systems. Within-breed selection programmes utilizing indigenous breeds are likely to be more sustainable than breed substitution and crossbreeding. In addition, they help to maintain biodiversity. Indigenous genotypes were predominantly found among pastoral/extensive farmers and mixed crosses among smallholders. In general farmers perceived crosses less favourably than indigenous breeds for a range of traits. The effect was studied of including intangible benefits in the calculation of economic values of breeding goal traits. It resulted in increased values of traits related to longevity. Litter size and lambing frequency were more important traits in smallholder and pastoral production. 12-month live weight also featured prominently in pastoral production. Constraints to small ruminant productivity included low levels of management, disease and parasite challenge, inadequate feed and poor marketing. Nucleus breeding schemes are recommended to optimize the limited available resources. However, 'interactive cycling screening' schemes would be more practical under village settings as the farmers are actively involved in genetic improvement, and minimal recording is required in the commercial flocks. A single nucleus could serve both the smallholder and pastoral production. In conclusion, it is prudent to examine the production system holistically, and involve the producer at every stage in the planning and operation of a breeding programme, integrating traditional knowledge, practices, behaviour and values.

Dedicated to

Asaneth, Linda and Lornah

Dedicated to

my late paternal grandparents

Mr. Augustine Kipkosgey Moita and Mrs. Martha Kaptich Moek (iyooh)

and

maternal grandparents

Mr. Thomas Kimutai Yator (late) and Mrs. Rosa Chebande Yator

whose genes I cherish to share and for their common philosophy that ‘whoever strives to feed and respect humanity matters on this earth’

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Chapter 1

General introduction

1.1. Importance of small ruminants in the tropics

Small ruminants (i.e., sheep and goats) are widespread in the tropics and are important to the subsistence, economic and social livelihoods of a large human population in these areas. Small ruminants are especially important to women, children and the aged, who are often the most vulnerable members of the society in terms of under-nutrition and poverty. The agricultural potential in the tropics varies, and consequently, a wide array of livestock production systems with different production goals and priorities, management strategies and practices are found (Carles, 1983; Lebbie and Ramsay, 1999). The major ones are the smallholders, found mainly in medium- to high-potential areas, who practice mixed crop-livestock farming. The pastoral farmers are found mainly in the medium- to low-potential areas and rely on livestock as their main source of livelihood. Mixed crop-livestock farming systems are currently on the increase due to increased human population pressure on a finite land base (Winrock, 1992; Steinfeld et al., 1996). In these traditional production systems, small ruminants provide both tangible benefits (i.e., cash income from animal sales, meat for home consumption, manure, fibre and skins) and intangible benefits (e.g., savings, an insurance against emergencies, cultural and ceremonial purposes) (Gatenby, 1986; Rege, 1994; Jaitner et al., 2001). In addition, small ruminants complement other livestock in the utilization of available feed resources and provide one of the practical means of using vast areas of natural grassland in regions where crop production is impractical (Rege, 1994). Despite their importance, few studies have elaborated on sustainable improvement programmes for the small ruminants in the tropics. In addition, the relative importance of the tangible benefits and intangible benefits are poorly understood.

Most of the developing countries are found in the tropics (Balls, 2003). These countries are currently experiencing high increases in human population, dramatic urbanization, monetarization of economies and income change (Winrock, 1992; Peters, 1999). The dominant issues to address therefore relate to reducing under-nutrition, enhancing food security, combating rural poverty, and achieving rates and patterns of agricultural growth that would contribute to overall economic development and environmental protection (FAO, 1995; Pelant et al., 1999). For instance, in the developing world demand for meat and milk, up to the year 2020, is expected to increase dramatically by, respectively, 2.8% and 3.3% per year (Delgado et al., 1999). Contribution from sustainable increase in livestock production would therefore be desirable in order to meet the demands of the human population on livestock populations and their products. Studies on how to deliver genetic improvement for small ruminants utilizing indigenous breeds under traditional production circumstances in the tropics are therefore necessary.

Of the world's sheep and goat populations, about 28% and 52% are found in the developing countries of the tropics (FAO, 2003). Production from small ruminants in developing countries is increasing substantially (de Haan et al., 1996; Morand-Fehr and Boyazoglu, 1999). Sheep and goat numbers are growing fastest in the mixed farming system, and most rapidly in the humid/sub-humid areas (de Haan et al., 1996). Sheep are found mainly in areas of variable agro-climatic characteristics, and with large and extensively managed pasture lands. Goats by contrast, tend to be more concentrated in dry tropical areas of poor agricultural potential and even on marginal lands (Morand-Fehr and Boyazoglu, 1999). For example, on a worldwide basis, about 16% of all sheep and 26% of all goats are found in sub-Saharan Africa (FAO, 2003). Of these, about 57% of the sheep and 64% of the goats are found in the drier and fragile arid and semi-arid zones (Lebbie and Ramsay, 1999). However, few studies have been done to determine the factors influencing the farming of small ruminants under traditional smallholder and pastoral production circumstances.

Tropical areas are endowed with a wide variety of indigenous small ruminant breeds that have evolved to adapt to the prevailing harsh environmental conditions and traditional husbandry systems (Baker and Rege, 1994; Lebbie and Ramsay, 1999). However, low genetic potential among indigenous tropical small ruminants is often assumed and breeding plans to replace these breeds by exotic breeds, or to cross them with exotic germplasm are often implemented unsystematically (Kiwuwa, 1992; Baker and Gray, 2003). This constraints farmers in the sense that they are pushed by economic forces to adopt germplasm for short-term benefit without properly accounting for longer-term sustainability (Kiwuwa, 1992). Opportunities exist to improve productivity, adaptation and welfare of tropical small ruminant breeds through within-breed selection (Woolaston and Baker, 1996; Njoro, 2001; Ayalew et al., 2003; Baker and Gray, 2003). However, literature is scarce on technical as well as socio-economic aspects of pure-breeding schemes for tropical small ruminants.

In selecting the most desirable breed or breed combination and selecting within a breed, one needs to start with defining the breeding objective. The breeding objective includes all relevant characteristics of an animal (e.g., production, reproduction, fitness and health characteristics) and assigns a value to each trait. The economic importance of each trait depends largely on the production circumstances. For instance, in many subsistence tropical farming systems, survival in the face of multiple stress (e.g., heat, disease and poor nutrition) is one of the most important traits, while increasing growth is of relatively lower value (Upton, 1985). In more intense production systems, productivity may take a higher priority. An issue that has received little attention in the tropics is the development of relevant breeding objectives for smallholder and pastoral production circumstances. Breeding objectives would provide guidance for people involved in genetic improvement programmes.

Improvement in performance of small ruminant flocks or populations over time can arise through improvement in management and feeding conditions, and through genetic improvement by use of genetically superior animals (Singh and Acharya, 1981). Genetic improvement results in small but cumulative effects, making it a powerful way of increasing efficiency of animal production (Nakimbugwe et al., 2002). Ideally, the steps involved in the design and implementation of a breeding programme include (Croston and Pollot, 1985; Baker and Gray, 2003):

(i) A good understanding of the production systems and the relative importance of the different constraints in these systems.
(ii) Clear definition of the selected breeding objectives supported by farmers.
(iii) Accurate methods of identifying superior genotypes.
(iv) Practical schemes which allow the superior genetic material to be used advantageously.

The current study will contribute to alleviation of under-nutrition and poverty among the vulnerable smallholder and pastoral households in developing countries of the tropics through development of sustainable breeding strategies that improve productivity of small ruminant livestock.

1.2. Objectives of the study

The objectives of this thesis were: (1) to identify breeding objectives for tropical small ruminants, and (2) to develop appropriate small ruminant breeding strategies. Most of the research in this thesis can be termed as system analysis research in which statistical modelling played a significant role. The focus is on traditional smallholder and pastoral production systems in developing countries of the tropics. Mostly, production circumstances in Kenya were used as a working example, but the methodology and, where possible, the findings are generalized. Sheep was used to study derivation of economic values and breeding programmes but the methodology and application are generic to goats. The results of the study will contribute to better understanding of small ruminant production systems in the tropics. This will help in the definition of the appropriate breeding objectives and subsequently the design and implementation of sustainable breeding programmes. To achieve the goal of this study, the following research questions were addressed:

(i) What factors determine the success or failure of small ruminant breeding programmes in the tropics?

(ii) What factors influence the farming of small ruminants under smallholder and pastoral production circumstances in the tropics?

(iii) What are the breeding objectives for small ruminants under smallholder and pastoral production circumstances in the tropics?

(iv) What are the impacts of tangible and intangible benefits in the breeding objectives for small ruminants in the tropics?

(v) What are the advantages and disadvantages of alternative pure-breeding structures for small ruminants in the tropics, in a technical as well as socio-economic sense?

(vi) Is it necessary to have different selection schemes for smallholder and pastoral production circumstances in the tropics?

1.3. Outline of the thesis

Subsequent to **Chapter 1** that presents the general introduction, **Chapter 2** presents a review of the successes and failures of within-breed selection breeding programmes for small ruminants in the tropics. This chapter highlights important factors determining the fate of breeding programmes. **Chapter 3** gives the results from a field survey undertaken to determine factors influencing the successful farming of small ruminants in smallholder and pastoral/extensive production in the tropics, taking Kenya as an example. The two production systems were broadly studied to identify constraints and opportunities for small ruminant improvement. **Chapter 4** deals with derivation of economic values for traits of meat sheep in medium- to high-potential areas of the tropics. A deterministic model was developed and subsequently used to derive economic values for important traits of sheep. Only the tangible benefits - cash income from animal sales, meat for home consumption and manure - are considered in this chapter. **Chapter 5** shows the impact of tangible benefits - cash income from animal sales, meat for home consumption, manure and skins - and intangible benefits - savings and insurance - of small ruminants in the breeding objective for an indigenous tropical sheep breed under pastoral production circumstances. **Chapter 6** presents an analysis of alternative pure-breeding structures for sheep in smallholder and pastoral production circumstances in the tropics. The genetic gains and rates of inbreeding, as well as socio-economic influences of different breeding schemes were examined with the objective of recommending the most appropriate scheme for village situations. **Chapter 7** deals with multi-trait evaluation of nucleus pure-breeding schemes for sheep in smallholder and pastoral production circumstances in the tropics. This chapter shows the outcome of combining several traits in the selection index. Using stochastic simulation, productive, reproductive and survival traits were considered simultaneously. The main aim was to determine if it would be necessary to operate two different breeding programmes for smallholder and pastoral production circumstances. **Chapter 8** integrates all the previous results, and other relevant information into general considerations for breeding small ruminants under smallholder and pastoral production circumstances in the tropics.

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Chapter 2

Successes and failures of small ruminant breeding programmes in the tropics: A review

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Abstract

Despite the large numbers and importance of adapted indigenous sheep and goats in the tropics, information on sustainable conventional breeding programmes for them is scarce and often unavailable. This paper reviews within-breed selection strategies for indigenous small ruminants in the tropics, highlighting aspects determining their success or failure. The aim is to better understand opportunities for genetic improvement of small ruminants by the resource-poor farmers in traditional smallholder and pastoral farming systems. Dismal performance of programmes involving breed substitution of exotics for indigenous breeds and crossbreeding with temperate breeds have stimulated a recent re-orientation of breeding programmes in tropical countries to utilize indigenous breeds, and most programmes are incipient. The success rate of some breeding programmes involving native breeds is encouraging. Definition of comprehensive breeding objectives incorporating the specific, immediate and long-term social and economic circumstances of the target group as well as ecological constraints was found lacking in some projects which failed. To achieve success, it is necessary to look at the production system holistically, and involve the producer at every stage in the planning and operation of the breeding programme, integrating traditional behaviour and values. The most promising breeding strategy to improve and sustain the indigenous small ruminant population is probably to address the issue of risk aversion through management measures and sire exchange rather that setting selection criteria for output-oriented traits, which cannot be matched without additional external inputs.

(***Keywords**:* Small ruminants; Breeding programmes; Tropics; Review)

2.1. Introduction

Despite the large numbers and importance of adapted indigenous small ruminants (i.e., sheep and goats) in the tropics, information on sustainable breeding strategies for them is scarce and often unavailable. This paper reviews within-breed selection strategies (village, commercial and national) for indigenous small ruminants in the tropics, highlighting aspects contributing to their success or failure. The aim is to learn from them, and better understand opportunities for improvement of small ruminants by the resource-poor farmers in traditional smallholder and pastoral farming systems in the tropics. Information is derived from published papers, project reports and evaluations, and field visits. However, this review is by no means complete in light of the fact that finding enough small ruminant breeding programmes, utilizing native breeds, described in sufficient detail and evaluated over a long time in the tropics is often difficult. The focus is rather general, as most programmes encountered tended to be generic in protocol and approach. The criterion of evaluating success or failure is if the project achieved its short- or long-term objective. It is important to acknowledge that this criterion of success or failure could be contentious, considering there could be two points of view – that of the farmer and that of the scientist and/or policy maker. In addition, it is difficult to have clear-cut criteria due to diversity of farmers and production circumstances in the tropics. As a first step in this study, a background of the strategies for genetic improvement, and the role of small ruminants in the traditional farming systems in the tropics is necessary, without which it would be difficult to evaluate a breeding scheme.

2.2. Strategies for genetic improvement of tropical small ruminants

2.2.1. Improvement pathways

Conventionally three main pathways have been considered for the genetic improvement of livestock: (i) selection between breeds (or strains), (ii) crossbreeding, and (iii) selection within breeds (or strains). The reader is referred to Baker and Gray (2003) for a detailed discussion on the application of these strategies in the tropics. For any of these strategies to be effective it is important to have a clear view of what traits are important in small ruminants for the particular environment being considered (Carles, 1983; Sölkner et al., 1998). Consequently, it is logical to first choose the most appropriate breed or cross, and then to consider whether this breed, or the ‘parent’ breeds in the case of crossbred animals, can be improved further by within-breed selection. Selection between breeds (or strains) can achieve dramatic and rapid genetic change when there are large genetic differences between breeds (populations) in traits of importance (Simm et al., 1996). However, it is costly when you need to replace males as well as females, and not always feasible to replace whole flocks of animals. In practice, ‘grading up’ or repeated crossing to the new breed leads to more gradual changes. It often only involves the use of males and/or semen (where artificial insemination is feasible) of the new breed. In the tropics, breed substitution of exotics for the indigenous breeds and crossbreeding with breeds from temperate regions have been widely used, but have invariably been unsuccessful or unsustainable in the long-term. This is due to incompatibility of the genotypes with the breeding objectives and management approaches of the prevailing low-input traditional production systems in these areas (Rewe et al., 2002; Wollny et al., 2002; Ayalew et al., 2003). These breeding strategies are therefore not discussed further in the current study. Within-breed selection of the adapted indigenous genotypes could be a viable option. Special attributes of tropical indigenous small ruminant breeds have been described in a number of studies (see Table 2.1 for details).

Within-breed selection is a strategy of genetic improvement usually carried out in individual populations. Selection within breeds or strains is intended to increase the average level of genetic merit of the population. Objective within-breed selection usually involves measuring and selecting on productivity (e.g., litter size, growth of the young and mature size). However, effective small ruminant breeding methods in smallholder production systems in the tropics are constrained by small animal populations, single sire flocks, lack of systematic animal identification, inadequate animal performance and pedigree recording, low levels of literacy and organizational shortcomings (Turner, 1977; Kiwuwa, 1992; Jaitner et al., 2001; Wollny et al., 2002). In addition to the factors constraining successful small ruminant breeding strategies in smallholder production systems, apart from small animal

Table 2.1. Some of the indigenous tropical sheep and goat breeds and their special attributes[a]

Breed	Region/country	Attribute	Reference
Sheep			
Blackbelly	Mexico/Caribbean	prolific (multiple births) productive	Segura et al. (1996) Baker et al. (1994)
Blackhead Persian	East Africa	relatively trypanotolerant heat tolerant	Baker (1995)
Criollo	Andean (Central America)	seasonal breeding	Iñiguez (1998)
Djallonké	West Africa (humid and sub-humid areas)	trypanotolerant	Yapi-Gnoaré (2000)
D'man	Morocco	fertility	Turner (1978)
Martinik hair sheep (mix of Caribbean breeds)	Caribbean (French West Indies)	use of tropical pastures resistant to gastro-intestinal parasites prolificacy and deseasonality	Naves et al. (2000)
Priangian and the Java Fat-tail wool	Java, Indonesia	fertility	Turner (1978)
Red Maasai	East Africa (humid and sub-humid areas)	resistant to gastro-intestinal parasites relatively trypanotolerant	Baker et al. (1999) Baker (1995)
St. Croix	Caribbean	resistant to gastro-intestinal parasites	Baker (1995)

Table 2.1. (*continued*)

Breed	Region/country	Attribute	Reference
Goats			
Galla	Kenya/East Africa	relatively trypanotolerant	Baker et al. (1994)
Garole	Rajasthan, India	adapted to hot humid conditions resistant to gastro-intestinal parasites	Nimbkar et al. (2002)
Creole	Guadeloupe	heartwater (cowdriosis) resistant	Matheron et al. (1987)
Mubende	Uganda	high quality skin	Wilson (1984)
Nubian	The Sudan	high milk yield	Wilson (1984)
Red Sokoto (Chevre Rousse de Maradi)	Sahel (Morocco)	high quality skin	Wilson (1984)
Small East African	Kenya/East Africa	resistant to gastro-intestinal parasites relatively trypanotolerant	Baker et al. (1998) Baker et al. (1994)
West African Dwarf goat	Ghana/West Africa	resistant to gastro-intestinal parasites trypanotolerant prolific (≈185.6%); good kidding interval	Osinowo and Abubakar (1988); Osaer et al. (1994); Tuah et al. (1992); Baker (1995)

[a]More information on indigenous tropical small ruminant breeds can be found on the websites: Domestic Animal Diversity Information System (DAD-IS) (http://dadis.fao.org/index.html) and Domestic Animal Genetic Resources Information System (DAGRIS) (http://dagris.ilri.cgiar.org/dagris/)

populations and probably single sire flocks, pastoral flocks face a problem of mobility. The infrastructure necessary for collection of reliable pedigree and performance data does not exist to set up a breeding programme involving the populations maintained by the mobile pastoral communities (Franklin, 1986; Kiwuwa, 1992).

Traits that represent a comprehensive breeding goal are mostly complex with components of production and reproduction, e.g., number or weight of offspring per year (Sölkner et al., 1998). Recording of such traits and individual animal identification is in many cases difficult under traditional smallholder and pastoral conditions. The difficulty to measure and value the intangible benefits (e.g., savings, insurance, ceremonial and prestige) derived from the animals presents more complications (Roeleveld, 1996). Strategies for genetic improvement that overcome these problems need to be considered. In this regard, nucleus schemes have been proposed as a good strategy for genetic improvement of small ruminants in developing countries (Turner, 1982; Hodges, 1990; Jasiorowski, 1990; Kiwuwa, 1992). These are discussed in the following section.

2.2.2. Breeding programmes

Two activities need to be distinguished in breeding programmes (van Arendonk and Bijma, 2003). The first is the generation of genetic improvement by selecting animals based on their estimated breeding value for the relevant traits. Secondly, there is dissemination of the improved animals to the commercial population. In large-scale small ruminant production, for instance in Australia or New Zealand, there could be millions of animals in the population. It is not worth or practical including them all in the active part of the breeding programme due to measurement costs, recording costs and lack of proper control (Kinghorn, 2000). Whereas flocks are not that large in developing countries in the tropics, resources are scarce and it is critical to optimize the little that is available. This is possible if the genetic improvement is generated in a small fraction of the population (referred to as the nucleus), while at the same time controlling the pedigree (i.e., inbreeding). All trait recording and genetic evaluation is done in the nucleus. Recording is not needed for the remainder of the population. The genetic progress is disseminated to the commercial population through use of males and/or semen (where artificial insemination is feasible) originating from the nucleus.

Basically, a nucleus breeding unit would require the pooling of superior animals with the highest genetic merit from many sources to form the foundation animals. Depending on the complexity and requirements of the breeding programme, a nucleus scheme can have different numbers of tiers and migration policies. Van der Werf (2000) has summarized the roles of the different tiers in a livestock breeding structure. Generally, the central nucleus and multiplier flocks generate sires for distribution to commercial farmers. A crucial point for the successful implementation of a breeding scheme in smallholder and pastoral production circumstances is adequate interaction between nucleus and farmers' flocks, in a technical as well as socio-economic sense. It is always important to bear in mind that nucleus breeding objectives impact on the whole scheme. The nucleus should therefore be set up with the breeding objectives of the farmer in mind. The nucleus could be open or closed. In a closed nucleus there is no upward migration of animals from the lower tiers to the nucleus, and all recording is confined to the nucleus. On the other hand, an open nucleus allows animals of high merit to be migrated up for breeding in the nucleus. Open nucleus breeding schemes have been recommended for small ruminants in the tropics (Jasiorowski, 1990). An open nucleus breeding scheme, from a genetic point of view is more interesting because it affords selection in a larger population, but this has consequences for infrastructure and costs because naturally it would involve some pedigree or performance recording in the lower tiers.

Small ruminant breeding programmes found in the tropics differ in design. Some are three-tiered with a nucleus, pre-nucleus (multiplier) and a base population (e.g., ITC, 2003) while others are two-tiered, involving only a central performance evaluation station (nucleus) and farmer flocks (base) (e.g., Yapi-Gnoaré et al., 1997). Some do not operate a nucleus at all (e.g., FAO, 1988). Certain programmes select only males (e.g., Yapi-Gnoaré, 2000) while others select both sexes (e.g., Darfaoui, 2000). It is apparent that the design of the breeding program will depend on the ecological region and on the production system the breeding programme is aimed at (van der Waaij, 2001).

The design of the breeding scheme has an impact on the anticipated results. For instance, selection of both male and female animals in an open nucleus would generate more genetic progress than selection of males alone. If lower tiers buy average males (and no females) from the tier above, they will lag behind the tier above by 2 generations (about 7 years in sheep and goats) of selection response (Bichard, 1971). Opening the nucleus pushes it to progress more quickly, and this benefits the whole scheme as the base will move as fast as the nucleus when the nucleus runs smoothly (Kinghorn, 2000). Overall response in open 2-tier schemes is 10-15% faster than in closed schemes when optimal design, from the genetic point of view and not necessarily cost, is applied, i.e., about 10% of the population in the nucleus and about 50% of the nucleus mated females born in the base (James, 1977). An open nucleus in the form of geographically diffused flocks could be used. It involves creating elite ‘nucleus’ matings in the flocks of birth of the female partners, with migration of males and/or semen to these flocks (Kinghorn, 2000). This relies on good pedigree information, and may not be easy to effect in traditional animal production systems.

The dilemma in genetic improvement programmes in developing countries in the tropics is how to effectively organize breeding schemes involving farmers at the village level, how to record such flocks and to monitor progress (Osinowo and Abubakar, 1988). To involve farmers, it is advisable to back the breeding programme with an effective extension service for maximum effect. The selection programme should be preceded with several years of extension work to train the farmers and boost their experiences and skills in small ruminant production techniques (Yapi-Gnoaré, 2000). During that period farmers should be made aware of the benefits derived from the recording activity (Moioli et al., 2002). Another possible problem with breeding programmes in developing countries is the frequently long and complicated bureaucracy involved in the distribution of improved animals from the nucleus to co-operating farmers. The procedure is often subject to abuse by those in authority or those with powerful connections. A fair system of distributing animals, for instance on a ‘first-come-first-served’ basis, needs to be agreed upon and made policy. Where facilities and resources allow, institutional nucleus farms could be expanded to generate more breeding stock to meet the demands of the commercial farmers. A point to note is that unless due consideration is made, selection of animals under institutional management is not likely to reflect the management conditions of commercial farms, resulting in genotype by environment interactions and wastage of selection opportunities due to ill-adapted animals to the local low-input conditions. Assuming the breeding programme is successfully launched, immediate returns to the farmer would likely emanate from non-genetic factors as the programme picks ups. These are discussed in the following section of this paper.

2.3. Non-genetic gains from breeding programmes

The motivation for rearing small ruminants and their functions are geared to natural and economic conditions and thus correspond to the requirements of the farmer (Peters, 1988), which in most cases are livelihood oriented. The breeding programme in principle must have expected outputs consistent with the producer’s objectives and would be driven by incentives (i.e., expected returns from the producers) to justify the producer’s investments – e.g., their and their family’s labour, hired labour and other costs, including the difficulties of controlled breeding required of the programme.

Much as within-breed genetic improvement can enhance output and profitability at all levels of production, from smallholder to large livestock enterprises (Holst, 1999), results in the traditional low-input management systems of the tropics may seem too long-term to be felt (Gatenby, 1986; Ponzoni, 1992). It seems therefore that the immediate to medium-term returns or perceived returns on investments in improvement programmes, will likely result from non-genetic gains, i.e., improved husbandry practices, and conflict resolution in terms of farmer’s expectations and involvement in the breeding programme (van Vlaenderen, 1985; Wollny et al., 2002; Ayalew et al., 2003). Consequently, any improvement of small ruminants through breeding would have to take into account other intervening factors likely to interfere with any progress made (Mwendia, 1997). There would be little value in implementing a carefully designed breeding programme if managerial, nutritional and animal health aspects are not being attended to in a manner which is considered satisfactory to the environment in question (Ponzoni, 1992). For example, manipulation of the management system could easily result in improved reproductive performance for indigenous type of small ruminants as long as their current productivity and functions are well understood. Generally, knowledge of the production objectives of the traditional small ruminant systems and how these may impact upon genetic improvement programmes would be necessary when deciding breeding programmes to adopt. These are discussed within their major types in the following section of this paper.

2.4. The role of small ruminants in traditional farming systems

2.4.1. Crop-livestock (agro-pastoral) production systems

Crop-livestock mixed farming systems comprise sedentary smallholder farmers carrying out mixed crop and livestock farming concurrently as the main activity. The mixed farming systems of the developing world contain about 64 percent of the small ruminants of the world (de Haan et al., 1996). These farming systems are a predominant feature and continue to develop with human population pressure increasing further (Steinfeld et al., 1996). Sheep and goat numbers are growing fastest in the mixed farming system, and most rapidly in the humid/sub-humid areas, underlining how human population pressure is reducing farm size and access to and use of resources (de Haan et al., 1996). In the tropics, the crop-livestock mixed farmers are found mainly in the medium- to high-potential areas (Rege, 1994) and they own small sizes of land. The animals are confined to small areas for grazing or left to wander freely around villages scavenging for feed (Gatenby, 1986). In some cases stall-feeding, where grass is cut and carried to the animals is practised. Smallholder farming is livelihood oriented. Unlike commercial farmers, smallholders tend to keep animals for family needs, rather than purely as an economic enterprise. Animals have intangible roles to the farmer (e.g., savings, insurance, cultural, ceremonial and prestige) and farmers expect their animals to fulfil these traditional functions (Peters et al., 1981; Wilson, 1985; Agishi, 1988; Peters, 1988; Ayalew et al., 2003). Survival of animals in the face of multiple stresses (heat, parasites and disease, and poor nutrition) is one of the most important traits, while increasing growth rate is of less value (Upton, 1985; Sölkner et al., 1998). Therefore, adaptability traits such as survival rates and reproductive performances become important (Franklin, 1986; Osinowo and Abubakar, 1988; Ponzoni, 1992). It is important to note that matings within smallholder flocks are largely uncontrolled and organized mating would naturally demand more labour, which is a serious problem at the time of land preparation for sowing or harvesting of crops (Gatenby, 1986). In addition, farmers may be keeping a mixture of breeds and would be difficult to sort out animals for pure-breeding.

2.4.2. Pastoral production systems

Pastoral farming systems are found mainly in the medium- to low-potential areas where crop production is difficult due to low rainfall and high evapo-transpiration. In these systems, livestock forms an integral part of the socio-cultural life of the people. Pastoral farmers rely on livestock as their main source of livelihood, and usually own relatively large numbers of animals under extensive or communal grazing and management. Most of the livelihood is directly from livestock use and sales or exchange (Adu and Lakpini, 1988). Pastoral communities often herd cattle, camels, donkeys, sheep and goats together. Only a few herd or raise sheep and/or goats exclusively (Adu and Lakpini, 1988; Peters, 1988). The mixed species approach is to ensure complementarity in forage use and direct benefit to the household in terms of tangible and intangible requirements (Adu and Lakpini, 1988). The animals therefore need to fit in the production system. Nomadic life, overgrazing and low productivity are common features of pastoral systems, especially in the arid areas. In recent times pastoral communities, especially in the medium potential areas, have changed a lot and are now tending towards sedentarized agro-pastoral systems compared to previously when they purely kept livestock. Encroachment of crop farmers from other communities, and adoption of crop-based foods by the pastoral communities, are now evident in some areas of the tropics.

Risk avoidance is an important integral part of breeding objectives in marginal areas (Jahnke, 1982; Sölkner et al., 1998). Due to the fluctuating harsh environment, both individual and flock survival are important. The farmers adopt a two-pronged approach. First, in addition to stock diversification, pastoral communities use mobility to counter problems of uncertainty in the timing and distribution of rainfall and hence availability of forages, water shortage and incidence of diseases (Adu and Lakpini, 1988). Secondly, farmers use adapted breeds that survive and thrive in the environment (Mason and Buvanendran, 1982). Therefore, survival (e.g., pre-weaning, post-weaning and adult animal) traits and reproductive traits (e.g., litter size and lambing frequency) are important under this system. Many of the pastoral communities have their own breeding methods (Carles, 1983; Gatenby, 1986) and they have different sets of cultural and social values by which to judge, appraise and decide on animals used to breed (Sölkner et al., 1998). For instance, in a study of nomads in northern Somalia it was observed that the breeding ram or buck has to posses specific qualities (Mirreh, 1978 cited by Sölkner et al., 1998): mostly female offspring, be well built, strong, a good fighter able to assert himself in the flock and its offspring should be healthy, able to withstand the dry period and have a good record of milk production.

2.5. Genetic improvement programmes

This section highlights key points of success or failure of within-breed genetic improvement strategies for indigenous small ruminants in the tropics. The criterion is if the improvement project achieved its objective. As indicated earlier, it is important to concede that this criterion of success or failure could be contentious, considering there could be two points of view – that of the farmer and that of the scientist and/or policy maker. Most genetic improvement programmes encountered tended to be generic in protocol and approach and therefore this study will not attempt to examine each and every programme in the tropics. The breeding schemes are divided into those based on a nucleus and without a nucleus. However, examples of the latter could not be found for breeding programmes that failed.

2.5.1. Successes of programmes

2.5.1.1. Nucleus-based breeding schemes

In response to declined animal imports from within the region due to drought, a national sheep selection programme was initiated in Ivory Coast in 1983 with the aim of improving growth and live weight of the local Djallonké sheep breed (Oya, 1992; Yapi et al., 1994; Yapi-Gnoaré et al., 1997; Yapi-Gnoaré, 2000). Only males were selected under a 2-tier open nucleus-breeding scheme. Involvement of experienced farmers and availability of technical support ensured the success of the project. However, no justification is given for selection of the traits or the definition of the breeding objective - improvement of growth and live weight of the local breed, while reproduction and adaptation are neglected (Sölkner et al., 1998).

A nucleus breeding scheme involving the indigenous locally adapted Deccani sheep was initiated in the semi-arid Deccan plateau in Maharashtra, India in 1993, although breeding of animals started in 1996 (Nimbkar et al., 2002). The aim is to get a sheep with a modest to manageable prolificacy and an optimum body size for meat production in the local environment, as well as being worm-resistant. The first step is introgression of the fecundity (*FecB*) gene into the Deccani breed from the Garole breed. Following successful establishment of a direct DNA test for the *FecB* gene (Wilson et al., 2001), there is now selection of those individuals with the gene and backcrossing them to the Deccani to reduce the proportion of the Garole genes further. Garole is native to a hot humid region and is not well adapted to semi-arid Deccan plateua, has a small size, poor milk yield (Nimbkar et al., 2002) and is susceptible to infections such as pneumonia (Nimbkar – Personal Communication).

The programme is still at the nascent stage and it is difficult to clearly state its fate at the moment, because the resulting genotypes are yet to be assessed for their suitability to the local production system. However, given the approach - the direct involvement of researchers with the local shepherd community, use of indigenous genetic resources, and no provision of free incentives – the programme has potential for success (Iñiguez, 1998). Setbacks in the programme include diseases resulting in lamb mortality and abortions, shortage of manpower, and inadequate feed for the animals. Other within-breed selection programmes in India involving important indigenous sheep breeds - Malpura, Sonadi, Muzzaffarnagari, Mandras Red, Mandya and Nellore are purportedly successful (Arora et al., 2002). Rams of these breeds are reportedly available for enhancing mutton production in farmers' flocks.

A very active Martinik hair sheep programme was initiated in the French West Indies in the early 1990's (Naves et al., 2000). Various indigenous hair sheep breeds from the Caribbean and mixed Martinican farms were grouped to form a population of Martinik hair sheep. The breeding goal was defined from a technical approach, according to the commercial objectives of the breeders: to improve the nursing ability of the dams, and growth and body conformation of the lambs. The aim was to sustain adaptation to the tropical climate – use of pastures, resistance to worms; and good reproductive characters – prolificacy and deseasonality. On-farm performance recording and selection of rams in a breeding station started since 1995 with the same criteria applied: number of lambings per year, litter size, viability of the lambs, live weight of the litter at 30 days of age, individual growth rate at 30 and 70 days, estimated live weight at 70 days and visual assessment of body conformation. Separate indexes are used for ewes on litter size and nursing ability. Dissemination of selected animals is organized by the breeding association and consists of young rams from the station and ewes from the elite farms. The selection base remains open, in order to include new farms and new breeding animals in the population under selection. The backbone of the success of this programme was the existence of a strong professional structure (breeder's association) for the maintenance and management of the sheep, active technical extension services, and initial funding from European structural funds. In Guadeloupe, the main difficulties in setting up the programmes were the absence of professional structures and lack of public financial support to initiate the operations.

A breeding programme involving the indigenous Damara sheep breed was started in Namibia in 1954 (von Wielligh, 2001). The initial stock, kept at Omatjenne Research Station near Otjwarongo, was founded from many animals confiscated by the then German colonial government from commercial farmers illegally grazing on restricted disease-free areas. The breed is adapted to arid and semi-arid conditions (< 500 mm of rainfall annually). It is resistant to most diseases, tolerant to internal parasites, has good feed conversion efficiency and a varied diet (grass, bushes and shrubs). The breed has been selected for mutton under bushveld savana area without losing its main characteristics and adaptive traits. It has shown significant increases in fertility and growth rates. For instance, from 1956 to 2000, the average weaning mass at 100 days increased from 22.8 to 24.6 kg and 24.0 to 28.5 kg, for ewe and ram lambs, respectively. The breed has gained immense popularity with the commercial farmers, and is even being exported from South Africa to other African countries, and its embryos to Australia. A breeder's association has been instrumental in popularizing the breed by dissemination of valuable information on the breed to commercial farmers through breeding journals and information profiles, extension officers, meetings and courses.

A breeding programme for improving the trypanotolerant Djallonké sheep and the West African Dwarf goat for low-input management systems was started at the International Trypanotolerance Centre (ITC) in The Gambia in 1994 (Dempfle and Jaitner, 2000). The programme aims at increasing the efficiency for meat production in combination with the improvement of the trypanotolerance trait for the two breeds. Currently, the scheme operates at a capacity of 200 breeding females and six breeding males for each species. The breeding goals were established through participatory rural appraisal with the farmers (Bennison et al., 1997). Performance testing, data and pedigree recording have been implemented and breeding value estimations based on growth traits have been developed and are now used for selection. Establishment of multiplication tiers started since 2000 in close collaboration with the government's Department of Livestock Services (DLS) (ITC, 2003). The programme operates as an open nucleus, with ITC providing technical assistance to participating farmers, through DLS, on flock management and recording. No other incentives are offered. Farmers enter into a contract with ITC to use males from the nucleus provided that they eliminate all other males in the flock. The selected commercial flocks have males screened annually for breeding in the nucleus. The programme is young and still has to rely on donor support, although the objective is to see it taken over by the government, and eventually by the farmers. It is difficult to clearly state its fate at the moment (N'Guetta Bosso – Personal Communication). However, given the approach – farmers' involvement, choice of local breeds, selection under low-input conditions, and no free incentives to the farmers (Iñiguez, 1998) - the programme has potential for success.

2.5.1.2. Schemes without nucleus

In northern Togo, an FAO/Togolese government funded sheep husbandry development project started in 1980 and involved individual and groups of men, appeared to have faired on well (van Vlaenderen, 1985; FAO, 1988). The project aimed to tackle a wide range of major aspects that constrained village-based sheep production. A key element in the success of the project was the development/extension strategy followed which not only emphasized simple technologies and easy to understand training methods but also focused on needs of specific target groups. Women's groups played a big part in the focus and success of the project (FAO, 1988). In terms of breeding, the project bought the best male lambs sired by the selected rams from the flocks in the project to avoid unintentional selection for low growth rate due to the tendency to first slaughter or sell the fastest growing male lambs. The groups were encouraged to sell their best three-month-old lambs to the project by a favourable selling price and by including this sale as an obligatory part of the ram contract. All other males in the flock had to be castrated at the age of 3 months. The selected male lambs were kept by the project until they were distributed at the age of almost 18 months to flocks distant from their flocks of origin to avoid inbreeding. To improve immediate profitability of new groups, the project, on contract, lend young ewes to them, to be paid back by the same number of young ewes (6-12 months old and ≥18 kg) within a period of 4 years, starting after one year.

An on-going sheep and goats project in south and south-east Asia using an integrated approach to the control of gastro-intestinal parasites with the aim of reducing mortality in young goats is purportedly successful (TAGAR, 2002). The underlying principles and approaches of the project is that each country develops its activities in the most appropriate way, following a pathway that meets the local needs and conditions. A basket of technology options are introduced to the farmers revolving around worm control but holistic enough to include all aspects of goat production and health. Aware of their needs, farmers chose not just one technology but mixed and matched options to fit their situations. Some have also been very keen in revising some recommendations to better fit the conditions and situations in the field, and the project has implemented some of these. The breeding component has benefited well. For instance, in Vietnam good bucks of the adapted native goat breed (Bach Thao) were provided to farmers to improve breeding in the focus farms. Farmers were informed on the negative effects of inbreeding and introduced to animal management and controlled breeding. For improving management, farmers needed to build houses. Farmers were sponsored 30% of the total value of the buck while very poor farmers were supplied with 100%. After two years bucks were transferred to other farms. All male kids 5-months onwards were managed and grazed in separate areas. After two years the results of using the improved goat breed showed increased production in general (e.g., reduced mortality and increased growth rate). Farmers paid more attention to this option after seeing the results. It has shown a good impact on production in rural farms (TAGAR, 2002). However, there is no data at the moment to discriminate between contribution of genetic improvement and non-genetic factors (Douglas Gray – Personal Communication).

2.5.2. Failures of programmes

2.5.2.1. Nucleus-based breeding schemes

A breeding and improvement programme for the D’man sheep breed in Morocco was started in the late 1970’s, based on an open nucleus scheme with the aim of conserving the breed, which was threatened by droughts and mismanagement, and to evaluate its performance under improved management (Darfaoui, 2000). Selection programmes initiated were intended to maintain ewes’ prolificacy rate at high levels and increase lamb growth rate to the level of the remaining national breeds. In the design of the programme, the development agency ignored the non-organized farmers (≈90% of the total farmers) and therefore the farmers benefited very little from animals produced by the multipliers. Most breeding animals ended up in slaughterhouses or as sacrifices during religious or other ceremonies instead of improving non-organised farmers’ flocks. Lack of continual monitoring to determine the proportion of animals maintained in the multiplier level or disseminated to the non-organized farmers hindered the progress of the scheme. In addition, it is debatable if selection for high prolificacy was desired in an environment prone to droughts.

In Senegal a programme was initiated to increase the productivity of the local Sahelian breeds (Peul, Touabire) and the trypanotolerant Djallonké sheep in the semi-arid and sub-humid areas, so as to increase meat supply, and subsequently reduce imports of sheep from neighbouring countries to celebrate religious ceremonies (i.e., Hedoul Adkha) (Fall, 2000). Initially a nucleus flock was reared on a state-owned research station but later extended to village flocks to expand the selection base of Peul sheep. A top-down approach was used to establish breeding goals, i.e., breeding goals were set by government technicians through interpretation of national objectives to increase meat supply. Due to insufficient involvement of farmers, opinion on constraints imposed by the livestock production system were not taken into account. Consequently, involvement of village flocks was not sustained.

Shortage of financial and logistic resources contributed more to the unsustainability of the project.

2.6. General discussion

In the current study, the published results on within-breed breeding programmes for indigenous stock was summarized. The number of publications was smaller than anticipated. This could be because utilization of indigenous tropical breeds is a recent awakening whistle, and most breeding programmes are incipient with little to report if any (Iñiguez, 1998). It is therefore not surprising that most reports just stop at the need to focus on the use of indigenous breeds. It is also possible that some genetic improvement programmes may be developing successfully in isolation but are not reported. In addition, those that are not successful are seldom publicised except in grey literature (Bremer, 1995; Mill, 1995), and then usually attributed to various aspects of underdevelopment (Ayalew et al., 2003). However, there is a lot to learn from the relatively few programmes reported in this study. Varying degrees of success have been achieved in strategies to genetically improve indigenous small ruminants present in the tropics. The aspects determining their success or failure, and other pertinent issues are discussed under the following headings.

2.6.1. Meeting the needs of local farmers

The success of most improvement programmes is generally not determined by their inherent structure, but by their compatibility with the breeding objective of the farming system and the involvement of farmers. Arguably, the role of small ruminants in the livelihood of the people has not always been properly understood or appreciated. One fact sticking out in the current study is that some breeding programmes which failed were designed by scientists and implemented by development agencies without taking into consideration all the needs of the farmers and the long-term impact of their actions. Consequently, programmes have been introduced that producers find unsuitable - unprofitable, too risky, too labour intensive, or impossible to implement. It was observed that definition of comprehensive breeding objectives incorporating the specific, immediate and long-term social and economic circumstances of the target group as well as ecological constraints was found lacking in most projects. The breeding objectives are in most cases too narrow, e.g., improvement of growth or increasing prolificacy.

Many factors militate against adoption of agricultural innovations and the farmer's support for an improvement project is unequivocal for its success. A study in Kenya by Batz et al. (1999) identified relatively complex, relatively risky and relatively costly new dairy cattle technologies to have a negative influence on their adoption by, and diffusion among resource-poor smallholder farmers. Small ruminant technologies would be no exception to these influences (Gatenby, 1986). The fact that those farmers were poorly educated and faced shortage of labour made them more hesitant to adopt new technologies (Batz et al., 1999). Farmers need to be aversive to risk and consequently they prefer to adopt new technologies that reduced risk relative to the traditional technologies. Any increased risk through less adapted animals would place the survival of the household members at risk (Wollny et al., 2002).

Small ruminant interventions with increased input costs by smallholder or pastoral farmers are rarely adopted (Makokha, 2002). As seen in the current study, improvement programmes that were seen to be successful were those that were simple, pragmatic and run at low cost. In addition, where somebody else was meeting the cost, like in the case of free incentives being given by the development agency, farmers readily adopted the technology (Bosman et al., 1996). Most farmers would abandon the programme when the incentives are stopped unless the programme resulted in a clear benefit to them. In a goat project in Nigeria, there was wide adoption of animal health techniques, partly because they were offered free of charge (Bosman et al., 1996). However, the farmers provided labour to bring and treat the animals and co-operated in data collection. In that study, adoption of management – housing, feeding and breeding did not show any of the innovations to be unsuitable, but rather showed a highly variable reaction, with a lower interest in the management innovations in those villages with the lowest pressure on the free-roaming management system. Ironically, housing animals was seen in some places to be providing an easy target for theft, and goats were let out during the night to curb the problem. To reduce the ‘free syndrome’ farmers should be encouraged to participate and own the programme right from the start. Incentives could be given only to promote initial use of the breeding programmes, and then make a gradual transition when the programme is successful. FAO (1988) suggested provision of loans so that the farmers get some financial benefit within a short time. In the past, a large number of projects have over-relied on donor support. Once the donor support is phased out the programme lacks the necessary funds to sustain it and either run inefficiently or totally collapses.

An issue to reckon with is that to establish an efficient breeding programme directly at village level seems to be extremely difficult, especially with respect to performance data as well as pedigree recording, and ensuring planned mating (Jaitner et al., 2001). The example of south and south-east Asia described earlier demonstrates a convincing, simpler and cheaper way of delivering an innovation. If farmers in developing countries in the tropics were organized, strategies could easily be put in place to have carefully planned simple and relatively cheap village breeding schemes. For instance, ‘ram/buck rotation schemes’ could be introduced without much difficulty, and at low cost. The key issue is to tackle socio-economic barriers – e.g., illiteracy, inadequate funds and poor infrastructure - that impact negatively on breeding programmes. Innovative commercial farmers could provide a good entry point for launching breeding programmes.

The breeding programme should be compatible with the socio-cultural aspects of the producer. For instance, in addition to the tangible benefits (e.g., cash from animal sales, meat for home consumption, milk and manure) small ruminants are kept for a variety of intangible benefits (e.g., savings, insurance and ceremonies). The breed involved should be able to fulfil these traditional roles of the farmer as well as productivity, i.e., is acceptable to the farmer and adaptable to production circumstances. Therefore, involvement of the farmers at any stage in the design and operation of the scheme would be imperative. A participatory rural appraisal would be essential to get an understanding of the farming system and a benchmark of what important traits are. Other stakeholders – large-scale commercial farmers, government and development agencies - should be fully involved in the exercise and their ideas incorporated in the breeding programme. Resolving conflict of interest between the stakeholders would then be paramount.

2.6.2. Infrastructure

2.6.2.1. Market incentive

Appropriate economic incentives are necessary drives for genetic improvement (Seleka, 2001). The small ruminant market in the tropics is heterogeneous – e.g., meat, milk, manure, and specific animals to slaughter for ceremonies and/or sacrifices. The diversity of the market may require a multi-purpose animal or lead to diversity in breeding goals. Marketing problems in the tropics can be classified into three categories (Mittendorf, 1981): (i) lack of marketing facilities, (ii) inadequate marketing organization and methods, and (iii) inadequate government policies and marketing - facilitating services (advisory, training and applied marketing research). An organized marketing system for small ruminants and/or their products is likely to be an area of concern unless the family consumes them (Gatenby, 1986; Arora et al., 2002; Makokha, 2002). The marketing chain may be simple, where the farmer may sell directly to a buyer, or complex in which case the small ruminants and/or their products may be sold several times, from the farmer through a sequence of middlemen to the final consumer (Gatenby, 1986; Arora et al., 2002). Irrespective of the nature, the breeding programmes should be market-oriented. This market should provide the right incentives. Otherwise, it leads to lack of cash incentives on the part of producers to invest in improved management and husbandry practices, and therefore inefficient breeding programmes (Seleka, 2001). In most areas of the tropics, middlemen control the market and exploit farmers by buying animals at low prices and selling them on at ‘exorbitant’ prices (Makokha, 2002). Formation of farmers’ associations and development of marketing facilities would help check this setback and enable farmers get better prices for their animals and/or products. Adding value to improved animals and/or their products is necessary to stimulate their appreciation and attract demand from the farmers and butchers/traders.

2.6.2.2. Support services

Provision of extension and veterinary services are a major pre-requisite for effective breeding programmes and are one of the major constraints in developing countries in the tropics. Extension activities to reduce risk of small ruminant diseases and create awareness on the value of an improved animal as well as convince the farmers and butchers/traders of the good ideas of a breeding programme would be essential. Slaughter and/or sacrifices of improved breeding stock would then be reduced and the breeding programme sustained. In addition, farmers have to be convinced that they cannot run a breeding programme individually due to lack of infrastructure to singly select animals, and need to co-operate. However, it is recognized that extension is often the weakest link in the chain of flow of information in agricultural research to the farmer (Gatenby, 1986; Ajala, 1988). In most cases, the social gap between the scientist and peasant farmer is very wide and progress cannot take place unless the extension worker can bridge this gap. Regular links between researchers, extension agents and farmers, combined with on the spot solving of problems would be a healthy development. The training needs of the farmers in the course of a project change and should constantly be identified (Ghamunga et al., 1993). In extension programmes, use should be made of existing structures (including traditional modes) for transfer of knowledge and information. Participatory approaches are necessary to enable full participation of the farmers and promotion of the breeding programmes. Thereafter, other conventional methods that have always been used, like livestock shows, trade fairs and field days could be used in combination with the participatory approaches. The media - radio, television, factual films (cinemas) and local dailies may proof useful to get a good coverage in disseminating information to the farmers. A specific newsletter or magazine (in an appropriate language) produced at regular intervals providing coverage of breeding and other aspects of small ruminant production, including market information, could enhance uptake of relevant technologies.

To enhance competence of extension services effective constant monitoring and evaluation schemes are desirable to provide information on breed characteristics, farmers' objectives and practices as well as identifying alternative solutions to identified technical and social constraints (Fall, 2000). In cases where nucleus schemes are used, continual monitoring to determine the proportion of animals to be maintained in the multiplier level or that disseminated to the commercial population is necessary to meet farmer demand and sustain the breeding programme. However, limited and unstable manpower is always a constraint. Society needs skilled practitioners to both determine optimal directions of genetic change and to design and implement sound breeding programmes (Detilleux and Leroy, 2002). Training curricular in most developing countries may not be in line with the demands of the local society. The availability of more qualified national scientists with knowledge of the local situations to provide technical support would contribute positively to the realization of the breeding schemes. However, motivation to attract and maintain such personnel is an issue of concern. Based on the experience in Senegal, Fall (2000) recommends that livestock development policies should encourage the establishment of private professional breeding flocks either owned individually or by private groups of farmers that would benefit from the scientific and technical assistance provided by research and extension institutions.

2.6.3. Inbreeding depression and conservation of genetic diversity

Genetic changes through within-breed selection range from about 0.5-3% per year (Smith, 1984). These changes might seem relatively small, but they are cumulative and permanent. For instance, in its first 44 years the Damara sheep breeding programme described in earlier sections of this paper registered an increase in the average weaning mass at 100 days of about 8% (22.8 to 24.6 kg) and 19% (24.0 to 28.5 kg), for ewe and ram lambs, respectively (von Wielligh, 2001).

In addition, a short-term gain from breeding programmes would come from resolving any inbreeding depression or (less likely) any gains from amongst strain (within-breed) variation through use of sires from unrelated sub-populations. It is important to note that farmers require and make use of breeding males they perceive to be superior. The males obviously have to fit in the production system to be acceptable (Mirreh, 1978 cited by Sölkner et al., 1998). In most villages, genetic change takes place through use of one or a few breeding males and with no selection of females. Risks of inbreeding are higher in small flocks kept by the smallholders (Gatenby, 1986) and through the use of few rams, a phenomenon most farmers may not be aware of or able to control. For instance, assuming an average of 50 ewes and 5 rams in a village, with no sire exchange and no adjustment for age, the approximate effective population size (N_e) (Falconer and Mackay, 1996) under free-roaming conditions would be less than 18 and the inbreeding coefficient about 3% per generation. Even in situations where communal herding or grazing is the normal practice, there is still a higher likelihood of dominant males getting more offspring in the flock and the male offspring continuing to dominate and breed, and hence a build up of inbreeding in the long-run (Nimbkar, 2000). While resolving the issue of inbreeding, it is important to consider if there are significant strain differences for performance that will not be offset by lack of adaptation of 'imported' sires to local disease challenge.

One of the sideline outcomes of within-breed selection of indigenous small ruminants is the maintenance of biodiversity. Genetic diversity is a requisite for food security and stability of the environment. Unless genetic resources are conserved, genotypes that have unique desirable properties for production in a given environment may not be available to sustain food production now and in the future (Gatenby, 1986; Anderson, 2003; Drucker and Scarpa, 2003). The most viable option is conservation through utilization. Due to their better adaptation to local environmental conditions, proper use of indigenous small ruminant breeds would contribute to improved food security and reduce pressure on the environment. Utilization of local breeds will help reduce external inputs in feeding and healthcare of animals and hence could increase the profit margin of smallholder farmers.

Because of the vital and valuable role they play both to the ecology and economy of their native countries, attention should be directed towards initiating breeding programmes that might ensure their continued survival for current and future generations (Ponzoni, 1992; Solti et al., 2001). Smallholder and pastoral farmers are the current custodians of the majority of indigenous genetic resources in the tropics, and their involvement in improvement and conservation programmes could easily pay dues (Baker and Rege, 1994). However, exploitation of genetic resources requires their effective and systematic documentation and all aspects of their performance in their harsh environment (Turner, 1978; Lebbie and Ramsay, 1999). To make conservation attractive and sustainable, the strategy must be associated with some benefit, which can be economic (Lebbie and Ramsay, 1999), or adaptation characteristics and in general fitting the production objectives of the farmer.

2.7. Conclusion

This study found a limited number of examples of sustainable breeding programmes utilizing the indigenous stock of small ruminants present in the tropics. The eminence of sustainable within-breed (population) improvement programmes in low-input livelihood-oriented production systems cannot be shunned. In principle, such breeding programmes must have expected outputs consistent with the producer's objectives and would be driven by incentives from the market to justify the producer's investment. The bottom line is that successful adoption of a technology depends on its compatibility with the needs of the farmer and the production system. It has to be relatively simple, relatively cheap and above all involve relatively low risks. It is necessary to look at the production system holistically, and involve the producer at every stage in the planning and operation of the breeding programme, integrating traditional behaviour and values. The most promising breeding strategy to improve and sustain the indigenous small ruminant population is probably to address the issue of risk aversion through management measures and sire exchange initiatives rather that setting selection criteria for output-oriented traits, which cannot be matched without external inputs. In addition, it important to remember that with breeding programmes, like any other enterprise, the reality is that while we strive to establish programmes that have a high chance of success, we should allow for a proportion of failures along the way instead of trying to set unrealistic goals for success rates, which in the end may harm the development process.

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Chapter 3

Small ruminant production in the tropics: a study of smallholder and pastoral/extensive farming systems in Kenya

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Abstract

A survey was conducted by way of personal interviews with 562 respondents comprising 459 farmers and 103 butchers/traders in selected districts in the central and western parts of Kenya, consisting of three predominantly smallholder and four predominantly pastoral/extensive districts. The study aimed to provide a better understanding of smallholder and pastoral/extensive sheep and goat farming systems in the tropics, by taking Kenya as an example. Results show that 58% of pastoral/extensive farmers and 46% of smallholders indicated livestock as their main activity. Small ruminants ranked closely behind cattle in their importance. Thirty four percent of the households kept only sheep, 18% only goats and 48% both species. The survey demonstrated the relative importance to the farmers of tangible benefits of farming sheep and goats (such as regular cash income, meat, manure and, in the case of goats, milk) versus intangible benefits (such as the role of small ruminants as an insurance against emergencies). Regular cash income and an insurance against emergencies were the highest priorities. Seventy eight percent of the farmers reported animal sales over the previous 12 months. Of these, the income was spent on school fees (32%), purchase of food (22%), farm investment (18%), medical expenses (10%), off-farm investment (9%), social activities (5%) and re-stocking (4%). Indigenous genotypes were predominant among pastoral/extensive farmers and mixed crosses predominant among smallholders. A range of traits: growth rate, size, shape, drought tolerance, meat quality, fertility, disease and heat tolerance, prolificacy and temperament were all considered important for both sheep and goats in both farming systems and across the different genotypes. Compared with other pure breeds Red Maasai sheep and Small East African goats were rated poorly in terms of size, shape, growth and fertility but highly in terms of drought and (Red Maasai) heat tolerance by both smallholder and pastoral/extensive farmers. In general, crosses were perceived less favourably than indigenous pure breeds. Size and performance ranked as the most important traits in the choice of breeding males. Approximately half the farmers inherited their males, reared them on the farm and kept them for an average of 2-3 years. Uncontrolled mating within the household's flock was predominant in both farming systems. Over 98% of the farmers reported incidence of disease, especially pneumonia (in pastoral/extensive areas), helminthosis, tick-borne diseases, diarrhoea and foot-rot. Over 95% of the farmers fed supplements in both dry and wet seasons. Pure exotic and indigenous X exotic genotypes fetched higher prices than indigenous genotypes due to their heavier body weight.

(***Keywords***: Small ruminants; Smallholder; Pastoral/extensive; Breeding programmes; Tropics)

3.1. Introduction

The importance of small ruminants (i.e., sheep and goats) to the socio-economic well being of people in developing countries in the tropics in terms of nutrition, income and intangible benefits (i.e., savings, an insurance against emergencies, cultural and ceremonial purposes) cannot be overemphasised. Small ruminants also play a complementary role to other livestock in the utilisation of available feed resources and provide one of the practical means of using vast areas of natural grassland in regions where crop production is impractical (Baker and Rege, 1994). Therefore, improvement programmes are necessary to increase and sustain the productivity of small ruminants in these areas so as to meet the demands of the human population on them. However, development of genetic improvement programmes for sheep and goats will only be successful when accompanied by a good understanding of the different farming systems and when simultaneously addressing several constraints – e.g., feeding, health control, management, and cost and availability of credit and marketing infrastructure (Baker and Gray, 2003).

Many small ruminant genetic improvement programmes have not been very successful in developing countries in the tropics (Sölkner et al., 1998; Rewe et al., 2002; Wollny et al., 2002). An important reason is that genetic improvement programmes have mostly been implemented without taking into consideration all the needs of the farmer. In addition, poor performance of imported breeds from the temperate developed world into tropical countries has created a negative image for genetic improvement programmes (Turner, 1978; Rewe et al., 2002; Ayalew et al., 2003). Few studies have elaborated on the many factors affecting the production and farming of sheep and goats in the tropics. Consequently, there is generally scanty information, from the farmers' perspective, on the entire spectrum of small ruminant farming, a situation limiting the scope of improvement interventions. The current study attempts to provide a better understanding of smallholder and pastoral/extensive farming systems, and complements past studies in the tropics (e.g., Mucuthi et al., 1992; Otieno et al., 1993; Mwendia, 1997; Peeler and Omore, 1997; Mahanjana and Cronjé, 2000; Jaitner et al., 2001; Seleka, 2001; Wollny et al., 2002). The study aims to help in the development of effective breeding programmes for sheep and goats in the tropics. More specifically, the survey aimed to:

a) establish why smallholder and pastoral/extensive farmers keep sheep and goats,
b) determine the relative importance to the farmers of tangible benefits of farming sheep and goats (e.g., cash income from meat, milk and manure) versus intangible benefits (e.g., the role of small ruminants to act as a source of income for future needs - banking or insurance),
c) understand why farmers in different production systems keep particular breeds,
d) know what attributes of sheep and goats farmers think are important,
e) establish from where farmers access their breeding rams and bucks and how long they keep them, and
f) understand the constraints that apply to successful farming of small ruminants.

3.2. Materials and methods

3.2.1. Sampling and questionnaire methodology

The survey was conducted by way of personal interviews with farmers (household survey) and butchers/traders (market survey) by teams of trained enumerators in selected districts in the central and western parts of Kenya (see Table 3.1 and 3.2; Fig. 3.1). The survey of farmers covered seven districts, and that of traders/butchers covered three districts. The household survey was designed such that there were three districts that were predominantly smallholder with mixed crop-livestock farmers (i.e., Nakuru, Nandi and Nyeri) and four that were predominantly pastoral/extensive (i.e., Baringo, Laikipia, Narok and Trans-Mara) (Table 3.2). Nyeri district also contains some medium- and low-potential pastoral/extensive areas, of which one division was selected. Although largely pastoral, Baringo also contains a smallholder, mixed crop-livestock highland area. One largely smallholder division was picked in the highlands and one pastoral division in the lowlands. A number of smallholder households were also selected during the random sampling of the two Laikipia district divisions. One division in Nakuru district was selected from medium-potential and one from high-potential zones in the district. The survey areas within

Table 3.1. Selection of samples per district, division and location in different regions of Kenya[a]

District	Divisions	Locations	Sub-locations
Nakuru	2 (16)	2 (4); 2 (4)	2 (2), 3 (3); 1 (1), 1 (1)
Nandi	2 (9)	2 (15); 2 (9)	3 (3); 3 (3); 3 (3), 2 (2)
Nyeri	2 (7)	2 (5); 2 (7)	3 (4), 3 (4); 3 (7), 3 (4)
Baringo	2 (14)	2 (8); 2 (5)	3 (3), 3 (3); 3 (3), 3 (3)
Laikipia	2 (6)	2 (6); 2 (9)	1 (1), 1 (1); 2 (2), 3 (4)
Narok	2 (8)	2 (4); 2 (5)	2 (2), 2 (2); 3 (3), 3 (4)
Trans-Mara	2 (5)	2 (4); 2 (7)	3(3), 3 (4); 2 (2), 1 (1)
Total	14 (65)	28 (92)	68 (78)

[a]Numbers outside brackets represent numbers sampled while those in brackets represent population totals.

each district were replicated at both the division and location levels, i.e., two divisions and two locations per division were picked in each district using prior information obtained from the field staff (Table 3.1). Most locations had three or fewer sub-locations and all were sampled. For locations that contained more than three sub-locations, three sub-locations were selected at random. Consequently, a total of 14 divisions, 28 locations and 68 sub-locations were sampled representing approximately 6% of all sub-locations in the seven districts (see Kosgey et al. (2004) for further details).

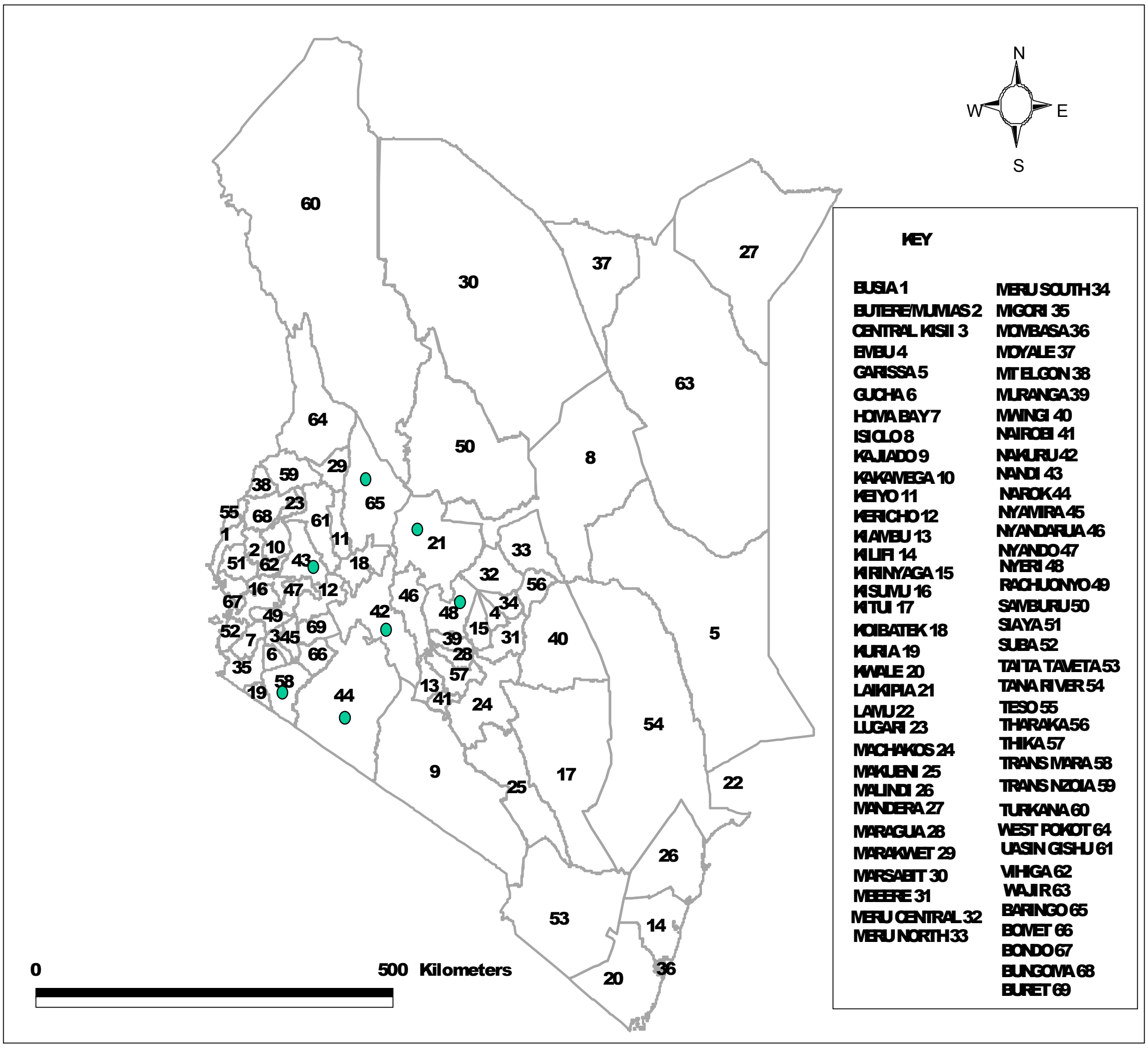

Fig. 3.1. Map of Kenya showing districts surveyed (marked with grey circles)

3.2.1.1. Household survey

The household survey used a set of structured questionnaires which were a slightly modified version of those designed for livestock breed survey in the southern African region (Rowlands et al., 2003). These questionnaires were designed to obtain information from respondents on general household characteristics, purposes of keeping small ruminants, animal breeds, traits of importance, breeding management, flock sizes and flock structures, animal health, feeding management, and marketing and prices of animals. Most questions were asked in the form of open questions. The enumerator ticked the answers given by farmers against a prepared list in the questionnaire, and then, where appropriate, asked the farmer to rank the top three. The main exception was for the question pertaining to traits of perceived importance. In this case the enumerator went through a list of predetermined traits one by one and asked the farmer whether he considered the trait to be either a good, average or poor characteristic of the breed(s) he/she kept, or to be a trait that was not of importance or about which he/she had no opinion.

Sampling was done through clustering of households within a sub-location. A cluster of households was formed within a given radius, the length of which depended on the household density. Transects were drawn within the cluster to make the sampling as random as possible. Only households with sheep and/or goats were picked along the transects, skipping those that did not have any small ruminants. A minimum of five households per sub-location owning sheep and/or goats were sampled for the household survey. The sample number was increased when there were more than 1,000 households in the sub-location according to the last census. In this case a minimum of 0.5% of the households in the sub-location were sampled. Data on households and human populations were obtained from the Central Bureau of Statistics (CBS) 1999 census.

3.2.1.2. Market survey

An interview of butchers/traders was done alongside the household survey in three districts (Baringo, Nakuru and Nandi) to establish meat prices of different categories of animals (i.e., pure exotic, exotic X indigenous crosses and indigenous). Butchers/traders within certain clusters of the household survey (and close by when not occurring within) were interviewed. Where possible a minimum of five butchers/traders were interviewed per sub-location.

3.2.2. Data analysis

Data were entered into a database in Access, the structure of which can be found in Rowlands et al. (2003). For the purposes of analysis the farmers were divided into two farming systems, namely smallholder and pastoral/extensive. A further sub-division into small ruminant species ownership was also used, namely those owning only sheep, those owning only goats, and those owning both sheep and goats. Results are presented mainly in the form of descriptive tabular summaries. Chi-square (χ^2) or *t* tests were carried out as appropriate to assess the statistical significance or otherwise of particular comparisons. Logistic regression with terms for farming system and breed was used to compare the qualities of traits (proportion of farmers ranking a trait to be good) across breeds.

Indices were calculated to provide overall ranking of (a) the purposes of keeping sheep or goats and (b) the traits used for choosing rams and bucks according to the formula:

Index = sum of [4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for a tick] given for an individual purpose or trait divided by the sum of [4 for rank 1 + 3 for rank 2 + 2 for rank 1 + 1 for a tick] summed over all purposes or traits.

Similar indices were calculated for ranking importance of livestock by species and source of cash income.

3.3. Results

3.3.1. General household information

Four hundred and fifty nine respondents (218 smallholder and 241 pastoral/extensive farmers) were interviewed for the household survey. Of these 158 (48% and 22%, respectively, of the corresponding totals for smallholder and pastoral/extensive farmers) owned only sheep, 83 (18% and 18%) owned only goats and 218 (34% and 60%) owned both sheep and goats (Table 3.2). The majority of the farmers (89%) were sedentary and the rest nomadic. The majority of pastoral/extensive farmers (58%) indicated livestock to be their main activity (see Table 3.3). The corresponding percentage of 46% for smallholders was significantly lower (χ^2_1 = 5.91, P <0.05). Thirty three percent of smallholders and 25% of pastoral/extensive farmers put crops first. Primary income from salary/wages ranked third.

The importance of small ruminants in the two farming systems is demonstrated in Table 3.4. Goats outranked cattle when goats were the only small ruminant species. This was partly due to the fact that 40% of these farmers did not own and, hence, rank cattle. Where both sheep and goats were owned each species was ranked similarly behind cattle. Sheep were also ranked second behind cattle when goats were not owned. Chickens were ranked third. In general, the rankings of importance of sheep and goats were very similar for both smallholder and pastoral/extensive farmers.

Table 3.2. Number of households by small ruminant species and farming system for the household survey, and numbers of butchers/traders for the market survey

Type of survey	District							
	Nakuru	Nandi	Nyeri	Baringo	Laikipia	Narok	Trans-Mara	Total
Main household survey								
Farming system								
Sheep								
Smallholder	41	40	18	1	3	2	0	105
Pastoral/extensive	19	0	13	2	1	18	0	53
Goats								
Smallholder	8	7	13	8	3	1	0	40
Pastoral/extensive	6	0	2	20	6	4	5	43
Sheep and goats								
Smallholder	19	14	17	11	10	1	1	73
Pastoral/extensive	16	0	6	19	17	50	37	145
Total								
Smallholder	68	61	48	20	16	4	1	218
Pastoral/extensive	41	0	21	41	24	72	42	241
Overall total	109	61	69	61	40	76	43	459
Market survey								
Butchers/traders[a]	25	55	-	23	-	-	-	103

[a](-) sign means survey not done in the district.

Table 3.3. Ranking of source of income within household by small ruminant species and farming system

Income source	Farming system					
	Smallholder			Pastoral/extensive		
	Households[a]	Households[b]	Ranking[c]	Households[a]	Households[b]	Ranking[c]
Sheep	(n=105)			(n=53)		
Livestock	103	45	0.42	52	33	0.49
Crops	99	37	0.39	41	10	0.31
Salary/wages	33	18	0.13	19	9	0.15
Relative's remittances	10	1	0.02	3	0	0.01
Home industries	4	1	0.01	4	1	0.03
Other[d]	5	3	0.02	1	0	0.01
Goats	(n=40)			(n=43)		
Livestock	37	17	0.39	43	19	0.49
Crops	35	14	0.37	23	12	0.26
Salary/wages	18	8	0.17	15	9	0.17
Relative's remittances	4	0	0.02	5	2	0.04
Home industries	3	1	0.02	1	0	0.01
Other[d]	4	0	0.03	3	1	0.03
Sheep and goats	(n=73)			(n=145)		
Livestock	70	39	0.44	145	87	0.49
Crops	71	21	0.39	110	38	0.33
Salary/wages	20	9	0.10	39	14	0.10
Relative's remittances	9	1	0.03	13	2	0.03
Home industries	4	1	0.02	7	0	0.01
Other[d]	3	2	0.02	14	4	0.04

[a]Households considering item to be an important source of income. [b]Households ranking income source first.

[c]Index = sum of [3 for rank 1 + 2 for rank 2 + 1 for rank 3] divided by sum [3 for rank 1 + 2 for rank 2 + 1 for rank 3] for all sources of cash income for a farming system.

[d]Includes business (livestock trading, pharmacy, rental houses and retail shops), bee-keeping and pastorhood (priest).

Table 3.4. Household ranking of the importance of livestock by small ruminant species and farming system

Species	Farming system							
	Smallholder				Pastoral/extensive			
	Households[a]	Households[b]	Households[c]	Ranking[d]	Households[a]	Households[b]	Households[c]	Ranking[d]
Sheep	(n=105)				(n=53)			
Cattle	93	93	87	0.44	45	45	31	0.40
Sheep	105	105	12	0.34	52	52	21	0.40
Chicken	96	93	6	0.20	45	41	1	0.18
Other[e]	18	7	0	0.02	17	7	0	0.02
Goats	(n=40)				(n=43)			
Cattle	23	23	21	0.31	27	27	18	0.30
Goats	40	40	18	0.43	43	43	23	0.47
Chicken	35	33	0	0.22	37	33	0	0.18
Other[e]	7	4	1	0.03	15	6	2	0.05
Sheep and goats	(n=73)				(n=145)			
Cattle	66	65	49	0.39	135	133	86	0.40
Sheep	73	69	13	0.28	144	139	32	0.30
Goats	73	64	9	0.26	145	142	26	0.27
Chicken	72	19	2	0.07	103	15	0	0.02
Other[e]	11	2	0	0.00	71	4	1	0.01

[a]Total households owning species. [b]Households considering livestock species to be important (i.e., a rank of 1, 2 or 3).
[c]Households ranking livestock species first.
[d]Index = sum of [3 for rank 1 + 2 for rank 2 + 1 for rank 3] divided by sum [3 for rank 1 + 2 for rank 2 + 1 for rank 3] for all species for a farming system. [e]Includes pigs, donkeys, rabbits, bees, fish, and other types of poultry (ducks, geese, guinea fowl and turkeys).

3.3.2. Purposes of keeping sheep and goats

Tables 3.5 and 3.6 present purposes of keeping sheep and goats, respectively, and the ranking of the importance of these purposes by farming system. The results indicate the relative importance to the farmers of tangible benefits of farming sheep and goats (such as regular cash income, meat, manure and, in the case of goats, milk) versus intangible benefits (such as the role of small ruminants as an insurance against emergencies). Most smallholder and pastoral/extensive farmers (on average 72%) put first the keeping of sheep either for regular cash income or as an insurance against emergencies. Although not statistically different by a χ^2 test the emphasis among pastoral/extensive farmers tended to be towards regular cash income (Table 3.5). Manure received a higher ranking among smallholder than pastoral/extensive farmers. For goats, regular cash income featured most strongly as an insurance against emergencies (Table 3.6). Only a few farmers kept sheep or goats primarily for breeding in both farming systems, and this purpose was among the lowly ranked. An interesting purpose, rarely reported in Kenya, is the milking of sheep, especially by the pastoral communities where milking was ranked first by 6% of households (see Table 3.5). None of the surveyed farmers kept goats for mohair.

Three hundred and fifty seven (78%) households reported small ruminant sales within 12 months preceding the interview. Their income was spent on school fees (32%), purchase of food (22%), farm investment (18%), medical expenses (10%), off-farm investment (9%), social activities (5%) and re-stocking (4%). The trend of expenditure in both farming systems was similar and generally comparable across small ruminant species, except perhaps for smallholder sheep farmers who appeared to be more selective in their expenditure. This may be due to small flock sizes and hence less total income to share across the different areas of expenditure.

Table 3.5. Purpose of keeping sheep and the ranking of the importance of these purposes by farming system

Purpose	Farming system					
	Smallholder (n=178)			Pastoral/extensive (n=198)		
	Households[a]	Households[b]	Ranking[c]	Households[a]	Households[b]	Ranking[c]
Regular cash income	107	69	0.20	149	80	0.22
Meat	138	16	0.19	156	22	0.16
Insurance/emergency	104	62	0.18	128	59	0.17
Manure	146	6	0.17	106	1	0.09
Planned investment	52	14	0.07	71	6	0.05
Ceremonies/celebrations	73	1	0.07	141	3	0.10
Wool	21	7	0.03	44	13	0.05
Dowry	39	1	0.03	79	0	0.04
Cultural rites	12	0	0.01	62	2	0.04
Milk	8	1	0.01	29	11	0.03
Skin	35	0	0.02	30	0	0.01
Breeding	10	0	0.01	15	0	0.01
Other[d]	24	1	0.01	46	1	0.04

[a]Households ranking purpose important (i.e., 1, 2, 3 or just a tick). [b]Households ranking purpose first.
[c]Index = sum of [4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for tick] divided by sum [4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for tick] for all purposes of keeping sheep.
[d]Includes blood, fat, pelt, to learn stockmanship and to keep oneself busy.

Table3.6. Purpose of keeping goats and the ranking of the importance of these purposes by farming system

Purpose	Smallholder (n=113)			Pastoral/extensive (n=188)		
	Households[a]	Households[b]	Ranking[c]	Households[a]	Households[b]	Ranking[c]
Regular cash income	80	51	0.21	154	75	0.24
Meat	80	8	0.15	166	29	0.19
Insurance/emergency	69	23	0.14	122	50	0.17
Manure	97	3	0.15	91	0	0.07
Ceremonies/celebrations	45	0	0.05	117	2	0.09
Milk	62	18	0.13	80	20	0.09
Planned investment	39	7	0.06	59	9	0.05
Dowry	30	0	0.03	60	1	0.03
Skin	34	0	0.03	39	0	0.02
Breeding	17	2	0.03	6	0	0.00
Mohair	0	0	0.00	0	0	0.00
Cultural rites	5	0	0.00	43	2	0.03
Other[d]	27	1	0.03	33	0	0.02

[a]Households ranking purpose important (i.e., 1, 2, 3 or just a tick). [b]Households ranking purpose first.

[c]Index = sum of [4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for tick] divided by sum [4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for tick] for all purposes of keeping goats.

[d]Includes blood, fat, pelt and to learn stockmanship, shelter (clothing), bartering with honey, to keep oneself busy, and control (pick) ticks.

3.3.3. Breeds and breeding management

3.3.3.1. Breeds kept, their origin, lifespan, and traits of economic importance

The number of households that owned different small ruminant breeds by farming system and district are shown in Table 3.7. Households owning mixed crosses were predominant in smallholder production for both sheep and goats, followed by the indigenous genotypes. In the pastoral/extensive system the situation was reversed with most households owning the indigenous genotypes (mainly Red Maasai - 51% of the households and Small East African goat - 70%). Animals were mostly inherited or bought. The exotic genotypes were bought mostly from the market or commercial farms but the indigenous ones were generally inherited. Half of both smallholder and pastoral/extensive farmers reared their own males for breeding purposes on the farm (51% for smallholder and 52% for pastoral/extensive farmers for sheep; 43 and 62% for goats, respectively). When males were not reared, smallholders tended to borrow males (29% for sheep; 28% for goats) whereas pastoral/extensive farmers tended to buy them (28% for sheep; 20% for goats). Artificial insemination was not used in any of the flocks surveyed. In areas where families mixed and herded animals on common fields, matings took place at random with males present in the flocks. The males were then referred to as communal. Such mating, however, was reported by only 4% of farmers on average. Males were kept until about 2-3 years of age on average and up to a maximum of 8 and 6 years for sheep and goats, respectively, in both farming systems. Female sheep and goats were kept until about 4-5 years old on average, and up to a maximum of 14 years for sheep and 12 years for goats in smallholder, and up to a maximum of 10 years for sheep and 15 years for goats in pastoral/extensive systems.

The ranking of the importance of different traits as perceived by farmers for each breed in the two farming systems are presented in Tables 3.8 and 3.9. A range of traits: growth rate, size, shape, drought tolerance, meat quality, fertility, disease

Table 3.7. Number and percentage of households owning small ruminant breeds by farming system and district

Farming system	Breed	District								
		Nakuru	Nandi	Nyeri	Baringo	Laikipia	Narok	Trans-Mara	House-holds	% house-holds[a]
Sheep										
Smallholder	Red Maasai	4	14	7	10	1	1	1	38	21
(n= 178)	Dorper	1	6	2	2	8	0	0	19	11
	Merino	1	6	0	0	0	2	0	9	5
	Other purebreeds[b]	0	4	0	0	0	1	0	5	3
	Mixed crosses	54	34	25	0	7	0	0	120	67
Pastoral/extensive	Red Maasai	13	0	4	20	2	29	32	100	51
(n= 198)	Dorper	7	0	1	0	10	1	2	21	11
	Merino	0	0	0	1	1	17	0	19	10
	Other purebreeds[b]	0	0	0	0	0	15	0	15	8
	Mixed crosses	15	0	14	0	6	10	3	48	24
Goats										
Smallholder										
(n = 113)	Small East African	5	6	6	18	2	1	1	39	35
	Galla	0	0	0	0	1	0	0	1	1
	Other purebreeds[c]	4	0	3	0	2	1	0	10	9
	Mixed crosses	19	15	21	1	8	0	0	64	58
Pastoral/extensive	Small East African	14	0	0	39	1	39	38	131	70
(n = 188)	Galla	0	0	0	0	4	4	0	8	4
	Other purebreeds[c]	0	0	0	1	8	0	1	10	5
	Mixed crosses	8	0	8	0	10	12	3	41	22

[a]These percentages do not add up to 100% because some households own more than one breed.

[b]Corriedale, Hampshire Down and Romney Marsh.

[c]Alpine, Boer, Dual Purpose, Saanen and Toggenburg.

and heat tolerance, prolificacy and temperament were all considered important for both sheep and goats in both farming systems and across the different genotypes (Table 3.8). Other traits, including milk, were of lower importance and there were inconsistencies in the perceptions of the qualities of two of these traits (colour and horns) by smallholder and pastoral/extensive farmers. Compared with other pure breeds Red Maasai were rated highly by both smallholder and pastoral/extensive farmers in terms of drought and heat tolerance, but there were no perceived breed differences in terms of disease tolerance (Table 3.8). In contrast, other pure breeds (including Dorpers and Merinos) were considered generally to have better growth rate, shape and fertility than Red Maasai. Red Maasai were judged to have poor prolificacy but the rating of prolificacy levels for other breeds varied according to farming system (data not shown). Crosses were generally considered unfavourably relative to indigenous breeds for most traits, and in terms of size, growth and heat tolerance they were judged to be significantly poorer than Red Maasai. Similar trends were observed for goats (Table 3.8). Small East African goats were considered to be significantly smaller and to have poorer fertility and prolificacy, but to have better drought tolerance than other pure breeds. In general, crosses were perceived less favourably than indigenous pure breeds. Table 3.9 gives the odds ratios and their 95% confidence intervals for seven of the most commonly reported traits in Table 3.8. The odds ratio presented is a measure of the relative perception for a trait in a given breed when compared with the Red Maasai for sheep and the Small East African for goats. Essentially, if the odds ratio overlaps one (1) then there is no difference in the stated perception of the traits, a better perception when greater than one and a lower perception when less than one. The odds ratio is significant when its 95% confidence interval excludes one (1) (Bebe et al., 2003). For instance, the odds ratio of a farmer rating highly the growth rate of a Dorper was 8.56 that of a farmer rating highly the growth rate of a Red Maasai (Table 3.9). In contrast, the odds ratio for crosses compared with the Red Maasai was only 0.50. In terms of drought and heat tolerance odds ratios for other breeds and crosses compared with Red Maasai ranged from 0.17 to 0.65. Similar patterns were evident for other pure breeds of goats and crosses compared with the Small East African.

Table 3.8. Number of households perceiving different traits for each sheep and goat breed to be important (i.e., poor + average + good) and (in parentheses) the percentage of households perceiving the trait to be good

Trait	Sheep					Goats		
	Red Maasai (n=138)	Dorper (n=40)	Merino (n=28)	Other pure[a] (n=20)	Crosses (n=168)	Small East African (n=170)	Other pure[b] (n=29)	Crosses (n=105)
Size	133	38	27	20	161	166	28	104
	(59)	(79)*	(70)	(75)	(43)*	(54)	(75)*	(43)
Disease tolerance	131	37	26	19	157	163	27	99
	(75)	(65)	(73)	(53)	(62)	(83)	(67)	(68)*
Drought tolerance	131	39	27	20	152	165	28	91
	(81)	(69)	(56)**	(45)***	(70)	(88)	(68)*	(77)
Growth	127	38	28	20	153	162	28	102
	(56)	(92)***	(89)**	(80)*	(44)**	(57)	(93)**	(40)*
Fertility	132	35	26	19	149	161	26	93
	(62)	(94)**	(73)	(95)*	(48)	(59)	(96)**	(52)
Heat tolerance	126	36	27	18	138	157	23	83
	(79)	(56)**	(63)	(39)***	(59)**	(79)	(74)	(70)
Shape	121	37	27	20	126	153	26	91
	(62)	(89)**	(81)*	(65)	(44)	(69)	(73)	(41)***
Prolificacy[c]	126	32	26	17	136	155	25	59
	(29)	(47)	(46)	(41)	(17)	(34)	(80)***	(34)

Table 3.8. (*continued*)

Trait	Sheep					Goats		
	Red Maasai	Dorper	Merino	Other pure[a]	Crosses	Small East African	Other pure[b]	Crosses
Temperament	114	30	27	18	127	138	28	83
	(66)	(60)	(78)	(94)*	(60)	(54)	(54)	(43)***
Meat quality	103	34	24	19	96	152	24	60
	(81)	(100)	(79)	(100)	(70)	(88)	(96)	(70)*
Colour[c]	78	31	21	13	72	86	23	42
	(71)	(81)	(81)	(92)	(46)	(80)	(91)	(60)
Horns[c]	43	10	8	1	25	67	19	32
	(56)	(70)	(50)	(0)	(36)	(55)	(63)	(25)*
Milk	33	12	16	13	19	105	23	63
	(27)	(92)**	(56)*	(38)	(63)*	(27)	(65)*	(27)
Wool	0	0	13	8	31	-	-	-
	(0)	(0)	(77)	(75)	(39)			
Fat	2	1	0	0	2	-	-	-
	(0)	(100)	(0)	(0)	(0)			

*** P<0.001; **P<0.01; *P<0.05 when compared with Red Maasai (sheep) or Small East African (goats) as the reference breed in a logistic regression analysis of r/n, where n = number of farmers rating a trait important and r = number of farmers rating a trait good. Individual breed X farming system r/n values (10 for sheep and 6 for goats) were used in the analysis with terms for breed and farming system in the model.

[a] Breeds: Corriedale, Hampshire Down, Romney Marsh.

[b] Breeds: Alpine, Boer, Dual Purpose, Galla, Saanen, Toggenburg.

[c]Responses for sheep for smallholder and pastoral/extensive farmers were not consistent for prolificacy, colour and horns and so no overall significance values are given for sheep.

Table 3.9. Odds ratios and 95% confidence limits (in parentheses) of farmers' perceptions of 'good' for seven of the traits considered to be 'important' (see Table 3.8), comparing each breed with Red Maasai (for sheep) and Small East African (for goats) as reference breeds

Trait	Sheep				Goats	
	Dorper	Merino	Other pure	Crosses	Other pure	Crosses
Size	2.74	1.70	2.11	0.57	2.60	0.66
	(1.16, 6.48)	(0.69, 4.17)	(0.73, 6.16)	(0.35, 0.95)	(1.04, 6.46)	(0.39, 1.13)
Disease tolerance	0.65	0.91	0.37	0.62	0.44	0.52
	(0.29, 1.42)	(0.35, 2.37)	(0.14, 1.0)	(0.36, 1.07)	(0.18, 1.09)	(0.28, 0.97)
Drought tolerance	0.57	0.30	0.19	0.65	0.32	0.63
	(0.25, 1.29)	(0.12, 0.72)	(0.07, 0.51)	(0.36, 1.19)	(0.12, 0.82)	(0.30, 1.31)
Growth	8.56	6.56	3.24	0.50	9.57	0.49
	(2.50, 29.29)	(1.88, 22.86)	(1.02, 10.28)	(0.29, 0.84)	(2.19, 41.81)	(0.29, 0.84)
Fertility	11.64	1.67	10.86	0.71	21.11	1.01
	(2.65, 51.19)	(0.65, 4.29)	(1.41, 83.53)	(0.42, 1.20)	(2.76, 161.65)	(0.58, 1.78)
Heat tolerance	0.35	0.47	0.17	0.42	0.77	0.71
	(0.16, 0.77)	(0.19, 1.14)	(0.06, 0.49)	(0.23, 0.76)	(0.28, 2.12)	(0.37, 1.35)
Shape	6.01	2.86	1.16	0.67	1.28	0.32
	(1.96, 18.41)	(1.00, 8.16)	(0.43, 3.14)	(0.38, 1.18)	(0.50, 3.29)	(0.18, 0.58)

Table 3.10. Ranking of traits when choosing breeding rams/bucks by species and farming system in the two farming systems[a]

Trait	Sheep				Goats			
	Smallholder (n=178)		Pastoral/extensive (n=198)		Smallholder (n=113)		Pastoral/extensive (n=188)	
	Households[b]	Ranking	Households[b]	Ranking	Households[b]	Ranking	Households[b]	Ranking
Size	109	0.25	164	0.35	71	0.26	156	0.35
Performance	96	0.21	137	0.21	67	0.26	136	0.23
True to breed	80	0.20	79	0.13	47	0.18	60	0.11
Shape	72	0.11	111	0.13	43	0.10	104	0.13
Availability	56	0.13	28	0.04	29	0.09	23	0.03
Temperament	47	0.07	72	0.07	28	0.06	64	0.07
Colour	21	0.03	63	0.06	18	0.03	53	0.06
Horns	5	0.00	17	0.01	12	0.02	20	0.02
Other[c]	1	0.00	1	0.00	1	0.00	1	0.00

[a]Index = sum of [4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for tick] divided by sum [4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for tick] for all traits.

[b]Households ranking trait important (i.e., 1, 2, 3 or just a tick).

[c]Health status and adaptability to climatic conditions.

The importance of different traits when choosing a breeding ram or buck is shown in Table 3.10. Size and performance ranked as the most important traits in the choice of breeding males. ‘True to breed’ and availability featured more prominently among smallholder than pastoral/extensive farmers.

3.3.3.2. Type of mating, average age at first mating, average flock sizes and flock structures

Uncontrolled mating within the household’s flock was predominant (on average 46% for smallholder and 58% for pastoral/extensive farmers for sheep; 42 and 54% for goats). Group mating, in which a group of ewes or does is left with one or more rams or bucks to mate for a predetermined period, was the other main system practised by pastoral/extensive farmers (42% for sheep; 36% for goats). Smallholder households practised hand mating (25% for sheep; 37% for goats), more so than the pastoral/extensive households. Smallholder farmers mated animals for the first time at about 10-11 months of age both for males and females. A slightly wider age range of 9-12 months was reported in pastoral/extensive farming. Smallholders owned an average of 2.3±2.5 (SD) lambs, 1.7±2.7 weaners and 4.4±4.7 ewes and rams with a maximum flock size of 18 lambs, 18 weaners and 30 adults. The corresponding numbers for pastoral/extensive farmers were much larger: 14.5±24.3, 13.6±24.8 and 36.6±74.6, respectively with a maximum flock size reported of 150 lambs, 170 weaners and 594 adults. For goats the smallholders owned an average of 2.6±3.5 kids, 2.8±4.8 weaners and 5.7±7.9 adults (maximum 16 kids, 21 weaners and 33 adults). The corresponding figures for the pastoral/extensive systems were 9.2±12.2, 8.5±11.4 and 23.1±31.5, respectively (maximum 100 kids, 70 weaners and 200 adults). There were no overall significant differences between flock sizes for the two species within the two farming systems. However, by paired t-test comparison of means, farmers with both sheep and goats owned more of the latter than the former (young animals and weaners ($P<0.001$); adults ($P<0.01$)).

3.3.4. Animal health and feeding management

Over 98% of the households reported incidences of diseases in smallholder and pastoral/extensive farming systems (Table 3.11). Pneumonia, helminthosis, tick-borne diseases, diarrhoea and foot-rot were the most commonly reported. All these diseases were very prevalent among pastoral/extensive systems, but, except for pneumonia and, to a lesser extent, helminthosis, they did not assume the same importance among smallholders ($P<0.001$ by χ^2 tests). Most farmers sought veterinary help, mainly from the government veterinary service, private veterinarians and drug suppliers, with drug suppliers featuring predominantly among pastoral/extensive farmers (Table 3.11). Anthelmintics and antibiotics were the most common forms of treatment applied. Thirty three and fifty eight percent of smallholder and pastoral/extensive farmers reported use of anthelmintics for sheep. Corresponding figures for goats were 27% and 35%, respectively. Uses of antibiotics were reported by 29% and 92% of smallholder and pastoral/extensive farmers for sheep and by 26% and 85%, respectively for goats. Acaricide was mostly used to control ecto-parasites, applied to sheep virtually always by dipping but to goats mainly by spraying. Farmers keeping sheep reported visits from extension agents with an average of 3 (smallholder) and 4 (pastoral/extensive) visits per household within the last 12 months. On average 9% of the farmers attended one or more courses given by an extension agent on issues pertaining to small ruminants.

Over 95% of the farmers (on average across species and farming systems) fed supplements during both dry and wet seasons. Most supplementation in smallholder farming systems was in the form of roughage (in dry season: sheep – 64% of farmers; goats – 85%; sheep and goats – 73%; in wet season: sheep – 53%; goats – 59%; sheep and goats – 56%) and minerals (in dry season: sheep – 97%; goats – 90%; sheep and goats – 95%; in wet season: sheep – 94%; goats – 82%; sheep and goats – 89%). A smaller percentage of pastoral/extensive than smallholder farmers fed supplement roughage (on average 33% in the dry season and 23% in the wet season). They also largely fed mineral supplements (on average

Table 3.11. Number of households reporting prevalent disease and source of veterinary services by species and farming system

Disease	Sheep		Goats	
	Smallholder (n=178)	Pastoral/extensive (n=198)	Smallholder (n=113)	Pastoral/extensive (n=188)
Pneumonia	74 (42)[a]	56 (28)	34 (30)	77 (41)
Helminthosis	34 (19)	73 (37)	17 (15)	46 (25)
Tick-borne	14 (8)	75 (38)	7 (6)	61 (33)
Diarrhoea	13 (7)	58 (29)	8 (7)	46 (25)
Foot-rot	14 (8)	37 (19)	3 (3)	26 (14)
Skin diseases	4 (2)	16 (8)	1 (1)	8 (4)
Others[b]	16 (9)	66 (33)	14 (12)	55 (29)
Households reporting diseases	175 (98)	195 (99)	113 (100)	182 (97)
Veterinary service				
Government veterinarian	77 (43)	88 (44)	62 (55)	94 (50)
Private	94 (53)	40 (20)	58 (51)	*2 (15)9*
Drug supplier	71 (40)	143 (72)	50 (44)	131 (70)
Government extension officers	39 (22)	39 (20)	36 (32)	40 (21)
Other[c]	13 (7)	31 (16)	7 (6)	31 (17)

[a]Percentage of households presented in parentheses.

[b]Includes abnormal births, anthrax, bloat, blue tongue, eye infections, fever, flukes, foot and mouth disease, mastitis, nasal discharge, orf, plant poisoning, pox, pulpy kidney, rinderpest, salmonellosis, staggers gid, tetanus, trypanosomosis, wounds and abscess, and yellow fever.

[c]Includes non-governmental organisations (NGO's), community-based animal health workers and other animal health providers.

94% of farmers in the dry season and 85% in the wet season). Concentrate feed was also purchased by smallholders (in dry season: sheep – 13%; goats – 44%; sheep and goats – 25%; in wet season: sheep – 10%; goats – 36%; sheep and goats – 16%). Pastoral/extensive farmers, however, rarely purchased concentrates (on average 7% of farmers over both seasons).

3.3.5. Marketing and prices

Farmers sold their stock primarily to butchers, secondly to other farmers, thirdly at auctions, but hardly ever directly to abattoirs or through other routes. Respectively 74% and 76% of smallholder and pastoral/extensive sheep farmers did not have a preference for a particular season for selling their animals. Corresponding percentages for goats averaged 84%. The remainder either sold animals in the wet or dry seasons only. Farmers selling during the dry season slightly outnumbered those selling in the wet season. Pure exotic and indigenous X exotic genotypes, in that order, fetched higher prices than indigenous genotypes for both species ($P<0.001$) (Table 3.12) but prices varied significantly across districts, especially for sheep (all genotypes) and indigenous goats. The average price ratios for indigenous to indigenous X exotic and exotic genotypes were 1:1.3:1.4 for male and female weaner sheep, and 1:1.2:1.5 and 1:1.3:1.4 for male and female adult sheep, respectively. Corresponding ratios for goats were 1:1.2:1.3 for weaners and 1:1.1:1.3 and 1:1.2:1.3 for male and female adults, respectively. Generally, farmers preferred meat from exotic sheep and their crosses to that from indigenous breeds. In contrast, most farmers preferred indigenous goat meat to that from exotics and their crosses.

Table 3.12. Average prices (US$)[a] and their standard errors for different categories of animals by small ruminant species

Species	Genotype	Animal category						
		Weaner			Adult			
		n[b]	Male	Female	n	Male	n	Female
Sheep	Indigenous	80	11.55±0.49	11.99±0.48	82	23.16±1.40	83	20.35±1.03
	Indigenous X Exotic	84	15.23±0.48	15.72±0.48	82	28.49±1.36	83	25.39±1.00
	Exotic	82	16.60±0.47	16.91±0.51	81	33.53±1.32	81	29.09±1.03
Goats	Indigenous	90	11.88±0.45	12.29±0.44	95	25.23±0.99	95	21.24±0.75
	Indigenous X Exotic	75	14.25±0.47	14.87±0.49	75	27.43±1.12	75	24.93±0.92
	Exotic	61	15.47±0.49	16.04±0.52	60	32.13±1.31	61	28.20±1.13

[a]US$1.00 ≈ Kshs. 75.00 (Kenya shillings) at the time. [b]Applies to both male and female.

3.4. Discussion

3.4.1. Overview

It is important to have good understanding of a production system and the relative importance of the different constraints prior to initiating any genetic improvement programme (Baker and Gray, 2003). The purpose of the present survey was to provide a better understanding of smallholder and pastoral/extensive production systems in the tropics, by taking Kenya as an example. Smallholder farmers are found mainly in the medium- to high-potential areas (Rege, 1994). Smallholder farmers tend to keep animals for family needs, rather than purely as an economic enterprise. In this system, livestock may provide agricultural inputs, such as manure, and render the enterprise more secure by using residual capacities of production factors with low opportunity cost such as non-arable land, excess labour, by converting crops and crop residues into high value animal products and by balancing production and market risks (Jahnke, 1982). The importance of livestock to the production system is indicated in the present study in which 46% of the smallholders put livestock as their primary activity compared with 33% who put crops first. Pastoralist farmers rely even more on livestock as their main source of livelihood (58% in the present study) and usually own relatively large numbers of animals under extensive or communal grazing and management. They are found mainly in the medium- to low-potential areas. In recent times, pastoralist communities, especially in the medium potential areas, have been changing from purely keeping livestock towards agro-pastoral systems. This change is seen in the present study where 25% of the pastoral/extensive farmers put crop production as their main activity. Encroachment of crop farmers from other communities and adoption of crop-based food by the pastoral communities are now common features in the districts surveyed.

The results of the survey revealed a number of pertinent issues (i.e., opportunities and constraints) that, if addressed adequately, could help in developing effective small ruminant breeding programmes and in increasing the general productivity of the animals. Small ruminant production was seen not only to be important by both smallholder and pastoral/extensive farmers, ranking closely behind cattle, but also to provide a variety of benefits ranging from tangible to intangible ones. This agrees with other observations (Field, 1985; Okello, 1985; Jaitner et al., 2001; Seleka, 2001). This knowledge of the reasons for keeping small ruminants is a prerequisite for deriving operational breeding goals (Jaitner et al., 2001). Indeed, ignorance of this aspect has been a major constraint in the lack of success in genetic improvement programmes attempted in the tropics (Sölkner et al., 1998; Rewe et al., 2002). The importance that farmers attach to the income that can be generated from small ruminants and the variety of ways in which they use it, however, suggest that genetic improvement programmes could, if carefully planned, have good chances of success. One interesting purpose of sheep production observed by some farmers in this survey, and one rarely reported, is a requirement for milk, especially by the pastoral communities.

3.4.2. Biological aspects

3.4.2.1. Breeds and breeding management

Availability of animals with good genetic potential, a point raised by farmers at report-back meetings at the end of the survey, is a constraint to productivity of small ruminants in the tropics. However, the large percentage of pastoral/extensive farmers with flocks of indigenous breeds (e.g., Red Maasai sheep and Small East African goats) provides a potential for good genetic material. Farmers in the current survey either inherited their males and reared them themselves for breeding purposes or bought or borrowed them. Keeping of small ruminants for breeding purposes was lowly ranked. The predominance of uncontrolled mating in both farming systems and the small flock sizes in smallholder production, as discussed by Seleka (2001), increases the level of inbreeding. Communal herding, which allows breeding females to mix with breeding males from other flocks, can minimise inbreeding (Jaitner et al., 2001), but this appears to have been rarely practised among the farmers in this survey. Some males were kept up to 6-8 years of age which may not be sound production practice, especially if males are allowed to mate their own daughters. Size, performance and true to breed type ranked as the most important traits in the choice of breeding males. Whereas introduced pure breeds were generally considered better in size, growth rate, shape and fertility than the indigenous Red Maasai sheep and, the Small East African goat, they were rated poor in terms of drought and heat tolerance (Table 3.8 and 3.9), traits that are important in the harsh feed and temperature conditions of the tropics. The crosses, compared to the indigenous genotypes, were disadvantaged throughout most traits (Table 3.9). This is in agreement with previous observations that crossbreds are poorly adapted to the low-input traditional production systems of the tropics (Mason and Buvanendran, 1982; Iñiguez, 1998; Rewe et al., 2002; Wollny et al., 2002; Ayalew et al., 2003). From the findings in the current study, it would to be possible to select for faster growth rate, good size and conformation within indigenous breeds whilst at the same time maintaining the superiority of their adaptability traits.

3.4.2.2. Parasites and diseases

Poor health is the key limiting factor to productivity of sheep and goats in the tropics and the extent of the problem is demonstrated in this study. Most smallholders appeared to use government or private veterinarians, but a significant proportion of pastoral/extensive farmers appeared to depend on drug suppliers; this raises some doubts about the accurate diagnosis of disease. The number of extension visits to address the problems pertaining to the farming of small ruminants, however, was found to be minimal. Maximum productivity in a given system of production emerges when disease control is optimal (Gatenby, 1986). Thus, healthcare is an important problem to consider before genetic programmes can be seriously contemplated. Community-based animal health programmes may be one way forward (Njoro, 2001), and wider utilisation of indigenous breeds tolerant to disease another (Baker and Gray, 2003). Farmers did not discriminate between breeds in terms of disease tolerance (Table 3.8). This appears to contradict recent studies that unequivocally showed the Red Maasai sheep and the Small East African goat to be more tolerant than the introduced breeds in coastal Kenya (Baker et al., 1998; 1999; 2003a and b). However, this could be due to the different environments in which the study was done (see Baker et al., 2003a), or to the fact that disease prevalence was so high that it overrode any breed preferences detectable by farmers.

3.4.3. Ecological aspects

Inadequate feeding and poor quality feed are often regarded to be major factors limiting sheep and goat production. Climate and season greatly influences feed supply and quality of the feed. Unreliability of roughage production, especially during drought periods, is also a problem. The current survey revealed, however, that a high percentage of both smallholder and pastoral/extensive farmers fed supplements during both dry and wet seasons, especially minerals. Roughage was fed by many farmers in both production systems, but pastoral/extensive farmers rarely purchased concentrates confirming that small ruminants tend to be kept in low-input systems. Although the feed quality and quantity of many tropical grasses is often inadequate (e.g., Carles, 1983; Gatenby, 1986; Charray et al., 1992), it would appear from this survey that farmers are doing their best to attend to the nutrition of their stock from their limited means. Use of genotypes that are adapted to efficiently utilise poor quality feed (Baker and Rege, 1994) may be one option but this trait was not included amongst those used to characterise breeds in this survey.

3.4.4. Socio-economic aspects

Although not studied in the present survey the different socio-cultural ways of different communities (e.g., the Maasai of Narok and Trans-Mara districts and their Samburu counterparts in Laikipia compared with Kikuyu smallholders of Nyeri) will be important to consider in the adoption of any breeding programme. Previous improvement programmes of small ruminants ignored this fact and ended up unsatisfactorily (e.g., Sölkner et al., 1998; Rewe et al., 2002). The difficulty, however, is that the infrastructure necessary for collection of reliable pedigree and performance data does not exist (Kiwuwa, 1992) and, furthermore, it is unlikely that performance recording is logistically feasible in large numbers of smallholder flocks (Baker and Gray, 2003).

Farmers sold their stock primarily to butchers, and also to individual farmers and at auctions, but hardly ever to abattoirs, suggesting possibilities of none-competitive prices. Animals were often sold throughout the year, presumably often when prices were low, and this supports the results of other reports indicating that *ad hoc* sales of animals to meet emergencies prevail (e.g., Seleka, 2001). Farmers would likely not adopt improved management practices whilst proceeds from sale of animals are low (Seleka, 2001). Some farmers, however, only sold in dry or wet seasons, indicating a necessity to explore the possibilities of organised marketing of animals so that farmers can reap maximum benefit from sales. Current marketing information in the tropics is largely informal and obtained by talking to buyers or sellers who have conducted transactions. The fact that most butchers/traders were paying premium prices for pure exotic and indigenous X exotic crosses of both sheep and goats could influence the type of genotypes adopted by the farmers. However, the relative sheep prices found in the current study are very similar to the 40-60% advantages observed by Baker et al. (2003a) in live weight for Dorper versus Red Maasai sheep in a semi-arid environment in Kenya. Therefore, it is possible that butchers or traders were paying more for heavier exotic animals or exotic crosses (and not, for example, for any improved conformation) with the price per kg probably constant across stock classes.

3.5. Conclusion

The results from the present survey reveal several constraints that need to be taken into consideration when designing and implementing genetic improvement programmes for sheep and goats. It is thus necessary to look at the production system in a holistic way and involve target groups in devising effective small ruminant breeding programmes. An integrated systems approach to small ruminant improvement is likely to be the best option. For example, in a study of adoption of indigenous X exotic crossbred goats in smallholder production systems in Ethiopian highlands, Ayalew et al. (2003) found that the non-genetic improvement strategies – better feeding practices and greater attention to basic healthcare - were more successful than genetic strategies alone. The ultimate beneficiary in that study was the indigenous goat and not the exotic genotype that had been originally planned. If any genetic improvement is appropriate in the smallholder or pastoral/extensive environment in this study in Kenya, then emphasis of genetic improvement of the indigenous genotype may prove to be the best option.

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Chapter 4

Economic values for traits of meat sheep in medium to high production potential areas of the tropics

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Abstract

Breeding objectives were developed for meat sheep in smallholder production circumstances in the tropics. The traits considered were litter size, lambing frequency, pre-weaning, and post-weaning lamb survival to 12 months, ewe survival, lamb live weight at 12-month, mature ewe live weight, consumable meat, kg of manure dry matter sold per ewe per year and residual dry matter feed intake. Three evaluation situations were considered: (i) base with constant number of ewes, (ii) fixed feed resource and (iii) setting feed costs to zero. Sensitivity analysis of economic values to price levels of inputs and meat production was carried out. The fixed feed resource situation appropriately describes smallholder production circumstances. In the base situation, meat production accounted for about 88% of revenue and manure the remaining 12%. Variable costs represented about 95% of the total cost. For the fixed feed resource situation, economic values (US$ per ewe per year) were 12.94 for litter size, 10.18 for lambing frequency, 0.19 for pre-weaning lamb survival, 0.24 for post-weaning lamb survival, 0.36 for ewe survival, 1.02 for 12-month lamb live weight, 0.14 for mature ewe live weight, 0.51 for consumable meat, 0.08 for kg of manure dry matter sold (per ewe per year) and -0.04 for residual dry matter feed intake. Litter size and lambing frequency were the most important traits in a breeding objective for smallholder production. Relative to the base situation, setting feed costs to zero had similar results as the situation with restricted feed resource but resulted in larger differences. Sensitivity analysis of economic weights to changes in prices and production circumstances indicated that future economic values for traits might change dependent on levels of output and prices. The exceptions, with regard to changes in meat price are kg of manure dry matter sold per ewe per year and residual dry matter feed intake, and with regard to feed costs are consumable meat and kg of manure dry matter sold per ewe per year. Economic values for 12-month lamb live weight, mature ewe live weight, consumable meat, kg of manure dry matter sold per ewe per year and residual dry matter feed intake were not sensitive to changes in management and marketing circumstances. Caution is recommended when the breeding objectives presented here are applied not to

disadvantage smallholders in poor climatic years, when farmers are at their most vulnerable situation.

(***Key Words***: Sheep; Breeding objectives; Economic values; Smallholder farmers; Tropics)

4.1. Introduction

The potential and scope of sheep as producers of meat in the tropics, especially in the arid and semi-arid areas, is well recognized (Upton, 1985; Gatenby, 1986; Winrock, 1992; Rege, 1994; Peeler and Omore, 1997). The production of sheep meat is largely from indigenous breeds and application of objective breeding methods is rare. Sheep in the tropics are a form of investment that is a quick source of cash, especially in the predominantly minimal-input traditional production systems (Upton, 1985; Gatenby, 1986; Lebbie and Ramsay, 1999). Generally, sheep are successfully integrated with arable systems and also with other livestock species in smallholder production (Upton, 1985; Ponzoni, 1992; Rege, 1994) and they usually graze non-arable areas of the farm (Rege, 1994) such as hilly and rocky grounds.

Animal breeding generally aims to obtain a successive generation of animals that will produce desired products more efficiently under future farm economic and social circumstances than the present generation of animals (Groen, 2000). Definition of the breeding objective is generally regarded as the primary step in the development of structured breeding programs (Harris, 1970; Danell, 1980; Ponzoni, 1986). The breeding objective involves calculation of economic values for all biological traits that have an impact upon profitability (James, 1982, 1986).

Formal breeding objectives for subsistence production systems are scarce in the tropics (Amer et al., 1998). Detailed economic assessments of costs (C) and revenues (R) for tropical areas are rare. Likely factors contributing to this situation include illiteracy, lack of record keeping, small flock sizes and the many roles animals play in smallholder systems (e.g., as a form of insurance, banking reserve, source of prestige, etc.). This has forced animal breeders in the past to just define breeding objectives in purely biological terms (Franklin, 1986). In the biological definition, *C* and *R* are expressed in energy and/or protein terms, and in the economic definition the expression is usually in terms of money. The biological definition is not ideal because not all *C* and *R* can be expressed in terms of energy and/or protein (Groen, 1989).

A wide array of livestock production systems with different major outputs exist in the tropics (Carles, 1983; Rege, 1994). The present paper focuses on the development of a breeding objective based on a profit function (US$ per ewe per year) including the specification of revenue and feed and other costs of production for an indigenous meat sheep population reared under smallholder farming, taking production circumstances in Kenya as a working example. In the context of this study, smallholder refers to production circumstances found in both the high-potential and medium-potential areas (Rege, 1994), with basic pest and disease control measures. Smallholder farmers, unlike commercial ones, tend to keep animals for family needs, rather than purely as an economic enterprise, and so do not necessarily have the motivation to gain from increased production, especially if increased production also involves increased risks (Amer et al., 1998). In this system, livestock may provide agricultural inputs, such as manure and render the enterprise more productive and more secure by using residual capacities of production factors with low opportunity costs such as non-arable land, excess labour, by converting crops and crop residues into high value animal products and by balancing production and market risks (Jahnke, 1982).

A point to note is that poor climatic years, when smallholders are most vulnerable, were not modelled in the current study and the breeding objectives calculated should be carefully applied not to disadvantage them. The model used in the present study will be extended to include intangible benefits (banking, insurance and prestige) and extended to develop breeding programmes in subsequent papers.

4.2. Materials and methods

4.2.1. Model description and definitions

In the selection index theory, the aggregate genotype (i.e., the breeding goal) is usually defined as a linear function of traits to be improved, each multiplied by its economic value, which is the value of a unit change in the trait while keeping the other traits in the aggregate genotype constant (Hazel, 1943). In this study, a deterministic static model that assumes no variation in characteristics among animals was used for calculation of economic values (EVs) for important traits of meat sheep. The model describes quantitative relationships between levels of genetic merit for the traits considered and levels of output of the farm. It assumes a constant environment, which may not always be the case. Total annual profit of the flock was derived as the difference between costs and revenues of the system as shown in Eqs. (1)–(3). Throughout this study all costs and prices are expressed in US dollars ($). The productive unit is the ewe and the time unit is 1 year. The inputs for the production system were roughage feed, management (i.e., labor, spraying or dipping, veterinary services and mineral supplements), marketing (i.e., transport of live animal and carcass, and levies for auction, slaughter and meat inspection) and fixed costs. The outputs are the revenues from sale of cull-for-age ewes and rams, surplus yearlings, and manure from all the categories of animals.

Table 4.1 describes the assumptions made for the input variables of the model. The input parameters were derived from the literature, the market, farmers and expert opinions. Seasonal variation in animal performance and prices were not included in the model. The cost of recording in the flock or application of the selection index was ignored. To simplify the situation all the carcasses were assumed to have the same grade and the different cuts of the carcass to have the same price. The amount of manure was derived for each category of animals based on the assumed amount of roughages fed and their digestibility. In the calculation, a linear relationship of manure with feed intake was assumed. As animals are usually kept in penned enclosures at night (Gatenby, 1986; Jaitner et al., 2001) for security

Table 4.1. Overview of the assumed values of the input variables of the model[a]

Variables	Abbreviation	Value	Variables	Abbreviation	Value
Production variables					
Average daily gain lambs (g per day)	-	80.00	Mortality rate of ewes (% per year)	m_5	10.00
Average daily gain yearlings (g per day)	-	60.00	Mortality rate of lambs (% per year)	m_1	20.00
Birth weight (kg)	-	3.00	Mortality rate of rams (% per year)	m_6	10.00
Body weight at 12 months of age (kg)	12mLW	25.00	Mortality rate of replacement males and females (% per year)	m_3 and m_4	10.00
Consumable meat (%)	CM	60.00	Mortality rate of yearlings (% per year)	m_2	15.00
Litter size (average over parities per ewe lambing per year)	LS	1.18	Weaning rate (lambs per ewe per 12 months)	-	1.27
Mature weight of ewes (kg)	ELW	30.00	Weaning weight (kg)	-	10.00
Mature weight of rams (kg)	-	40.00			
Management variables					
Age at attainment of mature weight (months)	-	18.00	Fraction of cull-for-age ewes, excluding mortality (8 years)	-	0.12
Age of ewe at first lambing (months)	-	18.00	Fraction of cull-for-age rams, excluding mortality (2 years)	-	1.00
Age at first mating (months)	-	12.00	Fraction of yearlings sold at hogget or wether age (12 months)	-	0.82
Age of replacement stock at selection (months)	-	12.00	Lambing frequency (lambings per ewe per year)	LF	1.50
Age of surplus yearlings when sold (months)	-	12.00	Ram culling age (years)	-	2.00
Ewe culling age (years)	-	8.00	Weaning age of lambs (months)	-	3.00

Table 4.1. *continued*

Variables	Abbreviation	Value	Variables	Abbreviation	Value
Feed intake variables					
Average roughage intake for ewes (kg DM per head per day)	RF_5	0.60	Average roughage intake for replacement stock (kg DM per head per day)	RF_3 and RF_4	0.60
Average roughage intake for lambs (kg DM per head per day)	RF_1	0.20	Average roughage intake for yearlings (kg DM per head per day)	RF_2	0.43
Average roughage intake for rams (kg DM per head per day)	RF_6	0.68			
Management costs (C_h) per adult ewe					
Dipping ($ per head per year)	$C_{d:y}$	1.70	Helminth control ($ per dose per head)	C_{wc}	0.39
Drugs and veterinary service charge ($ per head per year)	C_v	1.50	Mineral supplements ($ per head per year)	C_{ml}	2.70
Marketing costs (C_m)					
Costs of animal sale and slaughter ($ per head)	C_l	2.00	Transport of live animal to market ($ per head)	C_t	0.71
Prices					
Manure price ($ kg^{-1})	P_o	0.02	Labour costs ($ per shepherd per 100 head per month)	P_{lb}	25.71
Meat price ($ kg^{-1} carcass)	P_m	2.00	Roughage feed price ($ per kg^{-1} DM)	P_{rf}	0.04
Fixed costs ($ per head per year) – fencing, troughs, equipment, etc.	FCF	1.00			
Manure					
Amount collected (% DM intake per head per day)	O	50.00			

[a]All costs and prices in US$, US$1.00 ≈ Kshs. 70.00 (Kenya shillings) at the time.

reasons, it was assumed that only half the days' manure was collected then because of the difficulty to collect it during the day when animals are grazing in the fields. Farm-gate price was assumed for manure sold and therefore no transport or marketing costs were incurred.

The number of animals slaughtered for home consumption was considered to be negligible, although this may not always be true. Therefore, receipts from skin sales were considered to accrue to the butcher and were excluded from revenue calculations. Relatively few breeds of sheep indigenous to the tropics are utilized for wool (e.g., Gatenby, 1986). Consequently, this study focused on meat and hair or wool were ignored, especially in light of poor prices and lack of organized markets for these products prevailing at the moment.

It was assumed that the fresh grass consumed by the sheep was produced on the farm and that no commercial concentrate feed was provided to the animals. Supply of labour by the farmer was set to be fixed per animal per year but varied with the size of the flock. It was considered equal for all animal categories except for replacement stock that were considered to require half the amount of labour per animal. Replacement stock was assumed to need less care than the young stock and breeding animals. Opportunity cost for the farmer's labour for other farm tasks in smallholder farming systems was used to arrive at the cost of labour. Veterinary care was assumed to be optimal and therefore, reasonable average costs have been used. Eqs. (4)–(6) give details on derivation of the variable costs. Other costs not related to flock size were included in the fixed costs.

4.2.2. Animal flows and events

Fig. 4.1 shows a diagram of animal events and animal flows of a hypothetical flock of 100 ewes assumed for convenience of calculations. This represents the number of ewes present over the entire period. The values calculated can be re-scaled to any desired flock size. Six animal categories were distinguished according to age: (1) lambs (0–3 months old); (2) yearlings (4–11 months old); (3) replacement

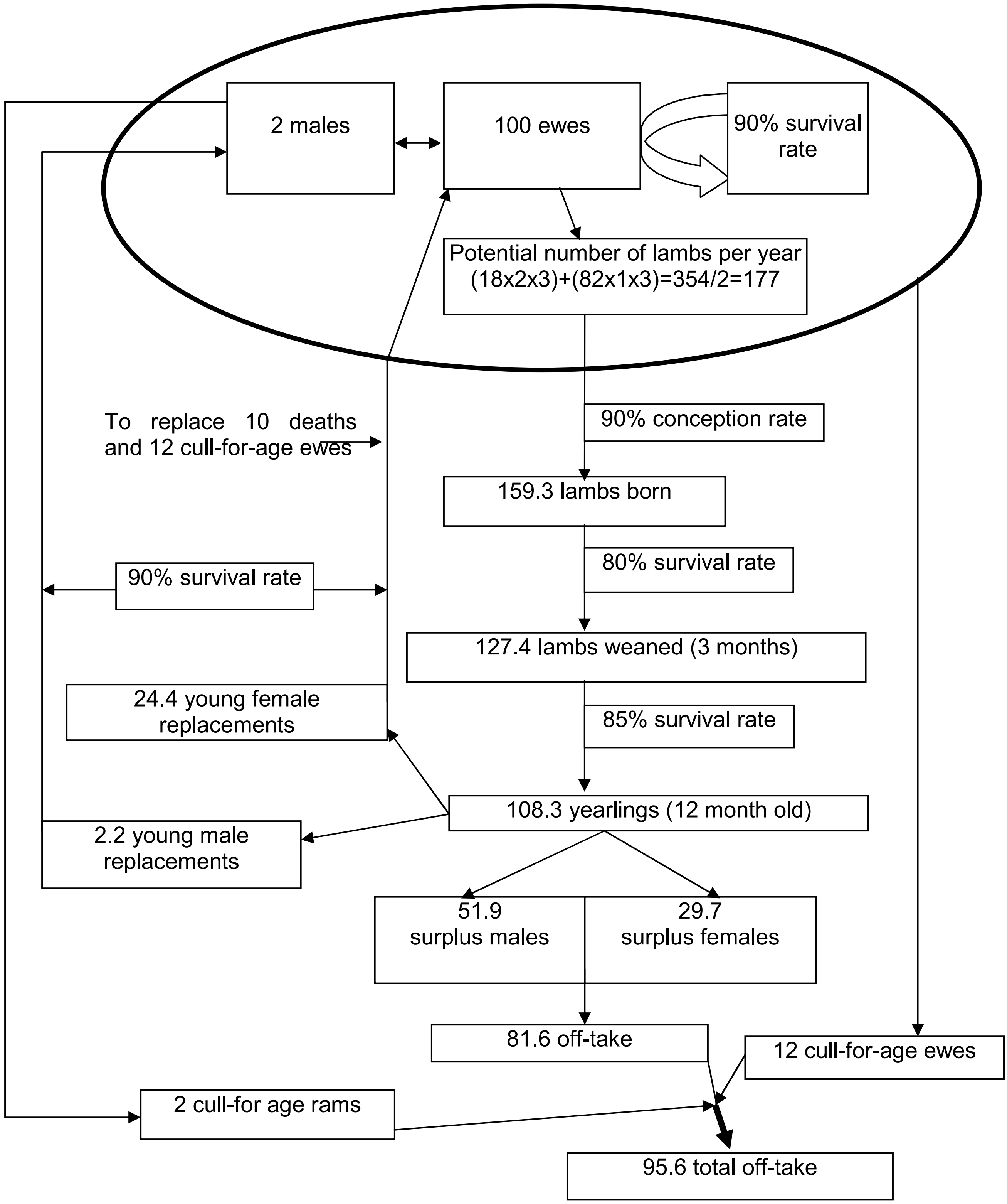

Fig. 4.1. Flock dynamics for an indigenous meat sheep

females (12–18 months old); (4) replacement males (12 months old); (5) breeding ewes (>18 months old) and (6) breeding rams (>12 months old).

It was assumed that 50% of lambs born were males although some reports indicate varying sex ratios in tropical sheep, e.g., 56% males (Adu et al., 1985 cited by Olayiwole and Adu, 1988), 49% males (Seabo et al., 1994), 50% males (Odubote, 1992), etc. All males not required for breeding were assumed to have been castrated before weaning while all breeding males were assumed to have been culled after 1 productive year at 2 years of age.

The length of the breeding season varies for sheep but near the equator all-year-round breeding can occur, although there may be seasonal differences in ovulation rates (Turner, 1985). Consequently, the frequency of lambing per ewe was set at three times in 2 years (Mason, 1980; Carles, 1983; Wilson, 1985) although this usually varies from one production system to another, with breeding management (Wilson, 1985), and breed of sheep. Twinning rate was assumed to be 18% (Semenye and Musalia, 1990). A single-born lamb was assumed to have the same value as a twin-born lamb. With the assumed 90% conception rate, the proportions of ewes with 0, 1 and 2 lambs were derived to be 0.1, 0.74 and 0.16, respectively. The figures were then adjusted to a 12-month basis by multiplying by 1.5. This study assumed that half of the pre-weaning lamb mortality (m_1) occurred in the first week after birth with no costs incurred. The remaining half (10%) was assumed to occur equally between 1.5 and 3 months of age. Post-weaning lamb mortality (m_2) was set to occur equally between 6 and 9 months after weaning. The mortality rate of replacement stock (m_3 and m_4) was assumed to be 5% up to 15 months and 5% up to 18 months of age. Breeding ewe (m_5) and ram (m_6) annual mortality rate was assumed to be distributed equally for the entire period.

4.2.3. Profit equations

Total annual profitability of the sheep flock (T_f) was described by the following equation:

$$T_f = [N_e \times (R_e - C_e)] - C_{FCF} \quad (1)$$

where N_e is the number of ewes in the flock per year, R_e the average revenue, per ewe per year, C_e the average variable costs, per ewe per year, excluding C_{FCF} and C_{FCF} the fixed costs, per flock per year.

The revenue (R_e) was calculated from equation 2 as the sum of three revenues:

R_e = surplus yearlings meat + cull-for-age ewes and rams meat + manure

$$R_e = \sum_{i=1}^{6}[N_i \times f_i \times (1-m_i) \times (LW_i \times \frac{CM_i}{100}) \times P_m] + \sum_{i=1}^{6}[N_i \times f_i \times O_i \times P_o] \quad (2)$$

where *i* is the animal category (1—lambs; 2—yearlings; 3—replacement females; 4—replacement males; 5—breeding ewes and 6—breeding rams), *N* in this and the following equations *N* refers to number of animals present relative to number of ewes present, *f* the fraction of animals that are slaughtered in case of meat or producing manure in case of manure, *m* the mortality rate of animals (%), LW the live weight at slaughter of an animal (kg), CM the consumable meat, including 20% offal at half price of meat of an animal, P_m the price kg^{-1} of meat, *O* the manure production of an animal (kg per year) and P_0 the price of manure. The variable costs (C_e) were calculated from Eq. (3) as the sum of three costs:

C_e = feed + management + marketing

$$C_e = \sum_{i=1}^{6} N_i \times [C_{f_i} + C_{h_i} + C_{m_i}] \quad (3)$$

where C_f is the roughage costs per animal, C_h the management costs per animal, and C_m the marketing costs per animal. Average feed costs (C_f) were described by the following equation:

$$C_f = \sum_{i=1}^{6}[N_i \times \mathrm{RF}_i \times L_i \times P_{\mathrm{rf}}] \quad (4)$$

where RF is the daily DM roughage feed requirements for maintenance, growth and reproduction per animal, L the number of days an animal is present in the year, and P_{rf} the price kg^{-1} of DM roughage. Average management costs (C_{h}) were described by the following equation:

$$C_{\mathrm{h}} = \sum_{i=1}^{6}[N_i \times \{P_{\mathrm{lb_i}} + C_{\mathrm{wc_i}} + (N_{\mathrm{d:y_i}} \times C_{\mathrm{d_i}}) + C_{\mathrm{v_i}} + (D_{\mathrm{ml_i}} \times L_i \times P_{\mathrm{ml}})\}] \tag{5}$$

where P_{lb} is the opportunity cost of labour per year per animal, C_{wc} the average cost of helminth control per year per animal, $N_{\mathrm{d:y}}$ the average number of dippings per year per animal, C_{d} the per cost dipping per animal, C_{v} the average cost of veterinary services (drugs for incidental sicknesses, service charge, vaccinations, castration, tail-docking, etc.) per year per animal, D_{ml} the average daily mineral requirements per animal, L the number of days an animal is present in the year and P_{ml} the average price kg^{-1} of mineral.

Average marketing costs (C_{m}) per animal sold were described by the following equation:

$$C_{\mathrm{m}} = \sum_{i=1}^{6}[N_i \times f_i \times (C_{\mathrm{t_i}} + C_{\mathrm{l_i}})] \tag{6}$$

where f is the fraction of animals that were sold, C_{t} the cost of transport of live animal to the market and C_{l} the levies charged (auction fee, slaughter fee, meat inspection fee and carcass transport) per animal.

4.2.4. Elements of the model

4.2.4.1. Traits studied

Table 4.2 presents the traits, units and assumed values in the breeding goal that were studied using the model.

Table 4.2. List of breeding goal traits evaluated in this study

Trait	Unit	Abbreviation
Litter size	Average number of lambs born over parities, per ewe lambing per year	LS
Lambing frequency	Average number of lambings per ewe per year	LF
Pre-weaning lamb survival	Lambs surviving to weaning as a % of lambs born	PRWS
Post-weaning lamb survival	Lambs surviving to 12 months of age as a % of lambs weaned	PWS
Ewe survival	Ewes surviving as a % of ewes present over the year	ES
12-month lamb live weight, i.e., live weight at slaughter	kg	12mLW
Mature ewe live weight	kg	ELW
Consumable meat	Consumable meat output as a % of live weight at slaughter	CM
Manure sold	kg dry matter (DM) per ewe per year, i.e., summed over all animal categories in flock and then expressed on per ewe basis	MS
Residual feed intake	kg dry matter (DM) per ewe per year, i.e., summed over all animal categories in flock and then expressed on per ewe basis	RFI

4.2.4.2. Derivation of economic values (EVs)

Economic values for the traits considered were calculated for the following three different situations: (i) base with constant number of ewes; (ii) fixed feed resource for flock and (iii) setting feed costs to zero with constant number of ewes. The EV for a trait was defined as the change in flock profit (T_{f1}) resulting from a unit change in that trait, assuming all other traits remain constant. The EVs were calculated by evaluating T_{f1} numerically as the average value for all traits, then evaluating it after incrementing by one unit the trait in question (thus obtaining T_{f2}), and taking the difference T_{f2}-T_{f1} (Ponzoni, 1992). A point to note, however, is that in the current study, changes in *C* and *R* were given per percentage change in the trait considered while EVs were per unit change of the trait. Therefore, EVs in Table 4.4 may not be derived directly as the differences in total marginal *C* and *R*. Also discrepancies may arise due to rounding, since more decimals were used in the calculation of EVs than are presented in the table.

Residual feed intake (RFI) is the feed that cannot be accounted for, and is a linear function of feed intake, production and maintenance of body weight, and as such is an appealing characteristic to reflect production efficiency (van der Werf, 2001). Therefore, EV for RFI was derived as the difference between actual feed intake and that predicted from expression of other traits, i.e., maintenance, growth, reproduction and lactation. To be able to easily compare EVs from the different production situations studied (Table 4.4), relative economic values (REVs) were calculated by arbitrarily taking the EV for 12mLW as the standard.

Following the approach of Smith et al. (1986), the EVs under constant roughage-input were calculated according to the following equation:

$$\mathrm{EV} = \frac{((\Delta T_{f2} / \Delta t) - (\Delta \mathrm{FI}/\Delta t) \times (T_{f1} / \mathrm{FI}))}{N} \qquad (7)$$

where T_{f1} is the flock profit per year before genetic improvement, ΔT_{f2} the marginal change in flock profit per year after genetic improvement; FI the feed intake per ewe before genetic improvement (kg DM); ∆FI: marginal change in feed intake, per ewe after genetic improvement (kg DM), Δt the marginal change in trait (units of the trait) and N the number of ewes present (100).

4.2.4.3. Parameters in the base situation

Production level parameters used were chosen to represent an indigenous meat sheep under smallholder farming systems in Kenya, and price parameters represent average values in the country for the period 1999–2000. Table 4.1 gives the parameters that were used in the base situation.

4.2.5. Animal level

4.2.5.1. Feed intake

Energy intake was calculated from energy requirements for maintenance and production (growth, reproduction and lactation). Feed intake was defined in terms of dry-matter intake and composition of feed intake. For fresh grass and roughage, no prices were reported. Therefore, the price of a kg DM of roughage was set equal to half the cost of a kg DM of grass hay on the market. The reference roughage feed was green uncut kikuyu grass (*Pennisetum clandestinum*) which contains 20% DM.

It was assumed that lambs start consuming roughage from 1 month of age, and that they get half of their energy requirements from roughage and the other half from milk for that period up to weaning. Both male and female progeny were considered to have the same growth rate up to 12 months of age. Relative to pregnant ewes with single lambs, non-pregnant ewes were assumed to have 20% lower energy requirements. Breeding rams were assumed to consume the same amounts as pregnant ewes with single lambs to cater for higher maintenance requirements. Average live weights for animals used to calculate the amount of roughage consumed were 32.5 kg for rams and replacement males, 27.5 kg for ewes and replacement females, 17.5 kg for yearlings and 6.5 kg for lambs.

4.2.5.2. Dry matter intake

The animals were assumed to have received roughage *ad libitum*. Dry matter requirement was calculated from estimates of the mean intake of metabolizable energy by the various age and physiological categories, and weights of animals grazing on natural pasture in the tropics (Gatenby, 1986).

4.2.5.3. Energy level

Limited information is available on energy requirements for tropical sheep and energy values of tropical feeds. Eqs. (8)–(15) presented by Gatenby (1986) for tropical sheep kept outdoors were used to calculate the daily energy requirements. These are based on information from Ministry of Agriculture, Fisheries and Food (MAFF) (1975) for sheep under favourable conditions and are related to body weight (LW in kg). The recommendations given include a 5% safety margin (Gatenby, 1986). A further 15% was included for maintenance requirements because of the physical activity of grazing that increases the energy expenditure (Charray et al., 1992).

Energy requirements for maintenance (ME_m) in MJ per day was:

ME_m=1.8 + 0.1 LW for pregnant and lactating ewes (8)

and,

ME_m = 1.4 + 0.15 LW for growing and fattening sheep (9)

Energy requirements for growth (ME_g) in MJ per day was:

$ME_g = NE_g\, kg^{-1}$ (10)

where *kg* is the efficiency of utilization of ME for growth, and was calculated from the concentration of ME in the dry matter (M/D MJ kg^{-1}) of the feed according to:

$$k_g = \frac{0.0435M}{D} \tag{11}$$

and net energy for growth (NE_g) was derived by:

$$\log_{10} NE_g = 1.11 \log_{10} LWG + 0.004\ LW - 2.10 \tag{12}$$

Energy requirements for pregnancy (ME_p) in MJ per day were:

single lambs : $ME_p = (1.2 + 0.05LW) \exp 0.0072t$ (13)

twin lambs : $ME_p = (0.8 + 0.04LW) \exp 0.0105t$. (14)

where t is the number of days pregnant. Energy requirements for lactation (ME_l) in MJ per day were:

$$ME_l = 7.4MY \tag{15}$$

where MY is milk yield.

Milk yield was assumed to be 0.6 kg per day for ewes nursing single lambs and 50% more for ewes with twins (Gatenby, 1986).

4.2.5.4. Composition of feed

In vivo DM digestibility of kikuyu grass was assumed to be about 500g kg^{-1} DM (Minson, 1972; Hacker and Minson, 1981) and the average gross energy digestibility to be 3% lower than that of DM (Jeffery, 1971). Therefore in this study, gross energy digestibility of this grass was taken to be 47%. The grass was assumed to have an average ME content of 6.52 MJ kg^{-1} DM (Herrero, 1997; Vargas et al., 2002).

4.2.5.5. Management

Table 4.1 presents costs of management per adult animal. Three components were considered for healthcare: general drugs and veterinary services, anthelmintics and ecto-parasite control. It was assumed that lambs and yearlings each used one-quarter and one-half the amount of drugs and veterinary services compared to adult ewes, respectively. On an animal basis, replacement stock were assumed to have used the same doses and services as adult ewes. Lambs were assumed to be dewormed at weaning and then twice every 4.5 months after weaning, respectively. Deworming was set to be twice per year for replacement stock and once for breeding animals. Relative to ewes, anthelmintic doses were assumed to be a half and three-quarters for lambs and yearlings, respectively. Spraying or dipping of animals was assumed to be twice per month. Lambs were scheduled to be sprayed or dipped for the first time at 2 weeks of age with half the cost of an adult animal.

Lambs were assumed to obtain half the amount of mineral supplements compared to the rest of the flock starting from the second month of age up to weaning. Management activities like tail docking, castration and dehorning were assumed to have been carried out by the farmer and did not require extra cost. Labour requirements were calculated by assuming one shepherd per 100 head of sheep working for 8 hours per day. It was assumed that the worker earned about \$25.71 per month, which was approximately equal to \$0.11 man-hour^{-1}.

4.2.5.6. Marketing

Marketing costs were assumed to be uniform for all animal categories sold. These were calculated as the sum of the average costs incurred between buying of a live animal and selling its carcass. On an animal basis, transport of live animal to the market, slaughter, and carcass transport were each estimated to be \$0.70 while auction and carcass inspection each cost about \$0.30. Slaughter charges, carcass inspection fee and carcass transport were assumed to be charged to the farmer because traders intrinsically reduce the price of the live animal by the same margin.

4.2.6. Changes in prices

Additional analysis was performed on the sensitivity of the EVs to changes in price levels of feed, management, marketing and meat. Changes of ±20% with respect to the original values were considered, under the base situation with constant number of ewes. Changes were performed one at a time, keeping all other parameters constant.

4.3. Results and discussion

4.3.1. Revenues, costs and economic values for the situations studied

4.3.1.1. Base situation

Table 4.3 presents the costs, revenues and profit for the base situation. The values presented are weighted by proportions of each animal category with respect to number of ewes present, and the totals are expressed per ewe per year. For instance, feed cost for 1.27 lambs was $2.68 and meat revenue from 0.82 yearlings was $25.72. Feed cost per ewe per year was $39.49 whereas the total profit per ewe per year was $-34.16. Surplus yearlings contributed an output of $27.39. However, this category of animals had a total cost of $29.48, resulting in negative profit. Variable costs represented about 95% of the total costs with feed costs being the most important accounting for approximately 57%. Cost of labor was about three-fold that of marketing, which was relatively lower. Fixed costs for the flock were minimal and are not expected to affect EVs for the traits studied.

Smith et al. (1986) and Ponzoni (1988) examined the implication of combining *C* and *R* in different ways. When *C* and *R* are combined as a difference, EVs are independent of the fixed costs of the flock. This eliminates the need to determine the magnitude of fixed costs, especially in developing sheep industries, particularly if the sheep are integrated to other farming activities or share some of the other facilities with another species (Ponzoni, 1992). Table 4.4 gives the initial costs and revenues,

Table 4.3. Costs and revenues per proportion of animals in each category to number of ewes present in the base situation, and profits ($) per ewe year in all the situations considered

	Animal category									
	Lambs	Yearlings off-take	Replacement		Breeding ewes[a]	Cull ewes[b]	Breeding rams[a]	Cull rams[b]	Total[c]	Percentage of total
			Females	Males						
Proportion of animals to ewes	1.27	0.82	0.24	0.02	1.00	0.12	0.02	0.020		
Input										
Feed	2.68	15.70	2.86	0.27	17.72	-	0.26	-	39.49	56.94
Management[d]	2.52	10.66	1.30	0.12	9.14	-	0.19	-	23.93	34.51
Labour[e]	1.06	3.67	0.28	0.02	3.01	-	0.06	-	8.10	11.70
Marketing	-	2.21	-	-	-	0.33	-	0.05	2.59	3.73
Fixed costs	1.30	0.91	0.12	0.01	0.98	-	0.02	-	3.34	4.82
Total	6.50	29.48	4.28	0.40	28.17	-	0.52	-	69.35	100.00
Output										
Meat	-	25.72	-	-	-	4.32	-	0.96	31.00	88.09
Manure	0.28	1.67	0.30	0.03	1.88	-	0.03	-	4.19	11.91
Total	0.28	27.39	0.30	0.03	6.20	-	0.99	-	35.19	100.00
Profit for each situation										
Base	-6.22	-2.09	-3.98	-0.37	-21.97	-	0.47	-	-34.16	
Fixed feed resource									-34.16	
Setting feed costs to zero									5.34	

[a]Meat output from footnote (b). [b]Input parameters already accounted for in breeding groups. [c]Weighted by animal proportions.

[d]Deworming: 2%; drugs and veterinary charges: 5%; ectoparasite control (dipping): 8% and mineral supplements: 9%.

[e]Already included in management.

marginal changes and EVs ($ per ewe per year) for traits for the base situation with constant number of ewes. The marginal values are weighted by animal proportions and result from a unit change in the genetic merit of the trait considered. For example, the initial total management cost was $23.93 and increased by $0.13 when LS and LF were each increased by one unit. Likewise, the initial total meat revenue was $31.00 and increased by $0.32 when ES was increased by one unit. The traits LS, LF, ELW and RFI had negative EVs. Marginal changes in costs linked to genetic improvement of the first three traits were higher than the associated changes in revenues. As would be expected, increase in genetic merit of RFI did not affect revenue, but resulted in a marginal increase of $0.39 for feed costs. For this reason, its EV was negative. The consequences of a change in LS and LF were equal, as expected. Improvement of LS, LF, PRWS and PWS resulted in the same marginal change of $0.34 for meat revenue and $0.03 for marketing costs. However, the EV for PRWS was negligible. ES had a higher EV than PRWS and PWS. Genetic improvement of ES gave a marginal change of $0.30 in revenue. Improvement of this trait yielded a negative marginal value for manure revenue due to the reduction in number of replacement females reared. Marginal feed and management costs associated with genetic improvement of ES were also negative. As expected, CM did not have an effect on costs of production.

4.3.1.2. Fixed feed resource

The EVs for the traits for the situation with fixed feed resource are shown in Table 4.4. Scarcity of feed is often experienced in the tropics, especially due to seasonal rain patterns. Feed supply can also be restricted by the available land for grazing as is mostly the case in smallholder production circumstances. Under a fixed roughage-input system, the EVs for all the traits included in the study were positive, except that for RFI. Relative to the base situation, the EVs for the traits increased except that for ES that decreased by about 28% (but in REV terms decreased by 54%), and for CM, MS and RFI that were not affected. EVs for LS and LF increased tremendously with REVs of 12.69 and 9.98, respectively.

Table 4.4. Initial costs and revenues per ewe per year with marginal changes for the base situation after a 1% increase in genetic merit for traits, and economic values ($ per ewe per year) per unit increase in genetic merit for traits under the base situation, situation with fixed feed resource and situation setting feed costs to zero[a]

Base situation	Initial	Trait[b]									
		LS	LF	PRWS	PWS	ES	12mLW	ELW	CM	MS	RFI
Costs											
Feed	39.49	0.18	0.18	0.18	0.14	-0.14	0.10	0.06	0.00	0.00	0.39
Management	23.93	0.13	0.13	0.13	0.09	-0.03	0.00	0.00	0.00	0.00	0.00
Marketing	2.59	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00
Fixed costs	3.34	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Revenue											
Meat	31.00	0.34	0.34	0.34	0.34	0.32	0.26	0.04	0.31	0.00	0.00
Manure	4.19	0.02	0.02	0.02	0.01	-0.02	0.01	0.01	0.00	0.04	0.00
Economic values for the different situations (relative economic values[c])											
Base		-0.53	-0.42	0.00	0.10	0.50	0.66	-0.03	0.51	0.08	-0.04
		(-0.80)	(-0.64)	(0.00)	(0.15)	(0.76)	(1.00)	(-0.05)	(0.77)	(0.12)	(-0.06)
Fixed feed resource		12.94	10.18	0.19	0.24	0.36	1.02	0.14	0.51	0.08	-0.04
		(12.69)	(9.98)	(0.19)	(0.24)	(0.35)	(1.00)	(0.14)	(0.50)	(0.08)	(-0.04)
Setting feed costs to zero		15.04	11.83	0.22	0.26	0.34	1.07	0.17	0.51	0.08	0.00
		(14.06)	(11.06)	(0.21)	(0.24)	(0.32)	(1.00)	(0.16)	(0.48)	(0.07)	(0.00)

[a]Changes in costs and revenues are given per % change in trait while EVs are per unit change of the trait.
[b]See Table 4.2 for definition of units and abbreviations. [c]Relative economic values given in brackets.

Few studies (e.g., Ponzoni, 1986, 1988, 1992) have made an attempt to examine EV for feed intake as a trait in the breeding objective. Maintaining feed costs constant affected the EVs for number of lambs weaned (NLW) and both yearlings (OFI) and ewe feed intake (EFI), but not for other traits (Ponzoni, 1992). Therefore, the fixed feed resource situation is deemed appropriate because when re-scaling to fixed feed supply is done, EVs are independent of feed costs. This resolves the problem of variation in the model. In addition, there will be no need to explicitly assign a value to the feed (Ponzoni, 1992), thus avoid the complication of costing feed as was attempted in the current study.

4.3.1.3. Setting feed costs to zero

The EVs for the situation setting feed costs to zero and with constant number of ewes are presented in Table 4.4. Farmers in the tropics may have no other option of utilizing the land or the available forage on the farm and no costs are incurred in forage production (i.e., feed is a by-product). This was the basis of the situation setting feed costs to zero. This practice is common in pastoral range systems. The level of some inputs in this system could be lower than for common smallholder production. For instance, disease control costs would be minimal. As expected, setting feed costs to zero increased EVs for all the traits in this study except for ES that decreased, and CM and MS that remained the same. Relative to the base situation the EV for ES decreased by about 32% (but in REV terms it decreased by 58%). Large increases occurred in the EVs for LS and LF indicating that these traits are more important in pastoral situations. This was not surprising because lambs and yearlings accounted for almost half the total feed cost (Table 4.3). The EVs for traits in this situation followed approximately the same pattern as for the fixed feed resource situation (Table 4.4). The differences between EVs for traits in these two situations were generally minor. However, values under the situation setting feed costs to zero were higher except that for ES trait that further reduced to 0.34.

4.3.2. Sensitivity analysis

Table 4.5 shows the EVs for the traits considered and their sensitivity to price levels of production inputs and meat for the situation with constant number of ewes and accounting for feed costs. Sensitivity of EVs for traits to price levels of inputs or products gives information on the likely direction of future genetic improvement, and production system which has important implications for practical breeding programmes. It is shown that future EVs for responsive traits might change dependent on level of output and prices.

The sensitivities are discussed relative to the base situation. As is expected, EVs for MS and RFI were not sensitive to price levels of meat. EVs for all the other traits were sensitive. EVs increased with 20% increase in price levels of meat and vice-versa. For example, a 20% increase in price of meat resulted in \$0.08 increase in EV for PRWS and \$0.09 reduction when the price was reduced by 20%. Evidently, CM may become more relevant in future meat market circumstances. The EVs for CM (0.51) and MS (0.08) were not sensitive to cost levels of feed, management and marketing. From Table 4.4 it can easily be noticed that genetic improvement of these two traits did not alter feed costs and therefore, price changes of feed did not influence the two traits. Neither cost levels of management nor marketing affected the EVs for 12mLW, ELW and RFI. This implies that future production and marketing circumstances may not affect EVs for these traits. Twelve-month LW and ELW were not responsive to price levels of marketing due to the fact that transport to the market and marketing levies are charged on a per head basis although animals are basically sold on live weight basis. Generally, the costs of transportation to the market are highly variable on a per head basis. Increased cost levels of management and marketing had a negative effect on EVs for LS, LF and PRWS, and vice-versa. Increase in cost of marketing resulted in a slightly lower EV for ES. RFI was sensitive to price levels of feed only. Consequently, its EV decreased with increase in price level of feed. The opposite was true for 20% reduction in cost of feed.

Table 4.5. Economic values ($ per ewe per year) for traits for the base situation with changes in price levels of inputs and meat, and constant number of ewes

Input / Output	Price level (%)	Trait[a]									
		LS	LF	PRWS	PWS	ES	12mLW	ELW	CM	MS	RFI
Feed costs	-20	2.58	2.03	0.04	0.13	0.46	0.75	0.01	0.51	0.08	-0.03
	+20	-3.65	-2.87	-0.05	0.07	0.53	0.58	-0.07	0.51	0.08	-0.05
Management costs	-20	1.70	1.34	0.03	0.12	0.49	0.66	-0.03	0.51	0.08	-0.04
	+20	-3.77	-2.18	-0.03	0.08	0.50	0.66	-0.03	0.51	0.08	-0.04
Marketing costs	-20	-0.03	-0.03	0.00	0.11	0.50	0.66	-0.03	0.51	0.08	-0.04
	+20	-1.03	-0.81	-0.01	0.09	0.49	0.66	-0.03	0.51	0.08	-0.04
Meat	-20	-6.32	-4.97	-0.09	0.02	0.43	0.46	-0.06	0.41	0.08	-0.04
	+20	5.25	4.13	0.08	0.18	0.56	0.87	0.00	0.61	0.08	-0.04

[a]See Table 4.2 for definition of units and abbreviations.

4.3.3. Disease resistance

Disease resistance has been noted as an important attribute of some tropical sheep genotypes (e.g., Rege, 1994; Baker, 1998; Baker et al., 1999). Due to the fluctuating harsh environment in the tropics, both individual animal and flock survival are important. This may be associated with adaptation to physical conditions as well as disease tolerance. In the current study, survival was taken as the trait reflecting differences in disease resistance. PRWS, PWS and ES were taken as indicators of disease resistance as specific reasons could not be identified for mortalities, and consequently no costs of curing a particular disease could be calculated.

4.4. General discussion and conclusions

There are conflicting reports about profitability of small ruminants under traditional management in the tropics, with some indicating low productivity due to high mortality rates or low utilization rates (e.g., Seleka, 2001) and others profitability (e.g., Jaitner et al., 2001). Due to the greater environmental and managerial complexity in the tropics (Franklin, 1986), some simplifying assumptions have been made in the present study. For instance, a constant flock size was assumed which will not normally be the case. Generally, animals are kept in small flocks with fluctuating numbers. Ordinarily, there is variation both within and between regions in the age at which surplus stock are sold. In practice *ad hoc* sales of animals to meet emergencies prevail, unlike in the commercial systems, because sheep act as a reserve. In addition, well-defined replacement policies are not apparent and some animals may therefore stay longer in the flock than sound production practice would justify. Moll (2001) has suggested that when financing and insurance markets are absent or ill-functioning, as is the case in most rural areas of the tropics, animals provide benefits in financing and as insurance for future expenditure. However, emergency (premature) sales are associated with considerable losses in forgone yearlings, forgone live weight and when animals are sold in periods with low market prices, i.e., sales for financing and insurance cannot be optimally timed (Ifar, 1996;

Bosman et al., 1997; Slingerland and van Rheenen, 2000; Moll, 2001). Farmers are also likely to aim at a constant off-take by delaying sale of animals. These aspects are likely to reduce EVs for the traits considered.

Since smallholder farmers rarely put any effort into pasture production, the feed cost is likely to be greatly lower than the 50% of the market price of hay assumed currently. Consequently, EVs found in this study are likely to be reduced. Generally, live animal markets in most tropical areas are subject to seasonal variation but prices may not influence sales (Seleka, 2001). In the dry period when feed availability is low, most farmers may want to dispose of their animals, resulting in relatively low prices due to a glut in the market. The converse is true in the rainy season. However, the overall impact is not likely to be great (Seleka, 2001) except in severe and extended drought conditions. This study modelled moderate climates only. Modelling of poor climatic years may be necessary in future studies so that breeding objectives proposed do not disadvantage the smallholder farmers when they are at their most vulnerable situation.

Actual feed intake of sheep in this study was set equal to nutrient requirement norms, which may not always be the case. Since the opportunity cost of farmer's labour for other farming activities was used to derive labour expenses in the current study, the labour costs of \$8.10 per ewe per year (Table 4.3) would actually signify a saving to the farmer, and therefore, contribute to increased EVs. Similarly, exclusion of costs of recording or application of selection index would likely increase EVs for the traits. Where hair or wool production are relevant, the EVs are also likely to increase. In most tropical areas, almost all offal is cleaned and consumed by humans (Gatenby, 1986; Rege, 1994). Consequently, actual meat outputs from sheep in traditional production systems are expected to be higher (Rege, 1994). This suggests that CM might become more relevant due to market reactions in the long-term, as was apparent from its sensitivity to price levels of meat (Table 4.4). This may necessitate its inclusion in the breeding goal at some later stage.

From Table 4.6, the following can be deduced about REVs for traits from the current study and other studies in the tropics that used a similar approach. REV for PRWS under the base situation in the current study was lower than REVs for NLW

Table 4.6. Relative economic values (REVs) for some traits in different studies in the tropics for the base situations and situations setting feed costs to zero

Trait	Breed				
	Indigenous (current study)		Pelibuey (Ponzoni, 1992)		Rasa (Ponzoni, 1992)
	Base	Setting feed costs to zero	Base	Setting feed costs to zero	Base
NLW[a]	-0.01	0.21	0.25	0.35	0.06
12mLW	1.00	1.00	1.00	1.00	1.00
ELW	-0.03	0.16	0.11	0.11	-0.03
OFI	-	-	-0.05	0.00	-
EFI	-	-	-0.05	0.00	-
RFI	-0.14	0.00	-	-	-

NLW: number of lambs weaned (%). 12mLW: 12 month live weight (kg). ELW: ewe live weight (kg).

OFI: yearlings feed intake (kg). EFI: ewe feed intake (kg).

RFI: residual feed intake (kg DM per ewe per year). [a]Pre-weaning survival in the current study (PRWS).

reported in other studies. The REV for ELW under the base situation was the same as for the Rasa breed (Ponzoni, 1992). However, the REVs were lower than those of the Pelibuey breed. REV for RFI under the base situation in the present study was lower than REVs for OFI and EFI for the Pelibuey breed. Feed intake as a trait in the breeding objective increases cost of feeding animals (Ponzoni, 1992). However, increasing feed intake capacity of ruminants may enable the use of lower quality feeds that require less intensive inputs (Amer et al., 1998). The general trend in the EVs found in those other studies is similar to the current work. However, accurate comparison cannot be made due to differences in production circumstances studied.

In conclusion results from this study provide information about the types of traits that should be considered in a breeding goal for indigenous meat sheep under smallholder production in the tropics. The situation with fixed feed resource appropriately describes smallholder production. For this situation, it was apparent that all traits except RFI had positive EVs, and reproductive traits, LS and LF, are more important. Survival was the underlying trait for disease resistance and is important in the tropics where sanitary conditions are poor, and parasite and disease incidence is high. However, the EVs for survival traits were relatively low in the current study. Generally, the study presents a framework for other studies for sheep in the tropics but further refinement of the model may be necessary.

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Chapter 5

Economic values for traits in breeding objectives for sheep in the tropics: impact of tangible and intangible benefits

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Abstract

In traditional management systems in the tropics, sheep constitute a source of easily convertible capital for financing purposes and insurance, a means of cultural and ceremonial functions, and a source of prestige, meat, manure and skins. In this study, breeding objectives were derived for an indigenous tropical sheep breed under pastoral production. Economic values were calculated for five situations: (i) base accounting for both tangible and intangible roles of sheep; (ii) accounting for manure, skins and intangible roles; (iii) accounting for 20% of animals sold, insurance, manure and skins; (iv) accounting for intangible roles only; and (v) accounting for tangible roles only. Sensitivity analysis to different levels of financing and insurance benefit factors, reproduction, survival and live weight traits was performed for the situation accounting for both tangible and intangible roles, and with a constant number of ewes. The economic value for a trait considered in a particular situation was calculated from the difference between the average performance level of the trait before and after incrementing it by one unit. The traits considered were litter size, lambing frequency, pre-weaning and post-weaning lamb survival to 12 months, ewe survival, 12-month lamb live weight, mature ewe live weight, consumable meat and kg manure dry matter sold per ewe per year. Generally, in descending order of the profits and economic values, the situations studied ranked as follows: (i), (v), (iii), (ii) and (iv). For the base situation, financing and insurance benefits accounted for 13% and 6% of the total revenues, respectively. Situation (v) had a profit that was about 35% lower relative to situation (i). In terms of genetic standard deviations, the economic values (US$ per ewe per year) for the base situation were: 2.81 for litter size, 6.40 for lambing frequency, 0.02 for pre-weaning survival, 0.03 for post-weaning survival, 0.05 for ewe survival, 1.81 for 12-month lamb live weight, 0.43 for mature ewe live weight, 0.09 for consumable meat and 0.01 for kg manure dry matter sold (per ewe per year). The economic values indicate that litter size, lambing frequency and 12-month lamb live weight are likely to be important traits in pastoral production. Sensitivity analysis showed that future economic values for all the traits considered, except kg manure dry matter sold per ewe per year, might change depending on levels of intangible benefit factors. Ewe survival and mature ewe live weight were not responsive to changes in reproductive traits, and pre- and post-weaning traits, and vice versa. It is concluded that it is necessary to include the intangible roles of sheep in tropical breeding programmes.

(***Keywords***: Sheep; Breeding objectives; Economic values; Intangible roles; Tropics)

5.1. Introduction

The vast majority of sheep in the tropics are managed in traditional ways (Gatenby, 1986) and perform several roles for the farmers, resulting in both tangible returns (TRs) and intangible returns (IRs) (Gatenby, 1986; Hunter, 1989; Slingerland et al., 1998; Jaitner et al., 2001; Seleka, 2001). IRs include financing, insurance and risk aversion (Upton, 1985; Jaitner et al., 2001), payment of bride price and use as gifts (Grandin et al., 1991; Breusers, 1996), as a status symbol or sign of wealth and as a form of ‘‘currency’’ in which social obligations are expressed (Rege, 1994). The implications of these additional roles of livestock on biological productivity are often disregarded in favour of technical facets such as nutrition and reproduction (Gatenby, 1986; Bosman et al., 1997), probably due to the difficulty of measuring and valuing them (Roeleveld, 1996). It is important to know the contribution of IRs in the breeding objective for sheep under traditional management in the tropics in order to design appropriate breeding schemes for them. The need to include IRs in breeding goal definition for low-input animal production environments is recognized (e.g., Bichard, 2000), but has not yet been implemented for sheep. The current study examines the impact of inclusion of IRs (i.e., financing and insurance) in a breeding goal for an indigenous hair sheep flock reared under pastoral production circumstances in the tropics.

5.2. Materials and methods

5.2.1. Bio-economic model description and definitions

The breeding goal is generally described as a linear function of traits to be improved, each multiplied by its economic value (EV), which expresses the value of a unit change in the trait while keeping the other traits in the breeding goal constant (Hazel, 1943). Several methods can be used to calculate EVs (Harris, 1970; Brascamp et al., 1985; Smith et al., 1986; Ponzoni, 1988; Groen, 1989). Deriving the EVs from the difference between costs (*C*) and revenues (*R*) has the advantage of simplicity (Ponzoni, 1988). Due to the complexity and diversity of tropical pastoral systems, and the lack of good estimates of inputs and outputs, a simplified bio-economic model was deemed appropriate to derive EVs for important traits of sheep in the current study. Relevant adjustments of input parameters to the bio-economic model developed by Kosgey et al. (2003) were made to reflect pastoral production circumstances rather than the more intensive smallholder production system (see Kosgey et al. (2003) for full details and assumptions of the model). The model is deterministic and describes quantitative relationships between average performance levels for the traits considered and levels of output of the farm. The model combines aspects of nutrition, reproduction, production and economics at the animal and flock levels. It was extended to include benefits from IRs (i.e., financing and insurance) of sheep in the calculation of economic values. Sensitivity of EVs to changes in levels of IRs and with respect to changes in reproduction, survival and live weight traits was also studied. Total annual profit of the flock was derived as the difference between *C* and *R*. Throughout this study all costs and prices are expressed in US dollars ($). The productive unit is the ewe and the time unit is 1 year. The inputs for the production system were management (i.e., labour, spraying/dipping, deworming and mineral supplementation) and marketing (i.e., transport of live animal and carcass, and levies for auction, slaughter and meat inspection). The outputs were revenues from financing and insurance benefits from yearlings, ewes and rams, sale of surplus yearlings, and cull-for-age ewes and rams, manure from all categories of animals, and surplus animals slaughtered for home consumption and skins from them. A constant number of ewes were used as a base of evaluation. The EV for a trait was calculated by evaluating annual flock profit (T_{f1}) numerically at the average value for all other traits, then evaluating it after incrementing by one unit the average performance level of the trait in question (thus obtaining T_{f2}) and taking the difference, T_{f2}-T_{f1} (Ponzoni, 1992). This was then expressed per breeding ewe present in the flock per year ($ per ewe per year) in order to accommodate both production and reproduction traits. If desired, the EVs can be expressed on a per flock basis by multiplying by the number of ewes in the flock. Periodical fluctuations in animal performance and prices were not accounted for in the model.

5.2.1.1. Elements and traits of the model

Table 5.1 describes the assumptions for the input variables of the model in the base situation. Production parameters were chosen to represent an indigenous hair sheep under pastoral farming system in Kenya, and prices represent average values in the country for the period 1999–2000. Table 5.2 presents the traits, units and assumed values in the aggregate genotype that were studied using the model. These set of traits are those presented by Kosgey et al. (2003) and are also relevant under tropical pastoral circumstances.

5.2.1.2. Flock dynamics

For convenience of making calculations and comparisons, the same flock size and composition described by Kosgey et al. (2003) was assumed in the present study (Fig. 5.1). This was a hypothetical flock of 100 ewes present over the entire period. The values can be re-scaled to any desired flock size. Six animal categories were distinguished according to age: 1—lambs (0–3 months old); 2—yearlings (4–11 months old); 3—replacement females (12–18 months old); 4—replacement males (12 months old); 5—breeding ewes (over 18 months old) and 6—breeding rams

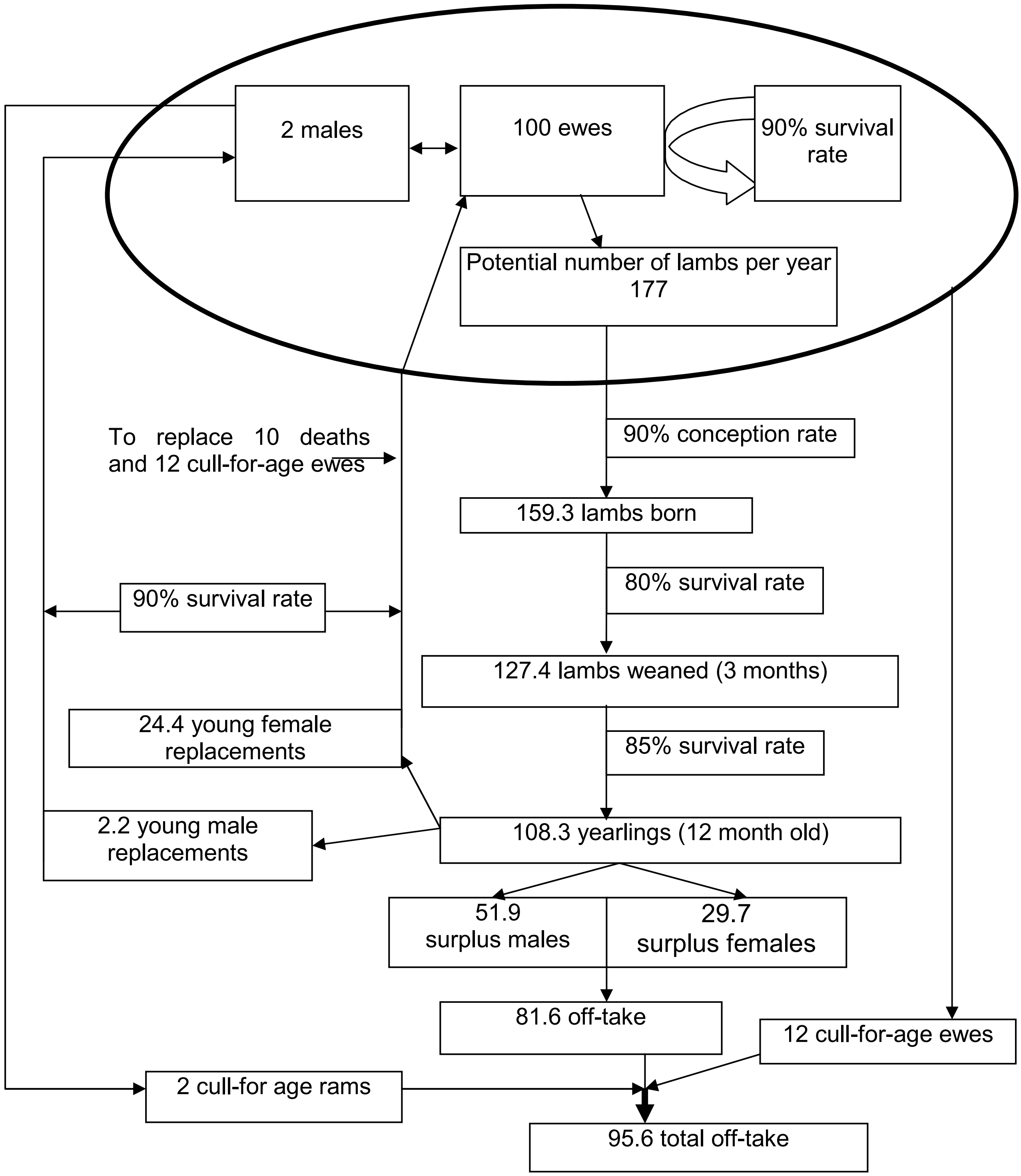

Fig. 5.1. Flock dynamics for an indigenous tropical hair sheep breed (Adapted from Kosgey et al. (2003))

Table 5.1. Overview of the assumed values of the input variables of the model in the base situation[a]

Variables	Abbreviation	Production circumstances		Variables	Abbreviation	Production circumstances	
		Pastoral	Smallholder			Pastoral	Smallholder
Production variables							
Average daily gain lambs (g per day)	-	80.00	80.00	Mortality rate of ewes (% per year)	m_5	10.00	10.00
Average daily gain yearlings (g per day)	-	60.00	60.00	Mortality rate of lambs (% per year)	m_1	20.00	20.00
Birth weight (kg)	-	3.00	3.00	Mortality rate of rams (% per year)	m_6	10.00	10.00
Body weight at 12 months of age (kg)	12mLW	25.00	25.00	Mortality rate of replacement males and females (% per year)	m_3 and m_4	10.00	10.00
Consumable meat yield (%)	CM	60.00	60.00	Mortality rate of yearlings (% per year)	m_2	15.00	15.00
Litter size (average over parities per ewe lambing per year)	LS	1.18	1.18	Weaning rate (lambs per ewe per 12 months)	-	1.27	1.27
Mature weight of ewes (kg)	ELW	30.00	30.00	Weaning weight (kg)	-	10.00	10.00
Mature weight of rams (kg)	-	40.00	40.00				
Management variables							
Age at attainment of mature weight (months)	-	18.0	18.00	Proportion of cull-for-age ewes, excluding mortality (8 years)	-	0.12	0.12
Age of ewe at first lambing (months)	-	18.0	18.00	Proportion of cull-for-age rams, excluding mortality (2 years)	-	1.00	1.00

Table 5.1. *Continued*

Variables	Abbreviation	Production circumstances		Variables	Abbreviation	Production circumstances	
		Pastoral	Smallholder			Pastoral	Smallholder
Age at first mating (months)	-	12.00	12.00	Proportion of yearlings sold at hogget or wether age (12 months)	-	0.82	0.82
Age of replacement stock at selection (months)	-	12.00	12.00	Lambing frequency (lambings per ewe per year)	LF	1.50	1.50
Age of surplus yearlings when sold (months)	-	12.00	12.00	Weaning age of lambs (months)	-	3.00	3.00
Ewe culling age (years)	-	8.00	8.00	Ram culling age (years)	-	2.00	2.00
Feed intake variables							
Average roughage intake for ewes (kg DM per head per day)	RF_5	-	0.60	Average roughage intake for replacement stock (kg DM per head per day)	RF_3 and RF_4	-	0.60
Average roughage intake for lambs (kg DM per head per day)	RF_1	-	0.20	Average roughage intake for yearlings (kg DM per head per day)	RF_2	-	0.43
Average roughage intake for rams (kg DM per head per day)	RF_6	-	0.68				
Management costs (C_h) per adult ewe							
Spraying or dipping ($ per head per year)	$C_{d:y}$	1.70	1.70	Helminth control ($ per dose per head)	C_{wc}	0.39	0.39
Drugs and veterinary service charge ($ per head per year)	C_v	-	1.50	Mineral supplements ($ per head per year)	C_{ml}	2.70	2.70

Table 5.1. *Continued*

Variables	Abbreviation	Production circumstances		Variables	Abbreviation	Production circumstances	
		Pastoral	Smallholder			Pastoral	Smallholder
Marketing costs (C_m)							
Costs of animal sale and slaughter ($ per head)	C_l	2.00	2.00	Transport of live animal to market ($ per head)	C_t	0.71	0.71
Prices							
Manure price ($ kg^{-1})	P_o	0.02	0.02	Labour costs ($ per shepherd per 100 head per month)	P_{lb}	1.29	2.57
Meat price ($ kg^{-1} carcass)	P_m	2.00	2.00	Price of a piece of skin	P_{kh}	0.57	-
Fixed costs ($ per head per year) – fencing, troughs, equipment, etc.	FCF	-	1.00	Roughage feed price ($ kg^{-1} DM)	P_{rf}	-	0.04
Manure							
Average amount collected (% DM intake per head per day)	O	50.00	50.00				

[a]All costs and prices in $, $1.00 ≈ Kshs. 70.00 (Kenya shillings) at the time.

Table 5.2. List of breeding goal traits evaluated in this study

Trait	Unit	Abbreviation
Litter size	Average number of lambs born over parities, per ewe lambing per year	LS
Lambing frequency	Average number of lambings per ewe per year	LF
Pre-weaning lamb survival	Lambs surviving to weaning as a % of lambs born	PRWS
Post-weaning lamb survival	Lambs surviving to 12 months of age as a % of lambs weaned	PWS
Ewe survival	Ewes surviving as a % of ewes present over the year	ES
12-month lamb live weight, i.e., live weight at slaughter	kg	12mLW
Mature ewe live weight	kg	ELW
Consumable meat	Consumable meat output as a % of live weight at slaughter	CM
Manure sold	kg dry matter (DM) per ewe per year, i.e., summed over all animal categories in flock and then expressed on per ewe basis	MS

(over 12 months old). These categories approximate the average age classes for indigenous tropical sheep under traditional management (e.g., Carles, 1983; Gatenby, 1986; Orji, 1988; Osinowo and Abubakar, 1988; Peeler and Omore, 1997). The number of animals in each category was expressed relative to number of ewes present over the year. Details of animal sales and mortalities can be found in Kosgey et al. (2003). Briefly, it was assumed that only a few adult males were necessary for breeding and that ewe lambs were kept for replacement and the surplus were sold. All breeding males were culled after one productive year at 2 years of age and ewes after 7 productive years at 8 years of age. The number and distribution of animals dying in each category over the whole year was accounted for (see Kosgey et al. (2003) for full details). With the assumed 90% conception rate, the proportion of ewes with 0, 1 and 2 lambs were derived to be 0.1, 0.74 and 0.16, respectively. The figures were then adjusted to a 12-month basis by multiplying by 1.5.

5.2.1.3. Parameters and information for the model

Information for this study was derived from the literature, farmers, the market and expert opinions. Generally, production parameters under pastoral production approximate those of the smallholder except feed, healthcare and fixed costs (Table 5.1). Therefore, most of the parameters are similar to those presented by Kosgey et al. (2003). In this paper, the input/output parameters that differ from those in the model described by Kosgey et al. (2003) for smallholder production will be highlighted. The cost of recording in the flock or application of the selection index was ignored. Labour was taken as part of management. Supply of labour by the farmer was set to be fixed per animal per year but varied with the size of the flock. It was assumed to be half of that of a smallholder because of the pooling of animals by families for herding by a member of one of the families, and derived as described by Kosgey et al. (2003). Opportunity cost for the farmer’s labour for other farm tasks in pastoral farming systems was used to arrive at the cost of labour. The current study assumed that one shepherd taking care of 200 head of sheep and working for 8 hours per day earned about $25.71 per month.

Marketing charges were assumed to be equal for all animal classes sold and were calculated as the sum of the average costs incurred between buying a live animal and selling its carcass. Values presented by Kosgey et al. (2003) for transport of live animal to the market, auctioning, slaughter, carcass inspection and carcass transport were used (Table 5.1). Slaughter charges, carcass inspection fee and carcass transport were assumed to be charged to the farmer because traders essentially reduce the price of the live animal by the same margin (Kosgey et al., 2003). The other variable costs of the flock were provision of minerals and healthcare. The latter was assumed not to be optimal (Gatenby, 1986). Only endo- and ecto-parasite controls were taken into account. It was assumed that animals were sprayed or dipped twice per month (e.g., Gatenby, 1986) to control ecto-parasites as is increasingly becoming the practice in pastoral production circumstances (Kosgey et al., unpublished), and dewormed two times per year for young stock up to 12 months of age and once per year for older stock.

Unlike in commercial systems, farmers in pastoral systems may have no alternative types of land use and no costs are incurred in forage production. There is also sufficient area for flock expansion. It was assumed that no concentrate supplements were provided to the flock. Therefore, feed costs were assumed to be negligible and ignored. This may not be consistent with a long term planning horizon usually involved in animal breeding. However, it was assumed that the environmental conditions were unchangeable, and breeding activities and breeding plans have to operate under this set of conditions (Sölkner et al., 1998). It was also assumed that capital has no alternative uses, and the opportunity costs were set to zero.

Under pastoral systems, there is hardly any fencing of grazing areas, feeding structures and maintenance of such facilities, field clearing and equipment that would contribute to fixed costs. Subsequently, it was assumed that fixed costs per animal were minimal and therefore disregarded (e.g., Gatenby, 1986). In addition, given the approach used in this study, fixed costs do not affect EVs (Ponzoni, 1988). This eliminates the need to determine the magnitude of fixed costs, especially in developing sheep industries, where sheep are commonly integrated with other farming activities or share some of the facilities with another species (Ponzoni, 1992).

It was assumed that 10% of the surplus animals were retained for home slaughter and therefore income from skins was included in the calculation of revenue although skins from sheep often have little value in most parts of the tropics (e.g., Carles, 1983). It was assumed that animals slaughtered at home had attained a significant part of their mature body weight and were of the same age and size. Therefore, skins produced were taken to be uniform, and sold per piece and not on weight basis. Skin sales from animals sold were considered to accrue to the butcher and were excluded from revenue calculations. Animals slaughtered for home consumption were accounted for as part of the revenue to the production system. The amount of manure was derived for each category of animals based on body weight, and the amount and digestibility of the roughage fed (see Kosgey et al. (2003) for details). In the calculation, a linear relationship of manure with feed intake was assumed. It was assumed that only half of it was collected because it is difficult to collect manure during the day as animals are grazing in the fields, but they are kept in penned enclosures at night (Gatenby, 1986; Jaitner et al., 2001) for security reasons. Manure was assumed to be traded. Farm-gate price was assumed for manure sold and therefore no transport or marketing costs were incurred.

Surplus and cull-for-age animals were assumed on the average to be sold twice a year in equal proportions. Although prices are mostly established on the basis of observation (per head) rather than sale on weight, it was assumed that animals were weighed, with a consumable meat yield of 60% (Kosgey et al., 2003). The meat price used in this study was internal to Kenya and does not reflect international market prices. To simplify the situation, all carcasses were assumed to have the same grade and the different cuts of the carcass to have the same price (Gatenby, 1986; Kosgey et al., 2003).

The farmer periodically reduces the flock in order to obtain disposable income for consumption or production requirements (Ifar, 1996; Nibbering et al., 2000). However, farmers rarely define in advance when the animals will be sold. Disposal of animals forms a clearly identifiable event, and measuring the outflow covers previous saving behaviour through the accumulation of embodied production and the purchase of animals (Bosman et al., 1997). Embodied production refers to change in body weight, or changes in animal numbers if analysis is at flock level. This could also include pregnancy (as proof of fertility). Note that due to loss of body weight, or reduced production prospects, embodied value can be negative in some years. The extra benefit derived from the financing role may be estimated by considering the costs or losses incurred in alternative ways of financing such as operating a savings account or obtaining credit other than through outflow of livestock (Ifar, 1996; Bosman et al., 1997).

Insurance involves the maintenance of capital stock embodied in the flock present on the farm, as a guarantee for offsetting shortfalls in earnings and unforeseen expenses in the future (Ifar, 1996; Bosman et al., 1997; Nibbering et al., 2000), for instance, a medical bill. Consequently, owning animals substitutes for paying insurance premiums in situations where markets for insurance are absent. The farmers' perspective of risks, particularly related to the weather, may influence the range of the insurance benefit factor. Formal insurance premiums provide cover to a certain limit and for a specific period. Therefore, insurance benefit is related to the average flock value for a given period of time (Ifar, 1996; Bosman et al., 1997), assuming that the whole flock is available to provide security through liquidation at any one time if the need arises. In this study, this period was set to 1 year.

The function of livestock in providing prestige to owners is related to the presence or absence of other means to display wealth, such as durable consumer goods, building materials and other spending possibilities. The estimation of the prestige benefit requires an understanding of the farmers' perception of social status as regarded by the community. This aspect was not considered in the current study due to lack of a good estimate of the prestige benefit factor.

5.2.2. Profit equations

Total annual profitability of the sheep flock (T_f) was described by the following equation:

$T_f = N_e \times (R_e - C_e)$ (1)

where N_e is the number of ewes in the flock per year, R_e the average revenue (per ewe per year) and C_e the average variable costs (per ewe year).

5.2.2.1. Revenues

Average revenue (R_e) per ewe per year was derived as the sum of values from Eqs. (2)–(6).

Intangible benefits were calculated from the procedures described in Eqs. (2)–(4), which are based on Ifar (1996) and Bosman et al. (1997). The total benefit from financing (B_f) is related to the value of the outflow per ewe (i.e., the part of the flock actually used to meet the farmer's lumpy cash needs) as:

$$B_{\mathrm{f}} = (1 + b_{\mathrm{f}}) \times \text{outflow value} \quad (2)$$

where the outflow value represents the average value of the sales during 1 year and b_f represents the financing benefit factor. There was insufficient evidence to apply estimates of interest rates from the informal credit markets. Inflation rate and the current interest rates of the formal credit market were applied. The factor b_f was assumed to be an average of 6.5% (i.e., reduction in purchasing power of cash savings) (CBK, 1999, 2000) plus 12% (the current average interest rate on a short- to medium-term credit obtainable by a member from a credit and savings society in Kenya for lumpy cash needs) (Bebe et al., 2002). Therefore, b_f was taken to be 18.5%.

The outflow value (\$) can be obtained from:

$$\text{Outflow value} = \sum_{i=1}^{6} [N_i \times f_i \times (1 - m_i) \times (LW_i \times \frac{CM_i}{100}) \times P_{\mathrm{m}}] \quad (3)$$

where i is the animal category (1—lambs; 2—yearlings; 3—replacement females; 4—replacement males; 5—breeding ewes and 6—breeding rams), f the fraction of animals sold (outflow) during the year, N in this and the following equations N refers to number of animals present in each category relative to number of ewes present (i.e., the proportion of animals in each category with respect to the total number of ewes present in the flock = 100), m the annual mortality rate of animals (%), LW the average live weight at slaughter of an animal (kg), CM the consumable meat, including 20% offal at half price of meat of an animal (%), and P_{m} the price kg^{-1} of meat.

The benefit derived from insurance, B_{a} ($ per ewe per year), was expressed as a fraction of the average flock value during 1 year (i.e., animals not sold):

$$B_{\mathrm{a}} = b_{\mathrm{a}} \times \sum_{i=1}^{6} [N_i \times (1 - f_i) \times (1 - m_i) \times (LW_i \times \frac{CM_i}{100} \times P_{\mathrm{m}})] \quad (4)$$

where b_{a} is the insurance benefit factor assuming average weather conditions (%).

As effectively no institutional insurance services are accessible to most pastoral communities, the factor b_{a} was set equal to 6%, which is the current average annual payment on an average medical insurance premium in Kenya (e.g., Bebe et al., 2002), as medical expenses is one of the key reasons for keeping livestock by the farmers (e.g., Bebe et al., 2002; Kosgey et al., unpublished).

Manure revenue (O_{s}) per ewe per year was calculated from the following equation:

$$O_{\mathrm{s}} = \sum_{i=1}^{6} [N_i \times Z_i \times O_i \times P_o] \quad (5)$$

where Z is the fraction of animals producing manure during the year, O the manure production of an animal (kg per year) and P_{o} the price of manure.

Revenue from animals slaughtered for home consumption ($\mathrm{HK_e}$) per ewe per year was calculated from the following equation:

$$\mathrm{HK_e} = \sum_{i=1}^{6}[N_i \times K_i \times \{(LW_i \times \frac{CM_i}{100} \times P_m) + P_{\mathrm{kh}}\}] \tag{6}$$

where K is the fraction of animals that are slaughtered for home consumption and P_{kh} the price of a piece of skin.

5.2.2.2. Costs

Variable costs (C_e) per ewe per year were calculated from Eq. (7).

$$C_{\mathrm{e}} = \sum_{i=1}^{6}[N_i \times (C_{\mathrm{h}i} + C_{\mathrm{mi}})] \tag{7}$$

where C_h is the management costs per animal and C_m is the marketing costs per animal.

Average management costs (C_h) per ewe per year were described by the following equation:

$$C_{\mathrm{h}} = \sum_{i=1}^{6}[N_i \times \{P_{\mathrm{lb}i} + (N_{\mathrm{d:y}i} \times C_{\mathrm{d}i}) + (D_{\mathrm{ml}i} \times P_{\mathrm{ml}i} \times L_i)\}] \tag{8}$$

where P_{lb} is the opportunity cost of labour per year per animal, L the number of days an animal is present in the year, $N_{d:y}$ the average number of sprays/dippings per year per animal, C_d the per cost spraying/dipping per animal, D_{ml} the average daily mineral requirements per animal and P_{ml} the average price kg^{-1} of mineral.

Average marketing costs (C_m) per animal sold were described by the following equation:

$$C_{\mathrm{m}} = \sum_{i=1}^{6}[N_i \times f_i \times (C_{\mathrm{t}i} + C_{\mathrm{l}i})] \tag{9}$$

where C_t is the cost of transport of live animal to the market and C_l the levies (auction fee, slaughter fee, meat inspection fee and carcass transport) per animal.

5.2.3. Scenarios evaluated

The primary objective of the current study was to examine the impact of inclusion of intangible returns on the economic values for traits of sheep in the breeding goal. This necessitated a study of alternatives that would clearly capture and quantify the benefits of IRs. Consequently, EVs for the traits considered were calculated for the following five scenarios: (i) base situation accounting for both TRs (i.e., meat, manure and skins) and IRs (i.e., financing and insurance); (ii) situation accounting for manure, skins and IRs; (iii) situation accounting for 20% of all theoretically saleable animals compared to scenario (i), insurance, manure and skins; (iv) situation accounting for IRs only and (v) situation accounting for TRs only. In some pastoralist communities (e.g., Grandin et al., 1991), fewer animals are sold, hence the basis of assuming 20% of the animals to be involved in total financing benefit. It is important to note that, in the present study, changes in costs (*C*) and revenues (*R*) are given per % change in the average performance level for the trait considered, while EVs are expressed per unit change in the average performance level for the trait. Consequently, EVs in Table 5.7 may not be obtained directly as the differences in total marginal *C* and *R*. Inconsistencies may also arise due to rounding, since more decimals were used in the calculation of EVs than are shown here. To be able to make comparisons of EVs from the different production circumstances studied easier, relative economic values (REVs) were calculated by arbitrarily taking the EV for 12mLW as the standard.

In comparing the value of traits, it is important to consider the units in which the traits are expressed and the amount of genetic variance. Published data on population parameters of the traits considered in the current study for tropical circumstances are scanty, a situation limiting the scope of comparison of the traits using their genetic variances. Therefore, literature estimates (Table 5.3) were collected and used to evaluate the value of traits per genetic standard deviation.

Genetic parameters of feed intake were used for kg manure dry matter sold per ewe per year. Since lambing frequency is a biological trait that follows the Poisson distribution (with random outcomes of 0, 1, 2 and 3 lambings per 2 years), its phenotypic variance was assumed to be equal to its mean.

Table 5.3. Estimates of population means (μ), heritabilities (h^2), phenotypic (σ_p) and genetic (σ_G) standard deviations of the breeding goal traits studied

Trait[b]	Parameters of the trait[a]			
	μ	h^2	σ_p	σ_G
LS	1.18	0.10	0.355	0.112
LF	1.50	0.07	1.225	0.324
PRWS	0.80	0.02	0.287	0.040
PWS	0.85	0.05	0.291	0.070
ES	0.90	0.10	0.500	0.158
12mLW	25.00	0.25	2.867	1.434
ELW	30.00	0.30	3.713	2.034
CM	0.60	0.40	0.228	0.144
MS	0.409	0.30	0.072	0.039

[a]See Table 5.1 for definition of units and abbreviations. [b]Derived from Chopra and Acharya (1971), Magid et al. (1981), Notter (1981), Oltenacu and Boylan (1981), Rae (1982), Carles (1983), Wilson (1985), Baker and Steine (1986), Fahmy (1986), Fogarty and Hall (1986), Gatenby (1986), van Vleck et al. (1987), Mbah (1988), Olayiwole and Adu (1988), Orji (1988), Osinowo and Abubakar (1988), Wilson (1991), Odubote (1992), Rajab et al. (1992), Waldron and Thomas (1992), Fogarty (1995), Matika (1995), Olesen et al. (1995), Lewis et al. (1996), Boujenane et al. (1998), Cloete et al. (1998), Sormunen-Cristian and Suvela (1999), Vagenas and Bishop (1999), Ingham and Ponzoni (2000), Michels et al. (2000), Mukasa-Mugerwa et al. (2000), Conington et al. (2001), Banos et al. (2002), Ermias et al. (2002), François et al. (2002), Rege et al. (2002), Rosati et al. (2002), Tosh et al. (2002), Kosgey et al. (2003) and Robert Banks (Personal Communication).

5.2.4. Sensitivity analysis

Given the uncertainty in the financing (b_f) and insurance (b_a) benefit factors, an analysis was performed on the sensitivity of the EVs to changes in levels of these factors. The same analysis was done with respect to changes in reproduction, survival and live weight traits. Changes of ± 20% with respect to original values were evaluated, under the base situation accounting for both TRs and IRs, and with constant number of ewes. Changes were performed separately, holding all other parameters constant.

5.3. Results

Tables 5.4 and 5.5 present the costs, revenues and profit for the base situation accounting for both tangible and intangible roles of sheep. The values presented are weighted by the proportion of each animal category with respect to number of ewes present, and the totals are expressed per ewe per year. For example, in Table 5.4, management costs for 0.24 replacement females was \$0.79 and insurance value from breeding ewes was \$0.44. Total management and marketing costs per ewe per year were \$16.64 and \$2.48, respectively. Management costs represented about 87% of the total cost and marketing about 13%. The total profit per ewe per year was \$22.72.

Financing and insurance benefits accounted for about 13% and 6% of the total revenues, respectively. Contribution of skins to revenue was negligible due to the small proportion of animals slaughtered at home that solely contributed skins sold by the farmer. All the animal categories had positive profits except lambs and replacement females. The lambs had only manure as a source of revenue. Their role in financing and insurance was included in the yearlings to avoid double counting. Replacement females had insurance and manure as sources of revenue, the total sum of which was lower than the cost of inputs.

Table 5.6 gives the initial costs and revenues, and marginal changes per ewe per year for the base situation accounting for both TRs and IRs. The marginal values are weighted by animal proportions. The marginal values result from a 1% change in the average performance level for the trait considered. For instance, the initial cost of marketing was \$2.48 and increased by \$0.03 when LS was increased by 1%. Similarly, the initial financing and insurance revenues were \$5.51 and \$2.33, respectively, and correspondingly increased by \$0.06 and \$0.01 when PWS was increased by 1%. Increase in the average performance level for 12mLW, ELW, CM and MS did not result in any marginal changes for management and marketing

Table 5.4. Costs and revenues per proportion of animals in each category to number of ewes present, and profit per ewe per year ($) in the base situation accounting for both tangible and intangible roles of sheep

	Animal category								
	Lambs	Yearlings off-take[a]	Replacement females	Replacement males	Breeding ewes[b]	Cull ewes[c]	Breeding rams[b]	Cull rams[c]	
Proportion of animals to ewes	1.27	0.82	0.24	0.02	1.00	0.12	0.02	0.02	Total[d]
Input									
Management	1.47	7.97	0.79	0.07	6.21	-	0.13	-	16.64
Labour[e]	0.53	1.83	0.14	0.01	1.50	-	0.03	-	4.05
Marketing	-	2.10	-	-	-	0.33	-	0.05	2.48
Total	1.47	10.07	0.79	0.07	6.54	-	0.18	-	19.12
Output									
Meat	-	24.50[f]	-	-	-	4.32	-	0.96	29.78
Financing benefit	-	4.53	-	-	-	0.80	-	0.18	5.51
Total financing benefit[g]	-	29.03	-	-	-	5.12	-	1.14	35.29
Insurance benefit	-	1.36	0.48	0.05	0.44	-		-	2.33
Manure	0.28	1.67	0.30	0.03	1.88	-	0.03	-	4.20
Skins	-	0.02	-	-	-	-		-	0.02
Total	0.28	32.08	0.78	0.08	7.44	-	1.17	-	41.84
Profit	-1.19	22.01	-0.01	0.01	0.9	-	0.99	-	22.72

[a] Insurance from those retained for replacement. [b]Financing value from footnote c. [c]Input parameters already accounted for in breeding groups. [d]Weighted by animal proportions. [e]Already included in management. [f]Includes animals slaughtered for home consumption. [g]Includes meat and intangible financing benefit.

Table 5.5. Estimated annual average costs and benefits ($) per ewe in the flock for the base situation[a]

Economic variables	Amount ($ per ewe per year)
Production output	
Cash from animal sales (meat)	29.78
Cash from skin sales	0.02
Total cash income	*29.80*
Net recurrent cash income[b]	*10.68*
Income in kind	
Home-slaughtered animals (10% surplus stock)	1.24
Manure	4.20
Change in stock value	23.26
Total income in kind	*28.70*
Benefits	
Value added[c]	39.38
Insurance benefit (6%)	2.33
Financing benefit (12%+6.5% = 18.5%)	5.51
Total benefits	*47.22*
Production costs	
Management	
Purchased acaricide (spraying/dipping)	5.55
Purchased anthelmintics (dewormers)	1.14
Mineral supplements	5.90
Opportunity cost of family labour	4.05
Marketing	
Transport (animals and carcasses)	0.65
Levies	1.83
Total purchased inputs	*19.12*

[a]Multiply by 100 to get the averages for the flock.[b]Total cash income minus total purchased inputs. [c]Total cash income plus total income in kind minus total purchased inputs.

costs. Increase in the average performance level for ES had a negative effect on management costs, insurance benefits and manure, but a positive influence on financing. Increase in the average performance level for LS, LF, PRWS and PWS had similar positive effects on IRs.

Table 5.7 compares the profits and EVs for the traits considered for all the situations studied. To gauge the impact of IRs, the main focus will be on the base situation accounting for both TRs and IRs, compared to the situation accounting for TRs only. The situation accounting only for TRs showed a profit of $14.88 per ewe per year, that was about 35% lower relative to that of the base situation. In this situation, all the costs were similar as for the base situation but meat, manure and

Table 5.6. Initial costs and revenues ($ per ewe per year) with marginal changes for the base situation accounting for both tangible and intangible benefits of sheep after a 1% increase in the average performance level for the traits considered

	Initial	Trait[a]								
		LS	LF	PRWS	PWS	ES	12mLW	ELW	CM	MS
Costs										
Management	16.64	0.09	0.09	0.09	0.07	-0.02	0.00	0.00	0.00	0.00
Marketing	2.48	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00
Revenue										
Meat	29.78	0.33	0.33	0.33	0.33	0.30	0.25	0.04	0.30	0.00
Financing	5.51	0.06	0.06	0.06	0.06	0.06	0.05	0.01	0.06	0.00
Insurance	2.33	0.01	0.01	0.01	0.01	-0.04	0.01	0.01	0.02	0.00
Manure	4.20	0.02	0.02	0.02	0.02	-0.02	0.01	0.01	0.00	0.04
Skins	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a]See Table 5.2 for definition of units and abbreviations.

Table 5.7. Profits and economic values ($ per ewe per year) per unit increase in the average performance level for traits under the different situations[a,b,c]

Situation	Profit	Trait[d]								
		LS	LF	PRWS	PWS	ES	12mLW	ELW	CM	MS
Base (with both tangible and intangible roles)	22.72	25.11	19.75	0.37	0.37	0.33	1.26	0.21	0.62	0.08
		(19.93)	(15.67)	(0.29)	(0.29)	(0.26)	(1.00)	(0.17)	(0.49)	(0.06)
		2.81	6.40	0.02	0.03	0.05	1.81	0.43	0.09	0.01
With manure, skins and intangible roles	-7.05	-2.43	-1.91	-0.03	-0.01	0.00	0.28	0.06	0.13	0.08
		(-8.68)	(-6.82)	(-0.11)	(-0.04)	(0.00)	(1.00)	(0.21)	(0.46)	(0.29)
		-0.27	-0.62	0.00	0.00	0.00	0.40	0.12	0.02	0.01
With 20% animals sold, insurance, manure and skins	4.11	4.18	3.29	0.06	0.08	0.08	0.52	0.21	0.31	0.08
		(8.04)	(6.33)	(0.12)	(0.15)	(0.15)	(1.00)	(0.40)	(0.60)	(0.15)
		0.47	1.07	0.01	0.01	0.01	0.75	0.43	0.05	0.01
With intangible roles only	-	-4.11	-3.23	-0.06	-0.03	0.01	0.24	0.04	0.13	0.00
	11.27	(-17.13)	(-13.46)	(-0.25)	(-0.13)	(0.04)	(1.00)	(0.17)	(0.54)	(0.00)
		-0.46	-1.05	0.00	0.00	0.00	0.34	0.08	0.02	0.00
With tangible roles only	14.88	18.86	14.84	0.28	0.28	0.31	1.02	0.17	0.49	0.08
		(18.49)	(14.55)	(0.27)	(0.27)	(0.30)	(1.00)	(0.17)	(0.48)	(0.08)
		2.11	4.81	0.01	0.02	0.05	1.46	0.35	0.07	0.01

[a]Changes in costs and revenues are given per % change in the average performance level for the trait while economic values are per unit change in the average performance level for the trait. [b]Relative economic values in brackets, and are related to the economic value for 12mLW for the particular situation. [c]Figures without brackets in second row for each situation are economic values per genetic standard deviation.
[d]See Table 5.2 for definition of units and abbreviations.

Table 5.8. Economic values ($ per ewe per year) for the traits for the situation accounting for both tangible and intangible roles of sheep with changes in levels of financing and insurance benefit factors, reproduction, survival and live weight traits, and constant number of ewes

Output	level (%)	Trait[a]								
		LS	LF	PRWS	PWS	ES	12mLW	ELW	CM	MS
Financing benefit factor (b_f)	-20	24.09	18.95	0.35	0.35	0.32	1.22	0.20	0.60	0.08
	+20	26.13	20.56	0.38	0.38	0.34	1.30	0.21	0.64	0.08
Insurance benefit factor (b_a)	-20	24.88	19.57	0.36	0.36	0.34	1.25	0.21	0.61	0.08
	+20	25.34	19.94	0.37	0.37	0.32	1.27	0.21	0.63	0.08
LS	-20	-	15.80	0.29	0.29	0.33	0.94	0.21	0.49	0.08
	+20	-	23.71	0.44	0.44	0.33	1.58	0.21	0.75	0.09
LF	-20	20.09	-	0.29	0.29	0.33	0.94	0.21	0.49	0.08
	+20	30.13	-	0.44	0.44	0.33	1.58	0.21	0.75	0.09
PRWS	-20	20.07	15.79	-	0.29	0.33	0.94	0.21	0.49	0.08
	+20	30.15	23.72	-	0.44	0.33	1.58	0.21	0.75	0.09
PWS	-20	19.77	15.55	0.29	-	0.33	0.94	0.21	0.49	0.08
	+20	30.45	23.96	0.45	-	0.33	1.58	0.21	0.75	0.09
ES	-20	25.11	19.75	0.37	0.37	-	1.26	-0.05	0.49	0.08
	+20	25.11	19.75	0.37	0.37	-	1.26	0.46	0.75	0.08
12mLW	-20	18.33	14.42	0.27	0.27	0.25	-	0.21	0.52	0.08
	+20	31.90	25.09	0.47	0.47	0.40	-	0.21	0.72	0.09
ELW	-20	25.11	19.75	0.37	0.37	0.37	1.26	-	0.60	0.08
	+20	25.11	19.75	0.37	0.37	0.32	1.26	-	0.64	0.09

[a]See Table 5.2 for definition of units and abbreviations.

skins were the only sources of revenue. Economic values for the traits in both situations were all positive. Economic values for LS, LF and 12mLW were relatively higher when IRs were included in the calculation of the breeding objective, suggesting the importance of these three traits in pastoral production. On the other hand, PRWS, PWS, ES and ELW were correspondingly similar under the two situations. As expected, MS was unaffected by inclusion of IRs in the derivation of EVs. The situation accounting for manure, skins and IRs had a profit of $-7.05, while that accounting for 20% of the animals sold, insurance, manure and skins showed a profit of $4.11. The situation accounting for only IRs resulted in a profit of $-11.27. These results illustrate the importance of the multiple roles of sheep in traditional production systems in the tropics.

The situation accounting for 20% animals sold, insurance, manure and skins had positive EVs for all the traits considered. The REVs generally indicated a similar trend to the situation accounting for both TRs and IRs. However, the EVs were smaller. As expected, the EV for MS was zero for the situation accounting only for IRs and was the same ($0.08, i.e., $0.01 per genetic standard deviation) for the other situations. However, the REVs were different. In this situation, the EVs for LS, LF, PRWS and PWS were negative.

Table 5.8 shows the EVs for the traits considered and their sensitivity to different levels of b_f and b_a, reproduction, survival and live weight traits, for the situation accounting for both TRs and IRs, and with a constant number of ewes. Economic values for most of the traits considered were relatively sensitive to different levels of b_f and b_a. As expected, EV for MS was not sensitive to different levels of financing and insurance benefit factors. Ewe survival and ELW were not responsive to changes in LS, LF, PRWS and PWS and vice-versa.

5.4. Discussion

5.4.1. Revenues and costs

The results from this study attest to the fact that financing and insurance roles of sheep are important in traditional production circumstances alongside TRs. However, they are unlikely to be important on their own. It is shown that total profit per ewe per year turns out to be higher when benefits from IRs are accounted for along with those from TRs (Tables 5.4, 5.5 and 5.7). This could explain why farmers in the tropics persist in keeping livestock despite apparent net economic losses in their flocks as shown for smallholder production discussed by Kosgey et al. (2003). Exclusion of feed and fixed costs also positively influenced the apparent profitability of the situations studied. The net effect is that the EVs are higher than for the smallholder production but the REVs are about the same. Table 5.6 shows how marginal changes arise with marginal increases in the average performance levels for the traits considered.

Profitability of small ruminants under traditional management in the tropics has been a contentious issue, with some results indicating a low productivity due to high mortality or low utilization rates (e.g., Seleka, 2001) and others profitability (e.g., Jaitner et al., 2001). This points to the fact that both the biological and economic parameters are likely to vary amongst tropical production systems. For instance, mortality rates could be substantially higher, and reproductive rates lower than currently assumed. In addition, very few previous studies have attempted to account for IRs. Therefore, the profit and, subsequently, the EVs are likely to be slightly higher in the current study.

In the calculation of financing benefit in this study, only interest and inflation rates were considered. It is worthy of note that savings in a bank may be even less attractive when transaction costs, transport and other obstacles farmers may experience in dealing with formal financial institutions are taken into account (Slingerland et al., 1998). Similarly, the stakes could be high in insurance given the marginal and fragile environmental conditions most pastoralist communities live in. If accounted for, these may further positively influence the EVs for the traits considered in the current study.

The estimation of the benefits from IRs is difficult and ideally would require comprehensive field research to establish the farmers' perception of the future and therefore, uncertain financial requirements and their abilities to meet these directly or through other means, including relevant alternative insurance options. In the current study, benefits from IRs essentially involve subjective estimates for factors b_f and b_a, directly as a result of lack of markets or imperfect markets for financing and insurance. Therefore, the estimation of these factors is inevitably open for discussion, and the estimated revenue of $41.84 per ewe per year in the base situation is simply a first estimate (Table 5.4).

5.4.2. Economic values

The EVs for the situation accounting for both TRs and IRs were all positive (Table 5.7). This implies that total revenues resulting from a unit increase in the average performance level for each of the traits considered were higher than the resultant total costs (Tables 5.4 and 5.6). The EVs in the current study are generally higher than those reported by Kosgey et al. (2003) for smallholder production in the tropics suggesting a lot of saving on feed costs and a higher contribution of IRs to revenue. However, the general trend is similar. Fixed costs are negligible in pastoral circumstances, and management costs marginal. This would lead to increased EVs. As would be expected, EVs for MS were the same in both studies. Increase in the average performance level for this trait resulted in the same marginal revenue for manure only and did not affect costs of inputs or other outputs. Litter size, LF and PRWS had the same marginal changes for all inputs and outputs (Table 5.6) because they had similar number of expressions. Ewe survival had a negative effect on management costs due to reduction in expenses associated with rearing replacement females because fewer replacements were required then. Insurance benefit is derived from animals that are not sold during the year, and therefore increase in the average performance level for ES would result in the sale of more replacements not required that would have contributed to insurance. For this reason, increase in the average performance level for ES by 1% had a negative effect on insurance.

The trend of EVs for the situation with TRs only was similar to the base situation but values were lower except for MS that was the same (Table 5.7). Consumable meat had the same REV as in the base situation. As shown by the REVs for the situation with 20% of the animals involved in financing, selling fewer animals remarkably lowered EVs for the traits considered except for ELW and MS. This was due to lower returns from surplus animals sold and financing benefit, and increased management costs. Generally, LS, LF and 12mLW appear to be the most important traits in pastoral production where IRs of sheep are important. Relative to the situation accounting for TRs only, the EVs for both LS and LF increased by about 33% when IRs were included in the model along with TRs.

5.4.3. Sensitivity analysis

Sensitivity analysis of EVs to changes in financing and insurance benefit factors is important given the subjective estimates used. Sensitivity analysis of EVs for traits to circumstances also gives information on the likely direction of future genetic improvement and production system (Smith, 1988; Kosgey et al., 2003). It is demonstrated that future EVs for responsive traits might change dependent on levels of the intangible benefit factors, and with respect to reproduction, survival and live weight traits. This is not surprising given the uncertainty in the estimation of b_f and b_a, and variation of reproductive and survival rates, as well as live weights of animals amongst tropical production systems. A point to always bear in mind is that the effort it takes to change a trait can vary considerably between traits, i.e., the trait can be of great importance but cannot be changed easily. However, decisions about which traits to target for genetic improvement should ideally be based on the extent to which each trait affects profitability (per head or per unit) of labour or land, not on whether the trait is difficult or easy to measure or change genetically.

5.4.4. General

Raising animals has often been found to be superior to saving money in a bank account, because net annual returns from livestock are higher than interest rates in the bank (Nibbering et al., 2000). Studies in other parts of the tropics indicate that revenues from small ruminants might be greatly improved when farmers could concentrate on animal production and have viable alternatives for financing (Slingerland et al., 2000; Slingerland and van Rheenen, 2000). Emergency (premature) sales are associated with considerable losses in forgone offspring, forgone live weight and when animals are sold in periods with low market prices, i.e., sales for financing can mostly not be optimally timed (Ifar, 1996; Bosman et al., 1997; Slingerland and van Rheenen, 2000). When these animals are not needed for emergency financing, they can generate higher revenues when sales are planned to coincide with important festivities such as religious ceremonies like Christmas, Tabaski, Ramadan, etc. (Slingerland et al., 1998).

According to Slingerland et al. (1998), when high monetary inputs are required, it will be more and more difficult to solve problems through social networks because money is not always promptly available, neither to give loans nor to repay loans. In fact, in most transactions, only small amounts change hands. Friends and family may also try to escape their responsibility of helping out or may not respect promises normally met in better times. Therefore, sheep facilitate the farmer to meet unexpected expenditures, e.g., medical care, ceremonies like marriages and funerals, etc. (Slingerland and van Rheenen, 2000). This may impact positively on EVs for most of the traits considered in this study. However, the development of formal markets may break the tendency of farmers to treat livestock as a store-of-wealth (Seleka, 2001).

To our knowledge, no other studies exist on the inclusion of IRs of sheep in the breeding objective for indigenous tropical genotypes, although the importance of these roles have been discussed in general terms (e.g., Carles, 1983; Gatenby, 1986; Hunter, 1989; Bosman et al., 1997; Slingerland et al., 1998).

5.5. Conclusion

Intangible benefits (financing and insurance) are a reasonable proportion of the total income from sheep under traditional production circumstances. These benefits had a considerable influence on EVs for most traits considered. Generally, IRs appear to greatly influence the EVs for reproductive traits and 12-month lamb live weight. Therefore, IRs need to be included in the breeding objectives for sheep under traditional management in the tropics. The current study provides a basis for inclusion of IRs in sheep breeding programmes in tropical conditions but further fine-tuning of the model may be necessary in future research.

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Chapter 6

Analysis of alternative pure-breeding structures for sheep in smallholder and pastoral production circumstances in the tropics

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Abstract

The key issue in this study was to technically compare, through stochastic simulation, different breeding programmes that vary in the level of interaction between breeders and producers. The breeding structures considered were: (I) a single closed nucleus providing seed-stock to village flocks, (II) a group of commercial flocks running a co-operative (‘ram circle’) breeding programme with no nucleus, (III) an interactive two-tier open nucleus breeding scheme, comprising a nucleus and a commercial tier - the best males are used within the nucleus while the remainder migrate to the commercial flocks, with no female migration, and (IV) as scheme III but with female migration between tiers. For the latter two schemes, 100% of the nucleus animals are distributed over village flocks every 3 years. The nucleus is then replaced by a new batch of selected males and females from the village flocks obtained through ‘interactive cycling screening’, based on ‘picking the best phenotype’ in the commercial flocks. Single trait selection was considered and based on estimated breeding value, using either best linear unbiased prediction or the individual’s phenotype as a deviation from contemporaries in the same flock, year and season. The results showed that genetic merit increased slightly and inbreeding decreased significantly with increase in nucleus size. For instance, with BLUP selection and trait measurement on both sexes, and first record established at year 2, a nucleus size of 100 dams with 50 dams mated to each sire resulted in genetic merit of 0.118 units and an average inbreeding coefficient of 0.119 while that with 500 dams gave a response of 0.134 with an average inbreeding coefficient of 0.037. Running one closed nucleus had a 6-24% advantage over a ‘ram circle’ in terms of genetic gain. Decreasing the dam to sire ratio was a simple way to avoid inbreeding in breeding schemes of small size, with very little compromise towards genetic gain or even an increase in the longer term. Relative to a two-tier nucleus (scheme I), ‘cyclic screening’ of commercial animals for use in the nucleus gave an almost optimum genetic response, while the villagers acquire superior breeding stock in return as an incentive to participate in genetic improvement. Participation of farmers offers them a sense of ownership of the breeding programme, and is likely to

make it more sustainable in the long-term. This study provides insight into the advantages and disadvantages of designed breeding structures, especially the ‘interactive cyclic breeding’ schemes, which should be useful in deciding breeding programmes to adopt for sheep in the tropics.

(***Keywords***: Sheep; Breeding structures; Tropics; Selection)

6.1. Introduction

Sheep play an important role in the livelihood of many people in the tropics, mainly through meat production (Carles, 1983; Gatenby, 1986; Kiwuwa, 1992), and they have potential for greater contribution through better management and genetic improvement (Kosgey et al., 2002). Traditional minimal-input systems with indigenous animal breeds predominate mainly in the arid and semi-arid areas, which practice pastoral-nomadic systems of livestock production (Gatenby, 1986; de Leeuw et al., 1991; Kiwuwa, 1992). A smaller proportion of small ruminants per household are traditionally kept in humid, semi-humid and highland eco-zones, where human populations practice sedentary agricultural and agro-pastoral production systems (e.g., Kiwuwa, 1992).

The traditional production systems may not render organized national or regional genetic improvement of productive traits of small ruminants feasible. Therefore, village breeding programmes are predominant in the tropics and have been defined by Sölkner et al. (1998) as those breeding programmes carried out by communities of smallholder farmers (villagers), often at subsistence level. Under smallholder production systems in the agro-pastoral areas, effective small ruminant conventional breeding methods are constrained by communal grazing, small flock sizes, single-sire flocks, lack of systematic animal identification, inadequate animal performance and pedigree recording, low levels of literacy and organizational shortcomings (Kiwuwa, 1992). In addition to the factors constraining successful small ruminant breeding strategies in smallholder production systems, apart from small flocks and probably single sire flocks, pastoral flocks face a problem of mobility. The infrastructure necessary for collection of reliable pedigree and performance data does not exist to set up a breeding programme involving the populations maintained by the mobile pastoralist communities (Franklin, 1986; Kiwuwa, 1992). Consequently, strategies for genetic improvement that overcome these problems need to be considered. In this regard, nucleus schemes have been proposed as a good strategy for genetic improvement of livestock in developing countries (Hodges, 1990; Jasiorowski, 1990; Kiwuwa, 1992). Depending on the complexity and requirements of the breeding programme, a nucleus scheme can have different numbers of tiers and migration policies. Van der Werf (2000) has summarized the roles of the different tiers in a livestock breeding structure. Generally, the central nucleus and multiplier flocks generate sires for distribution to commercial (i.e., smallholder and pastoralist) farmers. However, a crucial point for the successful implementation of a breeding scheme is adequate interaction between nucleus and commercial sectors, in a technical as well as socio-economic sense.

In this study, a nucleus is defined as a unit with several breeding males. The best ('elite') males in the nucleus population in each generation, and with female migration, the best females in the whole population are used in the nucleus to produce the best offspring. A breeding flock is considered as a breeding unit around one breeding male. At the village level, a private 'flock' might consist of only a few animals, but a group of smallholders within one village could commonly share a breeding male. The breeding male is then obtained either from the nucleus, or from another flock, i.e., a group of smallholders sharing a breeding male.

One option other than a central nucleus is to run a co-operative 'ram circle' breeding programme among a number of larger commercial groups. According to Kiwuwa (1992), once recording has improved on the part of the farmers, co-operative breeding schemes based on central nucleus flocks without associated multiplier flocks could be adopted. However, this is still quite infeasible in most production systems in the tropics. Information on the principles and experiences of co-operative breeding programmes can be found in a number of studies (e.g., Dodd et al., 1982; McMaster, 1982; Parker and Rae, 1982; Peart, 1982; Steine, 1982;

Williams, 1982; Kiwuwa, 1992; Ponzoni, 1992) and many of these relate to tropical scenarios.

A third option is an 'interactive cyclic' scheme, where breeding stock from the nucleus is regularly interchanged with village stock. There appear to be no previous studies on 'interactive cyclic screening' schemes. Such schemes may be an appropriate strategy for village-based breeding programmes in agro-pastoral and pastoral-nomadic production systems since it involves the village farmer community more intensively but with minimal recording required in the commercial flocks, which would otherwise be a big problem due to the various bottlenecks that would be encountered with data collection and analysis in these production systems.

The aim of this study was to examine more interactive breeding programmes, and to technically compare, through simulation, alternative sheep pure-breeding schemes. The interaction of nucleus schemes with commercial flocks, in particular the interaction between breeding flocks and commercial farmers was studied. The parameters used to compare the schemes studied were the obtained genetic improvement for merit (ΔG) and the average inbreeding coefficient (F). The effect of nucleus size and dam to sire ratio, and 'cyclic screening' of animals were evaluated. Incentives for producers to participate and contribute to the breeding programme were also considered.

6.2. Materials and methods

Stochastic simulation was used with 100 replicates of a breeding population with overlapping generations simulated for 10 years. All the calculations related to genetic merit are in units of phenotypic standard deviation (SD). One SD is generally equal to 10-20% of the mean. Therefore, a genetic response of 1.00 in 10 years reflects an annual genetic change equal to 1 to 2% of the trait mean. The calculated rates of genetic gain (ΔG) account for the effect of selection and inbreeding on genetic variance (Bulmer, 1980).

The breeding structures considered were: (I) a two-tier breeding scheme, comprising a single nucleus and a commercial tier. The nucleus was closed and there was no specific mating strategy applied (i.e., there was random mating of selected males and females), (II) a group of commercial flocks running a co-operative ('ram circle') breeding programme with no nucleus - males selected within each flock were used in another flock while females were selected but did not migrate between flocks, (III) an interactive two-tier breeding scheme, comprising a nucleus and a commercial tier (Fig. 6.1) - the best males were used within the nucleus while the remainder migrated to the commercial flocks, with no female migration, and (IV) as scheme III but with female migration between tiers. A commercial flock is defined as a breeding unit around one male, potentially comprising a group of smallholders or pastoralists within one village.

In scheme III and IV there was 'cyclic screening' of commercial animals for the nucleus every 3 years (Fig. 6.1). Screening was based on 'picking the best phenotype' in the commercial flocks and using this in the nucleus. The screened animals from commercial flocks were assumed to have no pedigree record, but had an own performance record obtained from simple recording introduced earlier in the

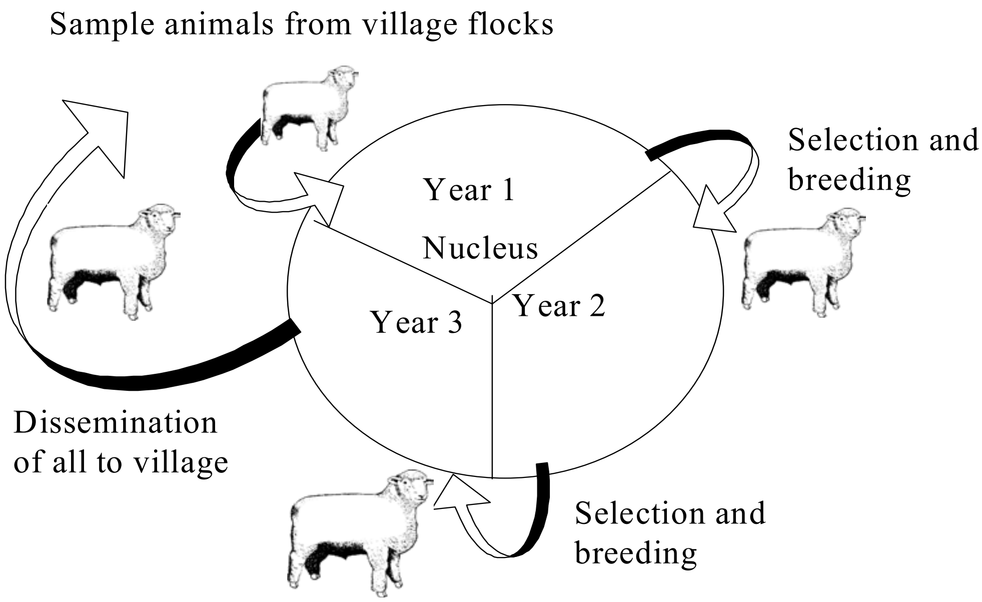

Fig. 6.1. 'Cyclic screening' of animals in the 'interactive cycling' schemes (i.e., scheme III and IV).

flock. A lower accuracy of selection (equal to the square root of half of the heritability) was then used, which makes it more realistic for smallholder and pastoral production circumstances in the tropics. Although the result is not a formal measurement, it was treated as such in the simulation. Both sexes were selected at the age of 7 months.

Selection in the nucleus was based on truncation using BLUP estimated breeding values (EBVs) as criterion, therefore optimizing selection across age classes. Pedigree information was absent for commercial-born animals in the nucleus. Animals not selected as nucleus parents were selected for dissemination to the commercial flocks. Only natural mating was considered. It was assumed that sire to dam mating ratio was the same in nucleus and commercial flocks. In all cases, survival probabilities decreased by 10% each year increase of age starting at 90% in year 1 (Kosgey et al., 2003). Age at drop of first progeny was assumed to be 2 years. The phenotype was recorded during the second year on both sexes with selection on traits that are measurable early in life and on both sexes, for example, survival traits (e.g., pre-weaning survival) and lamb birth weight. In addition, a trait recorded later in life (3 years of age) on females only was simulated which represents traits like reproductive traits (e.g., litter size and lambing frequency) and mature ewe weight.

In this study single trait selection was considered with a heritability of 0.25 and based on estimated breeding value (EBV), using best linear unbiased prediction (BLUP) or the individual's phenotype as a deviation from the contemporaries in the same flock, year and season. When only females were measured, and with selection on phenotype, males were selected based on 0.5*EBV(dam). Animals could be selected as parents irrespective of age or availability of records. For older animals, EBVs could include progeny information. However, progeny testing was not a pre-requisite for selection, but selection with BLUP could partly be based on progeny information. Genetic response was calculated from the mean breeding values over the simulated period per year. Inbreeding was calculated using the Meuwissen and Luo (1992) algorithm as modified by Quaas (1995).

6.3. Results

6.3.1.1. Effect of nucleus size and dam to sire ratios

Table 6.1 presents the results of closed nucleus versus 'ram circle' breeding schemes, and shows the effect of nucleus size, and dam to sire ratios on the rate of genetic response (ΔG) and the average inbreeding coefficient in year 10 (F_{10}). This refers to variations of scheme I and II. With an increased nucleus size, ΔG increases slightly whereas F decreases significantly. For instance, with BLUP selection and trait measurement on both sexes, and first record established at year 2, a nucleus size of 100 dams with 50 dams mated to each sire resulted in ΔG of 0.118 units and F_{10} of 0.119 while that with 500 dams gave a response of 0.134 with F_{10} of 0.037. The standard errors (s.e.) of ΔG reduced with increase in the size of the scheme indicating less variation in response when the scheme was larger. For example, s.e. reduced from 0.024 to 0.014 units when the nucleus size was increased from 100 to 500 dams. A similar effect was found in a 'ram circle'. However, ΔG for a 'ram circle' was little affected by the scheme sizes tested under phenotypic selection. Generally, response to selection was higher if a trait could be measured early in life and on both sexes. For example, with a population of 500 dams and BLUP selection ΔG were 0.134 and 0.111 units for the nucleus and the 'ram circle' schemes, respectively, when trait measurement was at year 2 and both sexes recorded with 50 dams mated to each sire. If trait measurement was at year 3 and on females only, the corresponding responses were 0.080 and 0.066, which was about 60% and 41% lower, respectively.

When more sires were used for a given flock size in both the nucleus and 'ram circle' schemes, ΔG decreased slightly but F_{10} decreased drastically. For example, in a nucleus of 100 dams and phenotypic selection in both sexes with trait measurement at year 2, units for ΔG were 0.100 and 0.097 for 50 and 20 dams per sire, respectively. The corresponding F_{10} values were 0.118 and 0.061. The 'worst case' scenario in terms of ΔG was when trait measurement was on one sex only with a smaller nucleus size. This was best illustrated by a nucleus scheme of 100 dams

Table 6.1. Responses per year (ΔG) in units of phenotypic SD, their standard errors (s.e.) and average inbreeding (F_{10}) after 10 years of BLUP or phenotypic selection in closed nucleus or 'ram circle' breeding schemes of varying size[a,b]

Scheme	No. of dams	No. of sires	Trait measurement	BLUP selection			Phenotypic selection		
				ΔG	s.e.	F_{10}	ΔG	s.e.	F_{10}
Nucleus	50	5	Year 2/both sexes	0.096	0.017	0.067	0.088	0.020	0.060
	100	10		0.099	0.014	0.036	0.091	0.017	0.032
	100	2		0.118	0.024	0.119	0.100	0.026	0.118
	250	5		0.129	0.017	0.064	0.107	0.022	0.055
	500	10		0.134	0.014	0.037	0.112	0.014	0.030
	100	5		0.109	0.017	0.063	0.097	0.022	0.061
	500	25		0.120	0.010	0.015	0.103	0.010	0.013
	500	5		0.145	0.017	0.066	0.120	0.020	0.056
	100	2	Year 3/females only	0.067	0.026	0.091	0.051	0.030	0.123
	500	10		0.080	0.014	0.027	0.055	0.014	0.032
	100	5		0.069	0.020	0.046	0.050	0.020	0.060
	500	25		0.070	0.010	0.011	0.050	0.010	0.013

Table 6.1. *Continued*

Scheme	No. of dams	No. of sires	Trait measurement	BLUP selection			Phenotypic selection		
				ΔG	s.e.	F_{10}	ΔG	s.e.	F_{10}
'Ram circle'	100	2	Year 2/both sexes	0.107	0.024	0.089	0.088	0.026	0.117
	250	5		0.112	0.014	0.034	0.099	0.017	0.032
	500	10		0.111	0.010	0.028	0.099	0.010	0.020
	100	5		0.096	0.017	0.036	0.089	0.020	0.034
	500	25		0.097	0.010	0.027	0.089	0.010	0.019
	100	2	Year 3/females only	0.060	0.026	0.084	0.051	0.026	0.112
	500	10		0.066	0.010	0.026	0.052	0.014	0.021
	100	5		0.056	0.017	0.036	0.046	0.017	0.044
	500	25		0.058	0.010	0.023	0.046	0.010	0.015

[a]Age at drop of first progeny is 2 years.

[b]Based on 100 replicates.

and 50 dams mated to each ram. In this case, ΔG was 0.067 and 0.051 units for BLUP and phenotypic selection, respectively. The corresponding s.e. were 0.026 and 0.030, with respective F_{10} values of 0.091 and 0.123, and were among the highest. This suggests a higher variation in response in phenotypic selection.

Responses from closed nucleus schemes tended to be higher than those from a 'ram circle' scheme of the same size. For instance, under phenotypic selection a scheme of 250 dams with 50 dams mated to each sire had ΔG of 0.107 units for the nucleus and 0.099 for the 'ram circle'. The latter scheme had lower F_{10}. Generally, ΔG was about 6-24% less for the 'ram circle' schemes compared to closed nucleus schemes. However, the responses tended to fluctuate less with variation in the size of the 'ram circle' scheme for a given dam to sire mating ratio. BLUP selection resulted in better ΔG than phenotypic selection for nucleus schemes of the same size but slightly higher F_{10} except with selection on traits measured late on one sex. This was surprising, as more inbreeding was expected with BLUP. The fact that males were selected based on 0.5*EBV(dam) might have caused this occurrence. Inbreeding became worse when the nucleus size was smaller and phenotypes were on females only (i.e., sires were selected based on their dam's record), and measured after selection as BLUP uses more information from relatives in such cases.

6.3.1.2. Effect of 'cycling screening' and migration of animals

Table 6.2 gives a comparison between a two-tier system (scheme I) and an 'interactive cyclic screening' strategy when only males were migrated to the village flocks (schemes III), and when both males and females were distributed from nucleus flocks (scheme IV). The figures presented for the commercial tier refer only to the mean of the animals going to commercial flocks. Genetic trends are illustrated in Fig. 6.2 and 6.3. In the two-tier system, the nucleus was basically closed, and excess males were distributed over commercial flocks. The nucleus was set up initially by selecting the best males and females from commercial flocks (based on a

Table 6.2. Responses (ΔG) in units of phenotypic SD in the nucleus, genetic lag (GL) between the nucleus and commercial tier and average inbreeding (F) in a 2-tier system (scheme I) and 'interactive cycling screening' strategies (scheme III and IV) based on BLUP selection over a 15-year period[a,b,c]

Year	Single 2-tier nucleus scheme				'Interactive cycling screening' scheme							
	ΔG Nucleus	GL Commercial	s.e.	F	ΔG[d] Nucleus	GL[d] Commercial	s.e.	F[d]	ΔG[e] Nucleus	GL[e] Commercial	s.e.	F[e]
1	0.373	0.373	0.036	0.000	0.369	0.369	0.032	0.000	0.352	0.352	0.035	0.000
2	0.388	0.388	0.039	0.000	0.365	0.365	0.035	0.000	0.349	0.349	0.039	0.000
3	0.676	0.256	0.041	0.010	0.680	0.294	0.035	0.011	0.669	0.270	0.042	0.010
4	0.758	0.314	0.042	0.019	0.749	0.033	0.055	0.000	0.747	-0.048	0.055	0.000
5	0.938	0.384	0.044	0.030	1.008	0.471	0.037	0.018	0.992	0.406	0.050	0.015
6	1.054	0.457	0.046	0.042	1.126	0.498	0.055	0.012	1.122	0.410	0.057	0.011
7	1.195	0.519	0.051	0.055	0.974	-0.172	0.054	0.000	1.053	-0.095	0.073	0.000
8	1.322	0.590	0.049	0.068	1.415	0.671	0.055	0.027	1.410	0.530	0.060	0.018
9	1.459	0.650	0.060	0.080	1.452	0.668	0.055	0.019	1.468	0.550	0.058	0.013
10	1.589	0.714	0.057	0.094	1.146	-0.253	0.055	0.000	1.257	-0.204	0.066	0.000
11	1.725	0.794	0.062	0.109	1.706	0.793	0.057	0.041	1.707	0.635	0.063	0.019
12	1.829	0.823	0.059	0.121	1.719	0.855	0.057	0.030	1.737	0.672	0.062	0.015
13	1.965	0.891	0.062	0.137	1.204	-0.366	0.062	0.000	1.404	-0.267	0.064	0.000
14	2.074	0.943	0.062	0.149	1.990	0.965	0.060	0.057	1.917	0.693	0.062	0.020
15	2.208	1.003	0.063	0.162	1.964	1.0647	0.057	0.047	1.926	0.750	0.062	0.017

[a]The nucleus size is 250 dams and screening on the offspring of 250 commercial animals. [b]Age at drop of first progeny is 2 years, and first record is established during second year, with both sexes recorded. [c]Fifty dams are mated to each sire. [d]Migration of sires only from the nucleus to commercial flocks (scheme III). [e]Migration of both sires and dams allowed (scheme IV).

lower accuracy equal to the square root of half of the heritability). In the 'interactive cyclic screening' schemes, all nucleus animals were distributed over village flocks every 3 years and the nucleus was replaced by a new batch of selected males and females from the village flocks (Fig. 6.1).

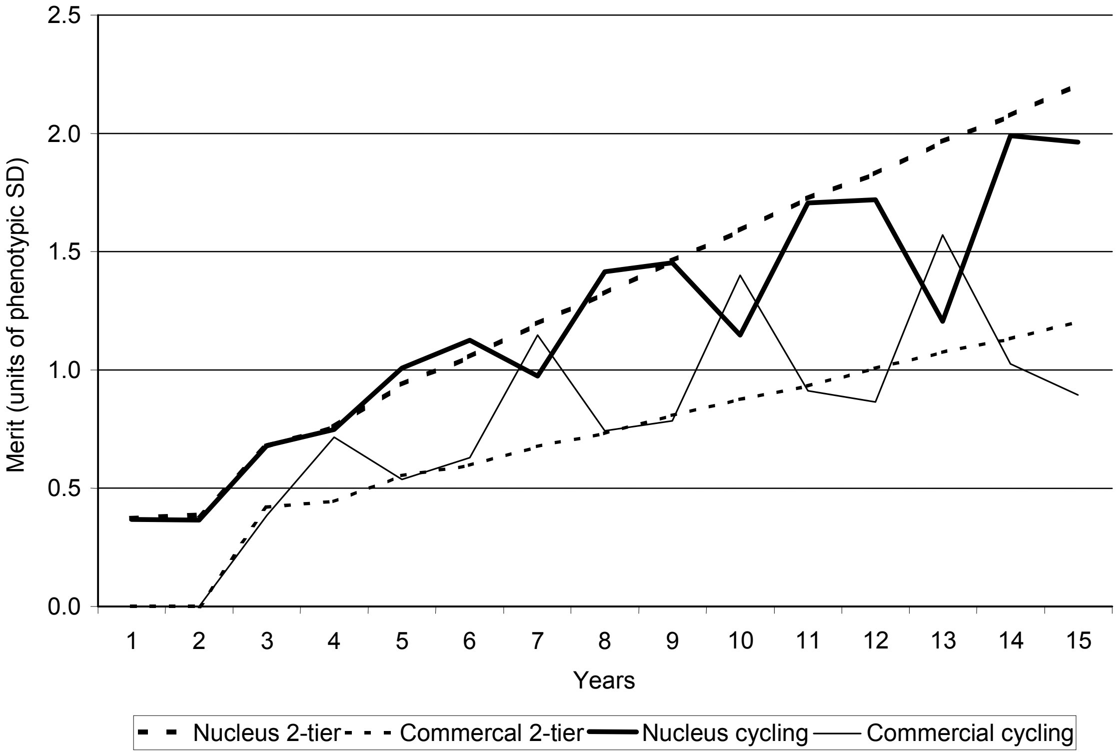

Fig. 6.2. Genetic improvement in nucleus and commercial flocks for a two-tier system (scheme I) and for a system with 3-yearly 'cyclic screening' of commercial flocks to replace the nucleus, and only males were migrated to the commercial flocks (scheme III). The nucleus size was 250 dams and screening on the offspring of 250 commercial animals, with 50 dams mated to each sire. Age at drop of first progeny was 2 years, and first record was established during second year, with both sexes recorded.

Generally, the genetic trends in the three schemes (I, III and IV) were quite similar over time (Fig. 6.2 and 6.3). As expected, the commercial flocks in the two-tier system (scheme I) genetically lagged behind the nucleus flocks. However, F increased to unacceptably high levels in such a scheme. In the 'interactive cyclic screening' scheme, the genetic mean fluctuated over time and the nucleus pulled ahead of the commercial population except when a new batch of village flocks was brought in. In that case, the commercial population got a genetic lift. For example, in scheme III in year 10 the commercial flock was about 22% ahead of the nucleus genetically. In the subsequent year, the genetic merit of the nucleus was about two times that of the commercial population since year 0. The reason for the slow down of genetic trend after year 10 and the negative response in year 12 in the commercial tier is not clear.

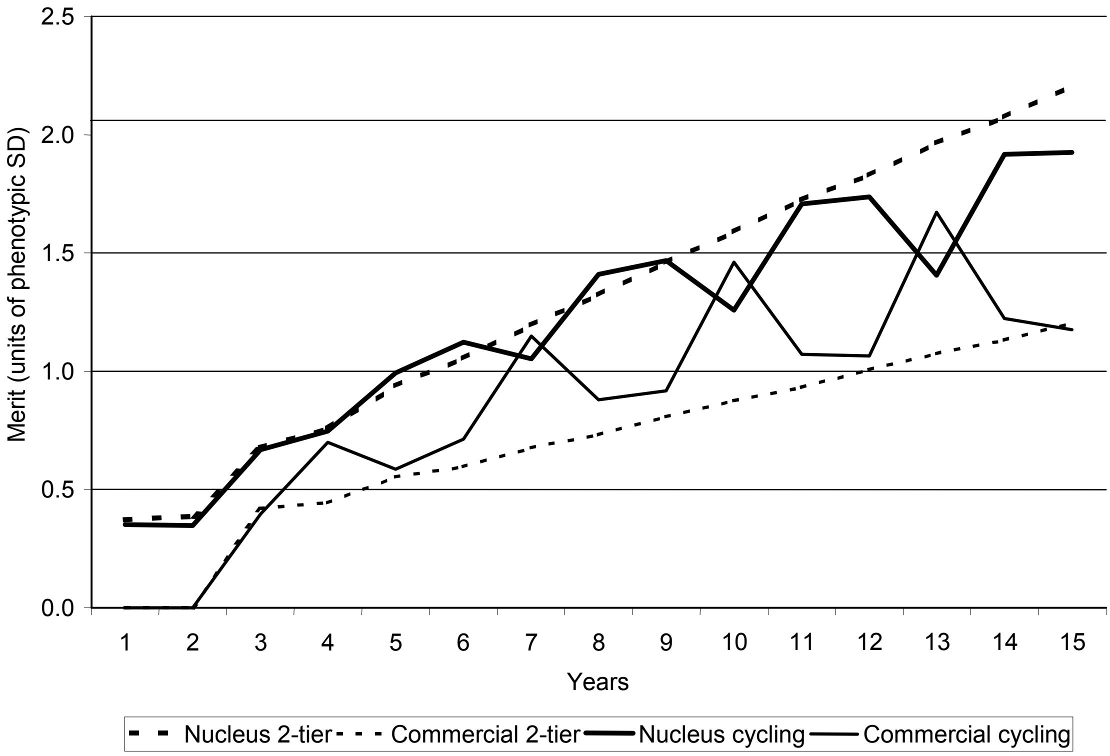

Fig. 6.3. As Figure 6.2, except both sexes were migrated to the commercial flocks (scheme IV).

The levels of F in the 'interactive cyclic screening' schemes also fluctuated but remained very low and were actually zero whenever a new batch of animals was 'picked' for the nucleus from the village flocks (Table 6.2). At year 15 for instance, F was just above 4% in scheme III. However, F was biased downward because the pedigree of commercial animals was not available and therefore not used for calculation of F. Generally, an 'interactive cyclic screening' scheme that allowed the migration of both males and females from the nucleus to the commercial flocks (scheme IV) resulted in slightly higher ΔG for commercial flocks compared with the scheme that allowed migration of males only (scheme III), and in the long-run F was lower. The variation in response was slightly higher for the scheme that allowed migration of both sexes. With BLUP selection the commercial flocks had a genetic lag that was on average about two generations behind that of the nucleus when only males were migrated. Genetic gains in 'interactive cyclic screening' schemes compared favourably in some instances with the two-tier scheme (scheme I). These schemes got a genetic lift when they received animals from the nucleus while the nucleus could or could not drop depending on the breeding values of the 'picked' animals from the commercial flocks vis-à-vis those they would replace in the nucleus (Fig. 6.2 and 6.3).

6.4. Discussion and conclusions

Structured breeding systems are important for the genetic improvement of sheep in the tropics. The aim of the current study was to determine the benefit of different pure-breeding nucleus schemes interacting with commercial flocks. The key issue was to technically examine different breeding programmes that vary in the level of interaction between breeders and producers under smallholder and pastoral production circumstances in the tropics.

Genetic improvement can be obtained from male and female selection with the first being the major contributor to genetic improvement. It is important from the outset to bear in mind that possible rates of genetic improvement depend on the time that the trait can be measured and whether or not the trait can be measured on both sexes or on females only.

A nucleus breeding structure is a convenient start for many breeding programmes as trait measurement, selection and mating are easier to manage

(Hodges, 1990; Kiwuwa, 1992; van der Werf, 2000). It is not worth including all animals of a population in the active part of a breeding programme due to measurement costs, recording costs and lack of proper control (Kinghorn et al., 2000). It is recommended that nucleus breeding programmes for sheep in developing countries evolve towards an open nucleus where the best females from the commercial population can be migrated up for breeding in the nucleus (Jasiorowski, 1990). The dilemma is how to effectively organize breeding schemes involving farmers at the village level, how to record such flocks and to monitor progress (Osinowo and Abubakar, 1988). To involve farmers, it is advisable to back the breeding programme with an effective extension service for maximum effect. Before initiation of the selection programme, it should be preceded with several years of extension work to train the farmers and boost their experiences and skills in sheep production techniques (e.g., Yapi-Gnoaré, 2000). During that period farmers should be made aware of the benefits derived from the recording activity (Moioli et al., 2002).

It was shown in the current study that nucleus size influenced both the rate of genetic response (ΔG) and the predicted average inbreeding coefficient (F). Genetic merit increased slightly with increase in nucleus size while F decreased (Table 6.1). Garrick et al. (2000) observed a similar trend with regard to ΔG and reported increases in costs of genetic improvement when the nucleus size was increased. Costs of running the schemes were not considered in the current study.

A genetic improvement programme from a small nucleus flock of few animals can give an unacceptably high level of inbreeding. However, this depends on the number of males used (Table 6.1). Increasing the number of males reduces F at very little expense of ΔG due to lower selection differential. It was shown in the current study that it is still possible to make greater ΔG even with smaller flocks. For instance, a nucleus with 50 dams and 5 sires gave ΔG that was only 12% lower compared to a nucleus of 100 dams and 50 sires, and 28% less than response from a scheme of 500 dams and 10 sires with BLUP selection (Table 6.1). The differences in ΔG tended to be lower with phenotypic selection. However, F_{10} was higher for the smaller scheme. Other studies have recommended that for a single nucleus-breeding flock, at least about 500 breeding females are needed (e.g., Turner, 1982; Udo, 1994). A smaller nucleus is permitted if it is started up with periodic recruitment of breeding males from commercial flocks, as effectively a much larger founder population is used for the nucleus, or if proper use is made of optimal contributions to help control inbreeding (Meuwissen, 1997).

There was some advantage of running one closed nucleus over a ‘ram circle’. The rate of genetic improvement was about 6-24% less for the ‘ram circle’ (Table 6.1). However, ‘ram circle’ breeding programmes can, to some extent, be useful when selection can be based on individual’s phenotype in both sexes. The difference between the nucleus and ‘ram circle’ schemes increased with selection on a late trait in one sex only compared to an early trait in two sexes.

BLUP selection leads to significantly more genetic gain than selection on individual phenotype but the increased gain is accompanied by more inbreeding. Using information from family members increases the chance of co-selection of members of the same (good) family (Belonsky and Kennedy, 1988). Dynamic selection rules (e.g., Wray and Goddard, 1994; Meuwissen, 1997) have been developed that maximize selection response while limiting the rate of inbreeding. At the same rate of inbreeding, Meuwissen and Sonesson (1998) found that the dynamic selection method obtained up to 44% more genetic gain than truncation selection on BLUP breeding values. The advantage of the dynamic selection method over BLUP selection decreased with increasing population size and with less stringent restriction on inbreeding.

Generally, a two-tier closed nucleus scheme supplying seed-stock to commercial flocks (i.e., scheme I) was better than the ‘interactive cyclic screening’ scheme in terms of genetic gain (Table 6.2). There is better trait measurement and selection in the nucleus and therefore an increased advantage over the ‘interactive cyclic screening’ schemes. In the latter schemes the commercial tier got a genetic boost only when they received improved animals from the nucleus and thereafter dropped again drastically. However, there was generally still substantial genetic trend, close to the results of the two-tier nucleus scheme (scheme I) (Fig. 6.2 and 6.3). To avoid the drop, the commercial flocks could be encouraged to use their own rams for an extra year and wait until the nucleus catches up again. It is important to note that not all commercial animals are replaced by nucleus animals after swap.

Opening the nucleus to the best animals from the commercial flocks would result in more sustained returns from selection in the commercial flocks due to more selection intensity, and therefore more certainty that the best females (and males) are selected, as a result of increased genetic variation in the next generation (Kinghorn et al., 2000). Open nucleus schemes provide an operational procedure for achieving greater genetic progress and more flexibility in meeting breeding objectives than does a closed nucleus (e.g., Parker and Rae, 1982). However, measurement costs and logistics of data collection in commercial flocks are likely to be huge and not feasible in developing countries in the tropics, and therefore the 'interactive cyclic screening' schemes proposed in this study would be more practical as minimal recording is required.

As in other places (e.g., Garrick et al., 2000), the sheep industry structure in the tropics is determined by the behaviour of breeders and farmers but there is often little individual incentive for these players to alter their practices despite overall benefit to the industry, plus the fact that they might not have the capital to buy breeding stock. Exchange breeding programmes where village flocks provide their best females and in return the villagers get breeding stock from the nucleus as an incentive to participate in genetic improvement will likely make the breeding programme sustainable in the long-term. Such might be the basis of setting up 'interactive cyclic screening' schemes because they accord participation of the farmers in the operations of genetic improvement. 'Cyclic screening' of commercial animals for use in the nucleus can give almost optimum genetic gains. Obviously, the nucleus will temporarily drop while the village flocks get a genetic lift. However, over time, ΔG is only slightly below that of a two-tier system (Fig. 6.2 and 6.3).

Although this study did not extensively examine ways to control inbreeding except the effect of different dam to sire ratios (Table 6.1), it is important to point them out due to the potential risk inbreeding poses in small breeding flocks in smallholder production circumstances commonly found in the tropics (e.g., Gatenby, 1986). Various methods have been proposed to reduce the rates of inbreeding in selection programmes while keeping genetic gains at the same level (for details see e.g., Grundy et al., 1994; Wray and Goddard, 1994; Santiago and Caballero, 1995; Meuwissen, 1997; Kinghorn et al., 2000). These methods can be applied in combination with genetic evaluation system. They require that the breeders are able to control mating strategies. It may be logistically difficult to control the mating strategy in traditional smallholder and pastoral animal production systems in developing countries in the tropics, and manipulating the dam to sire ratio could be a simpler solution. Dynamic selection methods to control inbreeding do rely on pedigree knowledge that is not often available in the tropics. Therefore, in a breeding scheme, these dynamic rules and pedigree recording are only required for the nucleus population. Within the nucleus, the number of matings per breeding male can be restricted to limit the rate of inbreeding, while still maintaining optimal genetic progress. A village flock could use fewer males if they regularly import new males from neighbouring villages or the nucleus flock.

Reproductive rates can be manipulated by reproductive technologies such as artificial insemination (AI) for males and multiple ovulation and embryo transfer (MOET) for females (e.g., Kinghorn et al., 2000). The natural reproductive rate of ewes will limit their contributions, resulting in some fixed contributions (Meuwissen, 1997). Nevertheless, in extensive production systems such reproductive technologies are not always available or necessary (van der Werf, 2000). Use of AI is feasible (Rege, 1994; van der Werf, 2000), and it could be usefully applied for efficient dissemination of genetic improvement from the nucleus to commercial flocks (van der Werf, 2000). However, transporting a ram is also easy and may just be as effective for dissemination purposes.

In conclusion, the current study generally provides new insights into the advantages and disadvantages of designed breeding structures, especially the ‘interactive cycling screening’ schemes, which is valuable in deciding breeding programmes to adopt for sheep in the tropics.

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Chapter 7

Evaluation of nucleus breeding schemes for sheep in smallholder and pastoral production circumstances in the tropics

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Abstract

Nucleus breeding schemes have been recommended to tackle the socio-economic hindrances to genetic improvement of small ruminants (i.e., sheep and goats) in developing countries of the tropics. The key issue in the current study was to evaluate whether a single nucleus breeding programme could be used for both smallholder and pastoral production circumstances in the tropics. Stochastic simulation was used to technically compare single closed nucleus sheep pure-breeding schemes that considered productive, reproductive and survival traits simultaneously. The effect of sire to dam mating ratio, age structures of breeding animals, survival rates of breeding animals and type of mating practised were studied. Firstly, direct responses ($) were calculated for each scenario. Secondly, the correlated responses for the alternative production system were evaluated. For the nucleus sire to dam mating ratio, the optimal scheme in terms of the total dollar response for both farming systems was one operating at 50 dams per sire, and 5-10 sires in the nucleus flock. The correlated responses for smallholder production ranged from 16% lower to 9% higher than direct responses for smallholder production. For pastoral production, correlated responses varied from 8% less to 15% higher than direct responses. With regard to age structure, the optimal schemes were those that had animals dropping their first progeny at 2 years of age and last progeny, respectively, at 3 to 4 and 3 to 7 years for males and females. For age structure, the correlated responses for smallholder production were, on average, the same as the direct responses, and varied between 9% less to 11% more than the direct responses for pastoral production. Generally, higher survival rates increased responses. Contrary to simple expectation, random mating resulted in higher responses than assortative mating. This could have been due to higher inbreeding in the latter case, which, relative to random mating was about 5% greater under smallholder and 70% greater under pastoral production. The correlated responses for the smallholder production were 3% and 1% higher than the correlated responses for random and assortative mating, respectively. For pastoral production the correlated response due to selection under smallholder production was 4% less than direct response for random mating, and similar for assortative mating. In conclusion, the results in the current study demonstrate that one breeding programme could serve both the smallholder and pastoral production if genotype and environment interaction is sufficiently low. However, further studies would be necessary when genetic parameters differ for the two production systems or when genotype by environment interaction is present.

(***Keywords***: Sheep; Nucleus breeding schemes; Smallholder, Pastoral; Tropics)

7.1. Introduction

Small ruminants are important to the livelihoods of people in the tropics in terms of both tangible benefits (e.g., cash income from sale of animals, meat for home consumption, manure and skins) and intangible benefits (e.g., savings, an insurance against emergencies, and prestige value from keeping large flocks) (Upton, 1985; Gatenby, 1986; Hunter, 1989; Slingerland et al., 1998; Jaitner et al., 2001; Seleka, 2001; Kosgey et al., 2003; 2004a and b). Their potential for far greater contribution to the animal protein supply through better management and genetic improvement is yet to be realized (Kosgey et al., 2002). Genetic improvement envisages the definition of relevant breeding goals and design of appropriate breeding strategies with well-structured populations (see also Ponzoni, 1992). The first key to genetic improvement is obtaining good records (van Vleck et al., 1987), a feat still logistically difficult to effect successfully in commercial animal populations in most developing countries in the tropics.

Implementation of performance and progeny-testing in the tropics are precluded by communal grazing, small animal populations, single sire flocks, lack of systematic animal identification, inadequate recording of animal performance and pedigree, low levels of literacy and organizational shortcomings (Kiwuwa, 1992; Jaitner et al., 2001; Wollny et al., 2002). In addition, apart from small animal populations and probably single sire flocks, pastoral flocks face a problem of mobility (Kosgey et al., 2004d). Consequently, improvement programmes have largely concentrated on the introduction of breeds from temperate environments for utilization either as purebreds or for crossbreeding (Turner, 1978a; Howe and Turner, 1984; Kiwuwa, 1992). Nucleus breeding schemes have been proposed as a good strategy to tackle the socio-economic hindrances – financial, human, infrastructural - to livestock improvement in developing countries in the tropics (Mason and Buvanendran, 1982; Turner, 1982; Smith, 1988; Hodges, 1990; Jasiorowski, 1990). Closed nucleus schemes do not require large scale infrastructure because recording is restricted to the nucleus flocks and use of available resources can be optimized, with better control of activities (Smith, 1988). In addition, the nucleus population provides an opportunity to record information on more traits than is possible in a decentralized breeding scheme.

The first step in planning any breeding system is to define carefully what the production objectives are for the particular environment being considered (Carles, 1983; Sölkner et al., 1998). Generally, meat production is the most important objective for sheep in the tropics, and in its broad sense, meat production depends on both adaptation and production traits. Therefore, the breeding goal should aim at an animal with good production, reproduction, fitness and health characteristics (Kiwuwa, 1992). The importance and the relative contribution of different traits to the overall performance depend on production circumstances, specifically the severity of the environmental constraints (Conington et al., 2001). For instance, in smallholder and pastoral tropical farming systems survival in the face of multiple stresses (e.g., heat, disease and poor nutrition) is one of the most important traits, while increasing growth rate is of less significance (Upton, 1985). In more intense production systems, productivity may take higher priority. What has not been studied often under tropical conditions is if separate breeding programmes are needed for the smallholder and pastoral production circumstances.

The aim of this study was to technically examine if there is need for different selection programmes for smallholder and pastoral production. Stochastic simulation was used to evaluate single nucleus pure-breeding schemes for indigenous sheep by considering productive, reproductive and survival traits simultaneously in the selection index. The parameters used to compare the schemes studied were the obtained genetic improvement for merit ($ index) and the average inbreeding coefficient.

7.2. Material and methods

Closed nucleus pure-breeding schemes for sheep were modelled under two sets of production objectives in the tropics: (i) smallholder and (ii) pastoral. A breeding population with overlapping generations was stochastically simulated for 20 years, using 600 replicates. Subsequently, the average direct genetic responses ($) were calculated for each scenario for the last 10 (i.e., from 11 to 20) years of the selection programme. Secondly, the average correlated responses for the alternative production system were evaluated for the same period. This was in order to avoid any big sampling errors in responses that may occur initially as the programme picks up. All the calculations related to genetic merit are in dollar index ($), calculated by multiplying the average genetic response of each trait considered by its economic value. The average inbreeding (F_{10}) was also calculated for the last 10 years of the selection programme. Both males and females were selected in the nucleus based on truncation using best linear unbiased prediction (BLUP) as a deviation from the contemporaries in the same flock, year and season. The best males were used in the nucleus while the second category males were used in the commercial flocks. The potential benefits from genetic change in important productive, reproductive and survival traits presented in earlier studies by Kosgey et al. (2003; 2004a) for tropical smallholder and pastoral production situations were estimated (Table 7.1). The calculated rates of genetic gain account for the effect of selection (Bulmer, 1980). An optimal breeding programme was recommended, based on the total merit index ($) and the degree of average inbreeding coefficient (F_{10}).

7.2.1. Production objectives

7.2.1.1. Indigenous sheep under smallholder production system

This objective assumes that the animals are used for tangible benefits (i.e., cash income from sales, meat for home consumption and manure) and are on a more improved level of management (Kosgey et al., 2003). This sector places more emphasis on human nutrition and subsistence. The sheep are mainly the indigenous type and are concentrated in the relatively medium- to high-potential areas. Flock sizes vary from a few sheep to about 100 in total. Normally, all ages and sexes of sheep are left to run together at all times and mating is at random within the flock.

7.2.1.2. Indigenous sheep under pastoral production system

This objective assumes that the animals are used for both tangible benefits (i.e., cash income from sales, meat for home consumption, manure and skins), and intangible benefits (i.e., financing, an insurance against emergencies, and prestige value from keeping large flocks) (Kosgey et al., 2004a). However, the economic values used in the current study do not include the prestige value from sheep. The sheep are the indigenous type and are found in the medium- to low-potential areas largely under communal or extensive grazing. Flock sizes are usually relatively large. Management and health costs are minimal, with hardly any fixed costs. Normally, all ages and sexes of sheep are left to run together at all times and mating is at random within the flock.

7.2.2. Traits, their genetic parameters and economic values

Table 7.2 shows the heritabilities, genotypic and phenotypic correlations of the traits in the breeding objective. There is generally an extreme paucity of reliable genetic parameters in the indigenous tropical flocks on the component traits of

Table 7.1. Traits used in the evaluation of breeding schemes

Trait	Unit	Abbreviation
Litter size	Average number of lambs born over parities per ewe lambing per year	LS
Lambing frequency	Average number of lambings per ewe per year	LF
Pre-weaning survival	Lambs surviving to weaning as a % of lambs born	PRWS
Post-weaning survival	Lambs surviving to 12 months of age as a % of lambs weaned	PWS
Ewe survival	Ewes surviving as a % of ewes present over the year	ES
12-month lamb live weight, i.e., live weight at slaughter	kg	12mLW
Mature ewe live weight	kg	ELW
Consumable meat	Consumable meat output as a % of live weight at slaughter	CM

From: Kosgey et al. (2003; 2004a).

Table 7.2. Heritabilities (along diagonal), genetic correlations (below diagonal) and phenotypic correlations (above diagonal) of the traits in the breeding goal

Trait	LS	LF	PRWS	PWS	ES	12mLW	ELW	CM
LS	0.10	0.10	0.77	-0.15	0.12	0.26	0.24	0.35
LF	0.11	0.07	0.00	0.00	0.12	0.50	0.52	0.09
PRWS	0.57	0.00	0.02	0.28	0.00	0.10	0.10	0.10
PWS	-0.48	0.00	0.30	0.05	0.31	0.48	0.48	0.48
ES	0.20	0.12	0.10	0.42	0.10	0.80	0.80	0.80
12mLW	0.20	0.10	0.10	0.72	0.71	0.25	0.76	0.76
ELW	0.12	0.00	0.20	0.91	0.20	0.91	0.30	0.30
CM	0.12	0.00	0.10	0.48	0.80	0.76	0.30	0.40

Derived from: Rae (1982), Carles (1983), Gatenby (1986), van Vleck et al. (1987), Ponzoni (1992), Fogarty (1995), Matika (1995), Ermias et al. (2002), François et al. (2002), Kosgey et al. (2004a), N'Guetta Bosso (Personal Communication), Robert Banks (Personal Communication).

Table 7.3. Population means (μ), heritabilities (h^2), repeatabilities (R), phenotypic (σ_p) and genetic (σ_G) standard deviations, and economic values (EVs) for traits in the breeding goal for smallholder and pastoral production[a]

Trait[b]	Parameters of the traits						
						EVs	
	μ	h^2	R	σ_p	σ_G	Smallholder	Pastoral
LS	1.18	0.10	0.15	0.36	0.11	12.94	25.11
LF	1.50	0.07	0.15	1.23	0.32	10.18	19.75
PRWS	0.80	0.02	0.02	0.29	0.04	0.19	0.37
PWS	0.85	0.05	0.05	0.29	0.07	0.24	0.37
ES	0.90	0.10	0.10	0.50	0.16	0.36	0.33
12mLW	25.00	0.25	0.45	2.87	1.43	1.02	1.26
ELW	30.00	0.30	0.30	3.71	2.03	0.14	0.21
CM	0.60	0.40	0.40	0.23	0.14	0.51	0.62

[a]From: Carles (1983), Ponzoni (1992), Kosgey et al. (2003; 2004a). [b]See Table 7.1 for definition of units and abbreviations.

importance. Therefore, average estimates from the literature were used. Where figures from the tropics could not be found, information from temperate areas was used. The economic values and other parameters of the traits used in the evaluation are given in Table 7.3. The economic values were undiscounted and calculated as the partial derivative of the profit with respect to each trait considered, holding all other traits constant at the mean value, and were calculated for each objective (Kosgey et al., 2003; 2004a). The difference between the smallholder and pastoral production were only in the economic values of the traits considered (Kosgey et al., 2003; 2004a). Genotype by environment interaction was assumed to be insignificant which may not usually be the case.

Reproductive rate and live weight are important traits for sheep in the tropics (Mason and Buvanendran, 1982; Ponzoni, 1992). Reproductive rates can be increased either by raising the number of offspring at parturition (i.e., litter size), or by decreasing the period between parturitions (i.e., increasing lambing frequency). The second alternative might be more practical in tropical sheep due to the long breeding seasons and frequency of low nutritional levels that might make the ewe find difficulty in rearing more than one lamb (Mason and Buvanendran, 1982). Although reproductive rate traits have low heritability (e.g., litter size with heritability of 0.10-0.15), they have been known to respond to selection (Turner, 1978b; Carles, 1983; Osinowo and Abubakar, 1988). In addition, the genetic correlations between prolificacy, growth rate and carcass quality are positive and therefore selection for the traits can be done simultaneously without any antagonism (Mason and Buvanendran, 1982; Carles, 1983). Consumable meat as a measure of meat yield is an important productive trait in the tropics (Gatenby, 1986; Kosgey et al., 2003). Health problems in the tropics often result from a generalized, rather than a specific lack of adaptation. Therefore, an overall measure of adaptation is desirable (Franklin, 1986). In this study, survival (pre- and post-weaning, and adult) was presumed to reflect disease resistance (Kosgey et al., 2003).

7.2.3. Factors studied

The effects of the following were examined:

(i) sire to dam mating ratios,

(ii) age structures of breeding animals,

(iii) annual survival rates of breeding animals and

(iv) type of mating practised in the nucleus (i.e., random versus assortative).

As a reference to compare other schemes, a base scheme with 10 sires and 500 ewes, and using natural mating with a sire to dam ratio of 1:50 was assumed. For this scheme, survival probabilities decreased by 10% each year increase of age starting at 90% in year 1 (Kosgey et al., 2003). Age at drop of first progeny was assumed to be 2 years for both males and females, while that at last drop was assumed to be 3 and 6 years for males and females, respectively. It was assumed that there was a probability of 0.2 of producing a single lamb from maiden females in age class 3 and 4, and 0.2 in each of the first 2 age classes of adult females. The last 2 age classes of adult females were assumed to each have a probability of 0.1 of having a single lamb.

7.3. Results and discussion

7.3.1. Factors influencing genetic progress

7.3.1.1. Effect of sire to dam mating ratio and age structure

Table 7.4 presents the effect of different sire to dam mating ratios in the nucleus scheme. Generally, an increase in the number of dams per sire increased the total dollar response and decreased the average inbreeding (F_{10}). However, a higher number of dams with fewer sires increased F_{10} which subsequently depressed the total dollar response. For instance, a scheme operating with 2 sires in smallholder production showed an increase of 8% in total dollar response from \$74.3 to \$80.3 when the number of dams per sire were, respectively, increased from

Table 7.4. The average direct (D) responses ($ index), correlated (C) responses (ratio to D) with standard errors (s.e.) and average inbreeding (F_{10}) for the last 10 years of a 20 year BLUP selection in closed nucleus schemes with varying sire to dam mating ratios in smallholder and pastoral production circumstances[a,b,c]

Breeding structure		Smallholder (s.e. =$0.9-1.0)			Pastoral (s.e. $1.7-1.8)		
Sires	Dams/sire	D	C	F_{10}	D	C	F_{10}
1	10	79.8	0.97	0.54	125.1	1.05	0.59
2		74.3	1.02	0.52	124.8	0.97	0.49
5		70.6	1.15	0.24	135.3	0.84	0.28
10		87.3	0.92	0.19	132.9	1.09	0.18
1	20	76.1	0.96	0.51	120.2	1.04	0.47
2		82.5	1.02	0.50	141.0	0.98	0.43
5		81.7	0.99	0.31	133.1	1.02	0.27
10		81.0	0.98	0.17	131.8	1.02	0.18
1	50	68.7	1.12	0.46	127.0	0.88	0.39
2		80.3	0.94	0.33	124.1	1.06	0.38
5		85.3	1.04	0.31	150.7	0.94	0.36
10		91.1	1.03	0.21	159.9	0.96	0.20
1	100	81.1	1.04	0.49	142.0	0.94	0.41
2		78.7	0.93	0.47	142.0	0.91	0.41
5		82.7	1.12	0.24	156.4	0.88	0.28
10		80.7	1.13	0.21	152.3	0.88	0.20
1	500	80.7	1.05	0.30	142.1	0.94	0.32
2		81.9	1.04	0.30	143.6	0.93	0.33

[a]Age at drop of first progeny is 2 years for both sexes and drop of last progeny is 3 years for males and 6 years for females.

[b]Adult animal survival rate of 90%. [c]Based on 600 replicates.

Table 7.5. The average direct responses (D) ($ index) and correlated (C) responses (ratio to D) with standard errors (s.e.) and average inbreeding (F_{10}) for the last 10 years of a 20 year BLUP selection in closed nucleus schemes with varying age structures of breeding animals in smallholder and pastoral production circumstances[a,b,c]

Male		Female		Smallholder (s.e. =$0.9-1.0)			Pastoral (s.e. = $1.7-1.8)		
First	Last	First	Last	D	C	F_{10}	D	C	F_{10}
2	4	2	6	91.8	0.97	0.28	134.5	1.11	0.26
		2	8	91.0	0.95	0.24	146.9	1.04	0.27
2	3	2	3	86.4	0.99	0.21	143.7	1.01	0.21
		2	5	86.4	1.00	0.22	145.6	1.00	0.23
		2	4	85.4	1.01	0.22	145.8	0.98	0.28
		2	6	91.1	1.03	0.21	159.9	0.96	0.20
		2	7	86.8	1.04	0.21	151.9	0.96	0.21
		2	8	84.9	1.05	0.23	151.5	0.94	0.21
1	2	1	2	54.2	1.06	0.50	91.0	0.93	0.50
		2	3	60.3	1.09	0.15	106.7	0.91	0.19
		2	5	69.0	0.96	0.13	108.2	1.04	0.14
		2	6	75.6	0.97	0.09	119.4	1.05	0.15
		2	8	71.2	0.91	0.13	105.7	1.11	0.10

[a]Breeding structure is 10 males to 50 dams. [b]Adult animal survival of 90%. [c]Based on 600 replicates.

10 to 50. Conversely, F_{10} decreased by 35% from 0.52 to 0.33, respectively. Relative to the base scheme the increase in total dollar response was about 18%. In the same scheme, when the number of dams was raised from 50 to 100, inbreeding increased to 0.47, representing an increase of 42%. By increasing the number of dams per sire, the effective population size was increased and therefore reduced F_{10}. However, selection intensity decreased, resulting in reduced responses. The optimal scheme in terms of total dollar response for both farming systems was one operating at 50 dams per sire, and 5-10 sires in the flock. Generally, increase in test capacity increased the total dollar response. Schemes operating at more than 100 dams per sire (not all results shown) would imply use of artificial insemination, which is currently not available in developing countries of the tropics due to lack of infrastructure, skilled manpower and financial resources. Schemes operating at 10 or 20 dams per sire would not be optimal in the use of sires and resources, and would result in more F_{10}. In addition, the pattern of responses for smaller schemes becomes unclear. The correlated responses in smallholder production due to selection under pastoral conditions varied from 8% lower to 15% higher than the direct responses. For pastoral production, the correlated responses ranged between 6% less to 9% higher than the direct responses. The results demonstrate that one breeding programme can serve both smallholder and pastoral production, irrespective of sire to dam mating ratio if genotype and environment interaction is sufficiently low.

Table 7.5 shows the effect of age structure of breeding animals. Generally, the direct responses increased and F_{10} decreased with reduction in the age of drop of last progeny. Conversely, mating and disposing of animals too early resulted in low total dollar response due to high F_{10}. For example, when males had their first progeny at 2 years of age and last progeny at 3 years, the direct total dollar response for smallholder production increased from \$84.9 to \$91.1 when age at drop of last progeny for females was reduced from 8 to 6 years. As expected, F_{10} decreased (from 0.23 to 0.21). Optimal schemes would be those that have females drop their first progeny at 2 years of age and last progeny at 5-7 years of age. More importantly is when females dropped their last progeny at 6 years of age. It was

Table 7.6. The average direct (D) responses ($ index) and correlated (C) responses (ratio to D) with standard errors (s.e.) and average inbreeding (F_{10}) for the last 10 years of a 20 year BLUP selection in closed nucleus schemes with varying survival rates of breeding animals in smallholder and pastoral production circumstances[a,b]

Survival rate (%)	Smallholder (s.e. $0.9-1.0)			Pastoral (s.e. $1.7-1.8)		
	D	C	F_{10}	D	C	F_{10}
50	82.2	1.05	0.19	144.3	0.95	0.17
60	82.2	1.03	0.18	142.8	0.96	0.20
70	85.6	0.97	0.21	139.4	0.97	0.20
80	84.2	1.05	0.23	148.8	1.06	0.21
90	91.1	1.03	0.209	159.8	0.96	0.20
100	86.2	0.97	0.216	140.6	0.98	0.22

[a]Age at drop of first progeny is 2 years and last drop is 3 years for males and 6 years for females.

[b]Based on 600 replicates with a mating structure of 10 sires and 50 dams per sire.

Table 7.7. The average direct (D) responses ($ index), correlated (C) responses (ratio to D) and average inbreeding (F_{10}) for the last 10 years of a 20 year BLUP selection in closed nucleus schemes for different types of mating practiced in smallholder and pastoral production circumstances[a,b]

Type of mating	Smallholder (s.e. = $0.9-1.0)			Pastoral (s.e. = $1.8)		
	D	C	F_{10}	D	C	F_{10}
Random	91.1	1.03	0.21	159.8	0.96	0.20
Assortative	88.3	1.01	0.22	148.7	1.00	0.34

[a]Age at drop of first progeny is 2 years, and last drop is 3 years for males and 6 years for females.

[b]Based on 600 replicates, and adult animal survival of 90%.

apparent that the influence of the age of males was more important than that of females. The correlated responses for smallholder production were on average similar to the direct responses. The correlated responses for pastoral production ranged from 6% lower to 11% higher than the direct responses.

7.3.1.2. Effect of survival rate and type of mating

Table 7.6 shows the effect of survival rate of breeding animals. The same survival rates were used each time for both males and females. A survival rate of less than 40% would not sustain the nucleus, because soon there would be a shortage of breeding animals. Although a clear pattern was not evident, both the total dollar responses and F_{10} tended to increase with survival rates for both farming systems. This was due to increased selection intensity and accuracy of selection as a result of many records being available. However, this may not always be the case if using optimal contributions theory. Much as increased selection intensity and accuracy of selection resulted in increased genetic gain for some traits, others resulted in negative responses. This, coupled with the increased F_{10}, would explain why for instance under smallholder production, the direct response reduced from \$85.6 to \$ 84.2 at 70% and 80% survival, respectively. As survival increased, the chance of co-selecting animals from the same family increased. This would result in reduced responses due to increased F_{10}. For instance, relative to the base scheme (90% survival) 100% survival rate reduced the total direct response by about \$5.0 as a result of 3% increase in F_{10}. The correlated responses for smallholder production ranged from 3% less to 5% more than the direct responses. On the other hand, the correlated responses for pastoral production varied from 5% less to 6% higher than the direct responses. In general, survival rate does not require the development of different breeding programmes for smallholder and pastoral production. However, it influences the efficiency of the breeding programme. Especially low survival rates lead to low selection intensity, because the number of animals to select from is reduced, giving lower genetic response.

Table 7.7 presents the effect of type of mating practised in the nucleus flock. These are comparisons between assortative mating versus random mating. Assortative type of mating is mating the best sires to the best females within the selected group of animals. Contrary to simple expectation, random mating resulted in higher response than assortative mating. The latter had a higher F_{10} compared to random mating, which suppressed the total dollar response. For instance, under pastoral production, the direct response of assortative mating was about 5% less relative to that of random mating (base scheme). The corresponding increase in F_{10} was 70%. This was due to the fact that assortative mating led to a higher probability of members of the same family being co-selected. The correlated responses for the smallholder system were 3% and 1% higher than the direct responses, for random and assortative mating, respectively. On the other hand, the correlated responses for pastoral production were 4% lower than the direct responses for random mating, and were the same for assortative mating. In general, the type of mating did not show the necessity to set up separate breeding nucleus schemes for smallholder and pastoral production.

7.4. Conclusions

Nucleus breeding schemes are important for the genetic improvement of sheep under smallholder and pastoral production circumstances in the tropics (Kosgey et al., 2004d). However, it is important to always remember that improvement of many traits at the same time by selection may seriously slow down the genetic progress in any one of them. This is especially if some of the traits considered are negatively correlated with each other. Before such a programme is carried out the relative importance of each trait needs careful evaluation (Charray et al., 1992). The minimum number of traits should finally be chosen, based on their relative importance, the heritability, and their genetic correlations (Carles, 1983).

Proper management of the nucleus is crucial for its success. Good husbandry to reduce mortality would help in obtaining higher genetic gains as a result of increased selection intensity and accuracy of selection (Table 7.5). However, appropriate steps are required to minimize inbreeding in the nucleus. Various methods have been proposed to reduce the rates of inbreeding in selection programmes while keeping genetic gains at the same level (for details see, e.g., Grundy et al., 1994; Wray and Goddard, 1994; Santiago and Caballero, 1995; Meuwissen, 1997; Kinghorn et al., 2000). Simply, the number of matings per breeding male can be restricted to limit the rate of inbreeding, while still maintaining optimal genetic progress (Kosgey et al., 2004d). Another possible problem with breeding programmes in developing countries is the frequently long and complicated bureaucracy involved in the distribution of improved animals from the nucleus to farmers (Kosgey et al., 2004c). The procedure is often subject to abuse by those in authority or those with powerful connections. There should therefore be an effective way to disseminate and make optimum use of improved animals from the nucleus. For instance, a fair and less bureaucratic arrangement in the sale of rams to commercial farmers, i.e., on a ‘first-come-first-served’ basis would be helpful (Kosgey et al., 2004c). Farmers could be encouraged to form village breeding groups, and commit themselves to their operation. Each group would then acquire one or more improved males that would be used in rotation. After a full circle the males could be exchanged between villages, preferably far from each other to reduce chances of inbreeding. For success and sustainability of such an arrangement, extension service is vital to help farmers draw up logistics of ram upkeep and rotation, and to resolve any conflicts that would arise on the use of the rams. Farmers should also be taught how to detect ewes that are on heat, in addition to general husbandry techniques, to enhance conception rates in their flocks.

In general, the current study shows the factors affecting genetic responses in closed nucleus breeding schemes, which should be valuable in making decisions regarding the operations of closed nucleus breeding schemes for sheep in the tropics. In conclusion, a single nucleus breeding programme could be used for both smallholder and pastoral production. However, further studies would be necessary when genetic parameters differ for the two production systems or when genotype by environment interaction is present.

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Chapter 8

General discussion and future considerations

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8.1. Objectives of the study

The current study focussed on the development of breeding objectives and breeding strategies for genetic improvement of small ruminants (i.e., sheep and goats) in the tropics. The production systems in these areas are mainly medium- to low-input, and characterized by variable environmental conditions. Production circumstances in Kenya are used for illustration, but where possible results are generalized. This section of the study starts with an approach to the design of a breeding programme, including the definition of the breeding objective, the choice of breed and the organization of a breeding programme. Subsequently, factors influencing marketing and off-take of animals and/or their products are elaborated. Consequently, the various elements on alternative breeding plans (i.e., nucleus, progeny testing and crossbreeding) are presented and their possible applications are discussed. Finally, the relevance of new technologies to small ruminant breeding programmes, contribution of the breeding programmes to conservation of biodiversity, and impacts of changing society on small ruminant breeding programmes are discussed.

8.1.1. Approach to the design of a breeding programme

Successful improvement programmes consist of three essential elements (Croston and Pollot, 1985): (i) clear definition of the selected objectives supported by farmers, (ii) accurate methods of identifying superior genotypes, and (iii) practical schemes which allow the superior genetic material to be used advantageously. In chapter 2, the top-down approach often adopted by development agencies in their design and implementation is an important reason for failure of small ruminant breeding programmes. The goal of the government is increasing production output and efficiency to ensure adequate food supply at favourable prices for the human population. On the other hand, the smallholder and pastoral farming systems in the tropics are livelihood-oriented and risk-averse, with farmers planning for themselves rather than for the national market (Wollny, 2003). The production, economic and social roles of small ruminants are the basis for decision making of the farming households (Udo, 2003), and animals have to match with these production objectives of the farmer and with the environment. A need therefore arises for harmonization of the production objectives of the farmers and those of the breeding organization.

A clear definition and understanding of the producer's multiple and often interacting production objectives and their contributions to the breeding goals are pre-requisites to successful small ruminant improvement (Olivier et al., 2002). When designing a breeding programme, the first step is to decide on breeding objectives, in conjunction with the farmers by participatory ways, that are achievable and relevant to the future of the breed and the farmers. Decision on what trait to improve is ideally based on the extent to which that trait affects profitability (per head or per unit of labour or land) and not whether it is difficult or easy to measure or change the trait (Ponzoni, 1992; Baker and Gray, 2003). As observed in chapter 4 and 5, little economic data is available for development of fully comprehensive profit functions under smallholder and pastoral production systems in the tropics. As a benchmark to initiate a breeding programme, it would simply do to list the traits perceived by the farmers as important, or purely in terms of economic returns (e.g., the dollar value for an additional kg of meat, or an additional lamb weaned) without any attempt to account for costs of production and to develop profit functions (chapter 3). Over time the breeding objectives can then be refined as data on input costs and prices become available (Baker and Gray, 2003). Care is required to ensure that selection opportunities are not wasted through a combination of excessively complicated and mis-directed objectives (Ponzoni, 1992). For instance, an accelerated lambing scheme would be irrelevant to a nomadic flock in an arid or semi-arid zone where animals have to trek long distances in search of water and fodder in the dry season (Osinowo and Abubakar, 1988). Litter size is one of the most important traits in the tropics (chapter 4 and 5). However, very high litter size may not be appropriate for natural rearing conditions with perennial seasonal feed shortage (chapter 2). An optimum litter size for the available resource base is therefore relevant. Through participatory approaches, an idea on the ideal litter size could be determined because communities understand their environment better than the development agency.

The second step is to decide, in conjunction with the farmers through participatory approaches, a suitable breed that would fit in the production system and farmer's production aspirations. There is a likelihood of conflict on choice of breed. In chapter 3 for instance, it was reported that exotic and crosses of exotic and indigenous genotypes fetched higher prices than the indigenous. Misconception on the large size of these genotypes and past aggressive promotions of the exotic-based germplasm by development agencies requires reversal in the thinking of farmers in most tropical areas. Researchers, through demonstrations and cost-benefit analyses involving the different genotypes kept by separate groups of farmers in a particular locality and for a set period, could help to convince farmers and development agencies of the advantages and disadvantages of each genotype. For instance, a recent study in Kenya by Baker et al. (2003) convincingly demonstrated the superiority of adapted indigenous breeds over introduced breeds in low-input harsh environments. In that study the indigenous Red Maasai sheep of East Africa was found to be up to 5-fold more efficient in terms of productivity than the introduced Dorper breed in the humid environment, while in the semi-arid environment there were no significant breed differences. However, the Dorper has been gaining popularity as a breed of choice in the arid areas, and for crossbreeding. This may not augur well for biodiversity, as it replaces the adapted Red Maasai.

The third step is the organization of the breeding programme, which is paramount to its success in bringing about genetic change and its long-term sustainability. In chapter 2, various designs of breeding schemes were witnessed, ranging from nucleus-based (with 2 or 3 tiers) to no nucleus (i.e., commercial flocks only). The design would depend on the amount of recording and degree of genetic gain aimed for, and the number of improved animals required for dissemination. However, care needs to be taken that results can be extrapolated to other environments (chapter 2). As indicated in chapter 2, 3, 6 and 7, it is difficult to select within commercial flocks due to illiteracy, difficulty in recording large extensive pastoral flocks, and too few animals in smallholder production circumstances to allow meaningful comparisons. Collation of views on the appropriate breeding strategy by participatory approaches with the farmers and development agencies is important, taking into account all constraints and available opportunities. The roles of the different actors in this process have to be properly spelled out. When the government is involved it has to guarantee continuity of the breeding programme in terms of funding and technical support once the donor has handed over the project to it or to the farmers. Implementation of the programme in phases to allow re-adjustment in case of any initial oversight or unforeseen occurrences, coupled with accountability and transparency for any actions taken are vital. It is worthy to note that good population estimates are necessary for an efficient breeding programme. However, livestock censuses are rarely done in most developing countries due to financial, technical and logistical constraints (e.g., Kosgey et al., 2004). It is desirable to encourage governments to provide regular structured estimates of populations and status of livestock management when planning and operating the breeding programme, and for rational policy-making (Wollny, 2003).

A dilemma highlighted in chapter 2 and 6 was how to effectively involve farmers in the breeding programme. In some cases therefore, the optimal scheme may not necessarily be the best in terms of genetic gain, but is convenient in terms of logistics and farmer's involvement. For example, interactive cyclic schemes studied in chapter 6 gave less genetic gain than a nucleus scheme but allowed better farmer participation, and a sense of belonging to the breeding programme which is essential for its adoption and sustainability. In addition to farmer's participation, the relative cost, relative complexity and relative risk were identified as the most important determinants of success or failure of breeding programmes (chapter 2). It is recommended that selection programmes begin at a very simple level in terms of techniques, infrastructure and logistics, and grow in relative sophistication as they demonstrate their effectiveness and generate returns (chapter 2; Kiwuwa, 1992; Ponzoni, 1992).

Breeding programmes often focus on men, disregarding the fact that most of the daily small ruminant management tasks are performed by other members of the household (i.e., women, children and hired labour) (chapter 3; Kosgey et al., 2004).

Men usually come in when major decisions like sale or slaughter of animals are to be made. Herding of small ruminants is mostly by children, and they are therefore likely to be more acquainted with the animals than their parents. Training them and exploring possibilities for giving them incentives to improve the overall management of small ruminants would be necessary. The small ruminant improvement project in Northern Togo (FAO, 1988) discussed in chapter 2 demonstrated how a breeding programme could be successful when women are involved. Livestock offer opportunities for women to generate household income and represent personal assets, in addition to providing reinforcement for social support networks and fulfilment of different cultural roles (Goe and Stranzinger, 2002). As seen in chapter 2, extension and veterinary services contribute to the success of breeding programmes. In essence, training of all members of the household on recording and the value of good records (through simplified audio-visual aids on principles of genetics and animal breeding), in addition to general management of the environment, animal health and marketing of animals and/or their products would be essential. Local literate people within the community (village) hired on contract are another viable alternative for achieving recording in commercial flocks.

8.1.2. Factors influencing marketing and off-take

In chapter 2 to 4, marketing of animals and their products was identified as one of the constraints on small ruminant improvement in the tropics (Mittendorf, 1981; Gatenby, 1986; Makokha, 2002). The markets function inefficiently, with middlemen exploiting farmers (Makokha, 2002), or *ad hoc* sales are common implying animals may not be sold at the optimal age or size (Ifar, 1996; Bosman et al., 1997; Slingerland and van Rheenen, 2000). Moreover, the markets are heterogenous – e.g., meat, milk, manure and specific animals for particular occasions. Inevitably, the breeding programme has to eventually be market-oriented to be sustainable. The farmer has to be able to sell and recoup the capital investment in order for the breeding programme to be meaningful. In addition, the farmer at some stage would be able to satisfy the consumption needs of the family, and have a surplus for sale to external markets to fetch money for inputs – e.g., anthelmintics, drugs, vaccines and concentrates - to maintain the improved stock.

In light of the market liberalization philosophy, farmers need to respond to take advantage of this. Small ruminant products are mainly consumed in urban areas and good infrastructure is therefore necessary to access socially acceptable markets. Trekking animals to distant markets normally results in weight loss and mortality of weak ones. In addition, costs of transporting live animals compared to carcasses are likely to be high due to bulkiness. Slaughterhouses and abattoirs, with refrigeration facilities (using solar or wind energy where electricity is not available), need to be set up strategically proximal to areas of small ruminant farming. External private investors could be encouraged to own and run the slaughter units, but with the local farmers buying shares in the units and deciding on the location to ensure a sense of ownership and community guarantee of sustainability of its operations. The government has to play a regulatory role by providing linkage between the farmers and the investors, and enacting laws that would guarantee security of the investment. Since pastoral areas are vast, it is not possible to set up slaughterhouses and abattoirs in all areas. A good option is to establish holding grounds strategically placed along the way to the nearest selling point, with provision of water and feed, and commercially managed by the community. The development agency could then provide technical assistance on the management of the holding grounds, and on conflict resolution over user rights and benefits to the community.

Another opportunity for farmers is to form service co-operatives that would serve as a consistent marketing channel. The co-operative would help to develop marketing facilities, actively seek external markets (including lucrative international markets) and help in transporting the animals and/or their products to the market. It could also purchase farm inputs that would be sold or loaned to members at marginal profit. Loans would be deducted slowly over a given period from animal sales. This way, the economies of scale and bargaining power will definitely favour a collection of farmers rather than individuals (e.g., Gatenby, 1986). However, farmers require technical assistance in organizational and management arrangements of co-operatives and awareness of possible pitfalls like fraud and dishonesty. When wool or mohair are traditional products of the small ruminant sector, assuring long-term contracts with the textile industry to guarantee stable market volume and producer prices would be useful (e.g., Olivier et al., 2002). In addition, when animals are not needed for emergency financing, higher revenues could be generated when sales are planned to coincide with important festivities such as religious ceremonies like Christmas, Tabaski and Ramadan (chapter 5). Regular meetings between the development agencies, farmers and traders/butchers would help to strike a mutual understanding on the need to morally support, and not exploit, each other as partners in the development of, and benefit from the small ruminant sector.

To reduce over-dependence on small ruminants, capable members of the smallholder and pastoral communities could be encouraged to venture into other sectors of the economy, e.g., formal employment and business. This would create a favourable balance between supply and demand of small ruminants and/or their products and therefore relatively stable prices for them, as well as environmental protection. Pastoral farmers who occasionally earn huge amounts of money through sale of large numbers of animals during favourable times require education on non-livestock forms for storing wealth that are less risky and that appreciate in value over time. Occasionally, real estate in urban areas, rural land or shares in companies and co-operatives, where the returns are good and stable are better alternatives than re-investing in livestock as seen in chapter 3. Similar attention is required for the insurance aspect of the small ruminants (chapter 3 and 5). If farmers could be offered alternative forms of medical insurance and sources of school fees, then they could start seeing small ruminant keeping differently, not only as a form of saving or insurance, but as an economic undertaking. However, a different approach from that used in modern insurance may be required to mobilize savings and link it to policies and procedures for credit provision. Financial institutions could be encouraged to go rural, and to formulate packages targeting the communities in collaboration with willing insurance companies.

8.2. Breeding strategies

Selection (which animals to choose as parents) and crossbreeding (which breed combinations) are classical approaches for genetic improvement. The following sub-sections discuss various breeding strategies to achieve genetic improvement through these two approaches.

8.2.1. Nucleus breeding schemes

Nucleus breeding schemes were studied in chapter 2, 6 and 7. These are central testing facilities where animals are comprehensively performance recorded and selected to get the best animals to be parents of the next generation, with the aim to achieve improvement in quantitative and measurable performance traits of importance (Simm, 1998). In addition, a nucleus accords control of inbreeding in the whole breeding programme (chapter 2). The nucleus could be open or closed (chapter 2, 6 and 7). In a closed nucleus there is no upward migration of animals from the lower tiers in the population to the nucleus, and all recording and genetic evaluation is confined to the nucleus (chapter 2). On the other hand, an open nucleus permits animals of high merit to be migrated up for breeding in the nucleus. An open nucleus requires recording and evaluation of animals in lower tiers. Table 8.1 summarizes the advantages and disadvantages of nucleus breeding schemes.

It is advisable when using centralized nucleus flocks to periodically test the animal’s genetic abilities against the prevailing environmental conditions on the farmer’s farms. On-farm performance evaluation would provide feedback, for example, performance under location-specific production conditions to both breeders and farmers (Kiwuwa, 1992). Details on on-farm evaluation can be found in the literature (e.g., Peters, 1989; Holst, 1999). A common problem with institutional nucleus farms that produce and distribute males in developing countries is that they often are too small for effective selection (Turner, 1982; Udo, 1994). In the past other nucleus schemes have proven to be unsustainable due to over-reliance on donor

Table 8.1. Advantages and disadvantages of nucleus schemes

Advantages of nucleus schemes compared with field breeding schemes	
-Control over husbandry and performance recording of animals	-Provide training centres for field personnel
	-Affords measurement of traits difficult to record in the field
-Lower total cost of performance recording on a national scale due to small number of animals involved	-Smallholder farmers benefit from co-ordinated effort, policy, pooled experience and shared facilities
-Overcome financial, infrastructural and logistical hindrances to genetic improvement in developing countries	-Accords possible use of expensive technologies (e.g., multiple ovulation and embryo transfer)
-Rapid generation turnover of animals can be maintained	-Enables development and use of new technologies
Advantages of an open nucleus compared to a closed nucleus	
-Reduces inbreeding	-Animals entering the nucleus are tested under similar conditions
-Breeding objectives are maintained for many years	-Optimal 2-tier schemes give 10-15% faster gain than closed schemes
-Affords selection in a larger population and benefit from exceptionally good animals outside the nucleus	-Permits control of the mix of genes released to commercial flocks
Disadvantages of an open nucleus	
-Needs continuous performance recording in co-operating flocks which requires infrastructure, technical back-up and high costs	-High risk of introducing diseases to the nucleus -Poor recording in commercial flocks would reduce genetic gain

Adapted from: Mason and Buvanendran (1982), Turner (1982), Smith (1988), Hodges (1990), Jasiorowski (1990), Ibrahim (1998).

funding and lack of proper management. The demands for improved germplasm from the commercial sector are therefore rarely met (chapter 2). It is advisable to start an open nucleus or closed nucleus breeding scheme with animals selected from different regions of the country. However, much as an open nucleus scheme is attractive genetically due to the larger number of animals to select from, its operation is quite challenging, and adequate financial support, technical back up and the active participation of recruited farmers is vital for its success.

8.2.2. Progeny testing

Progeny testing (PT) implies the offspring of young rams are measured and the results related back to the sire (Croston and Pollot, 1985). The process involves getting candidate males by selection, on the basis of parental information and in some cases performance test. Subsequently, the animals are mated at random to commercial females, and phenotypic information is collected on the resulting offspring. Based on progeny information, the best males are selected to be used to disseminate genetic material. Table 8.2 presents the benefits and limitations of PT.

Table 8.2. Benefits and limitations of progeny testing

Benefits	Limitations
-Enhances accuracy of estimation of breeding values of sires for the traits of interest	-Associated with long generation interval compared to selection based on own performance
-Useful to obtain information on sex-limited (e.g., milk) and post-slaughter carcass (e.g., meat flavour) traits, and for traits with low heritability	-Field PT requires infrastructure, logistics and finances for pedigree recording in commercial flocks
-Allows objective comparisons of males across studs and years	

Progeny testing would work well with artificial insemination, which is currently not possible in small ruminant commercial flocks in most developing countries (chapter 3). In addition, PT would be useful where ‘ram circles’ (chapter 6) are applicable to test teams of young males that have been selected for testing on their own performance. However, due to lack of artificial insemination, logistical and financial bottlenecks, potential PT in traditional production systems in developing countries is limited to a nucleus set up.

8.2.3. Crossbreeding

In crossbreeding animals from two or more breeds (e.g., indigenous adapted breed and an introduced breed) are used to produce offspring. Table 8.3 presents the benefits and limitations of crossbreeding. A variety of crossbreeding methods exist and detailed discussions on the theory, design and application can be found in the literature (e.g., Carles, 1983; Ponzoni, 1992; Swan and Kinghorn, 1992; Falconer and Mackay, 1996; Simm, 1998; Baker and Gray, 2003; Wollny, 2003). Crossbreeding offers the opportunity to exploit heterosis, i.e., the extra performance of the crossbred over the average of the parental breeds due to non-additive genetic effects. According to Baker and Gray (2003), the increase in performance due to

Table 8.3. Benefits and limitations of crossbreeding

Benefits	Limitations
-Utilization of heterosis (or hybrid vigour), especially for traits with low heritability like fertility, viability and disease resistance	-Requires more management in organizing matings than pure breeding -Crossbreds require a higher plane of nutrition and management relative to indigenous breeds
-Combining the merits of 2 or more breeds in one progeny group	-Populations of pure-bred animals should be kept
-Effect quick genetic changes	-Adapted exotic breeds for use in arid and semi-arid regions are rare
-Creation of new breeds (i.e., synthetics)	-Unsystematic crossbreeding is a threat to biodiversity
-Production of superior progeny for slaughter	

Adapted from: Mason and Buvanendran (1982), Gatenby (1986), Ibrahim (1998), Kinghorn et al. (2000), Baker and Gray (2003), chapter 2.

heterosis ranges from 0-10% for growth traits and from 5-22% for fertility and mortality traits. Heterosis effects are additive so for combined production traits like weight of lamb weaned per ewe mated per year the effects commonly range from 15-20%. When the aim is to utilize heterosis *per se*, constant crossbreeding would be required.

The benefits of crossbreeding in developing countries may have been overestimated (chapter 2; Ayalew et al., 2003) to an extent that improvement of livestock is often synonymous to crossbreeding (Wollny, 2003). The production environment needs to be able to sustain the crossbred genotype (Swan and Kinghorn, 1992). It would therefore be desirable that the crossbreds are evaluated not only in terms of their performance but also in terms of their adaptation, especially to the physical environmental conditions in which they are going to perform (Arora et al., 2002; Udo, 2003). For instance, in Kenya the primary reason for crossing the indigenous Red Maasai sheep with the exotic Dorper is to exploit the large size of the latter breed. According to Baker and Gray (2003), this is a viable option when the production system, especially in terms of climate and nutrition, is favourable enough for the crossbred genotype. However, when efficiency at the system level is considered the indigenous adapted breeds are more efficient and, therefore, preferred breed over a range of production environments.

Crossbreeding for small ruminants in the tropics is rarely systematic. Animals are largely kept extensively on pastoral range conditions (chapter 2 and 3), making it hard to systematically cross, e.g., F_1 with an unadapted breed. The scenario is worsened by inadequate extension service (chapter 2 and 3). In general, a structured and controlled crossbreeding programme requires considerable infrastructure for management and maintenance of pure breeds for its continuation. It is therefore a complex undertaking that makes it difficult to implement in traditional production systems of the tropics. If need arises for crossbreeding, judicious application is desirable to avoid potential problems, especially the long-term sustainability of desired level of crossbred genotype. Development of tropical breeds for use in upgrading instead of the poorly adapted exotic germplasm would be an option to consider towards sustainable crossbreeding programmes.

8.3. Proposed plan for Kenya

In this section, a proposal is made for selection of sheep in Kenya, which serves as an example for other countries. The country has a wide range of agro-ecological conditions ranging from the high potential to the arid and semi-arid (Jaetzold and Schmidt, 1982), and varied smallholder and pastoral farming systems (chapter 3). According to MARD (2000), there are about (millions) 17.9 small ruminants, comprising respectively, 7.04 and 0.87 hair and wool sheep, and 9.92 and 0.08 meat and dairy goats. The use of nucleus breeding schemes (closed and open) is discussed, followed by explanations on the integration of progeny testing and crossbreeding in the schemes. The proposal is based on the scenario that: (i) indigenous well-adapted breeds are available, e.g., the Red Maasai sheep, that is resistant to gastro-intestinal parasites, (ii) introduced pure breeds are available, e.g., Dorper, Romney Marsh and Corriedale, (iii) there is possibility for selection for both productivity and adaptability, (iv) one nucleus is able to serve both smallholder and pastoral breeding objectives (chapter 7), and (v) infrastructure is available, for example, government, university, parastatal (e.g., regional development authorities, Agricultural Development Corporation and Kenya Agricultural Research Institute), and private large-scale farms and ranches. The aim of the proposed scheme is to improve growth rate (12-month) and worm resistance of sheep. Subsequently, the improved animals are made available to the farmers for breeding.

8.3.1. Use of closed and open nucleus schemes

Use of nucleus breeding schemes in Kenya would contribute to: (i) improved recording and selection of animals, (ii) optimum utilization of the little available financial and human resources, and (iii) availability of good quality animals to the commercial farmers. Private large-scale or ranch flock or flocks owned by a parastatal organization, university or by the government are considered as the central nucleus, while other smallholder or pastoral flocks are considered to be the commercial population. To start the nucleus, apparently superior male and female foundation animals are screened from unrecorded commercial populations, either with a very simple recording system introduced temporarily in the field or by relying upon observation and the owner's knowledge of the animals (Mason and Buvanendran, 1982; Hodges, 1990; Ponzoni, 1992). Preferably twin-rearing ewes or those with a history of twinning in one or more earlier lambings are selected. Rams are selected from multiple-born lambs, based on size and constitution (Mason and Buvanendran, 1982). To minimize inbreeding, efforts would be made to have widely distributed base flocks to enable selection of rams from flocks that do not contribute ewes. These exceptional animals are then brought together in the nucleus flock to form the founder population for the nucleus population kept under controlled management and where routine performance recording of traits of interest is practiced.

Genetic resistance to internal parasites can effectively be measured from 5 months of age (Gray et al., 1992). Animals would therefore be selected at 12 months of age to allow for expression of both growth and worm resistance traits. Male offspring will be evaluated on own performance, and on the basis of their dam, full-sib and half-sib performances, and offspring performance. For selection of female offspring, they are appraised against the best ewes already in the nucleus flock.

8.3.1.1. Animal numbers

In this section the flow of animals in a nucleus scheme consisting of 500 ewes, is described, following the procedures outlined by Ponzoni (1992). Extrapolation to the entire sheep population in the country, and optimization of the improved males from the nucleus is given in later parts of this section. The assumptions for the nucleus (Fig. 8.1) are: natural mating with a male to female ratio of 1:50 (e.g., Ponzoni, 1992) hence 12 sires; twinning rate of 18% (Semenye and Musalia, 1990); age at drop of first progeny for both sexes is 2 years (see chapter 4-6). Other male to female mating ratios (i.e., 1:30 and 1:100) are indicated for comparison. Presented next are two examples, (i) to determine the nucleus size

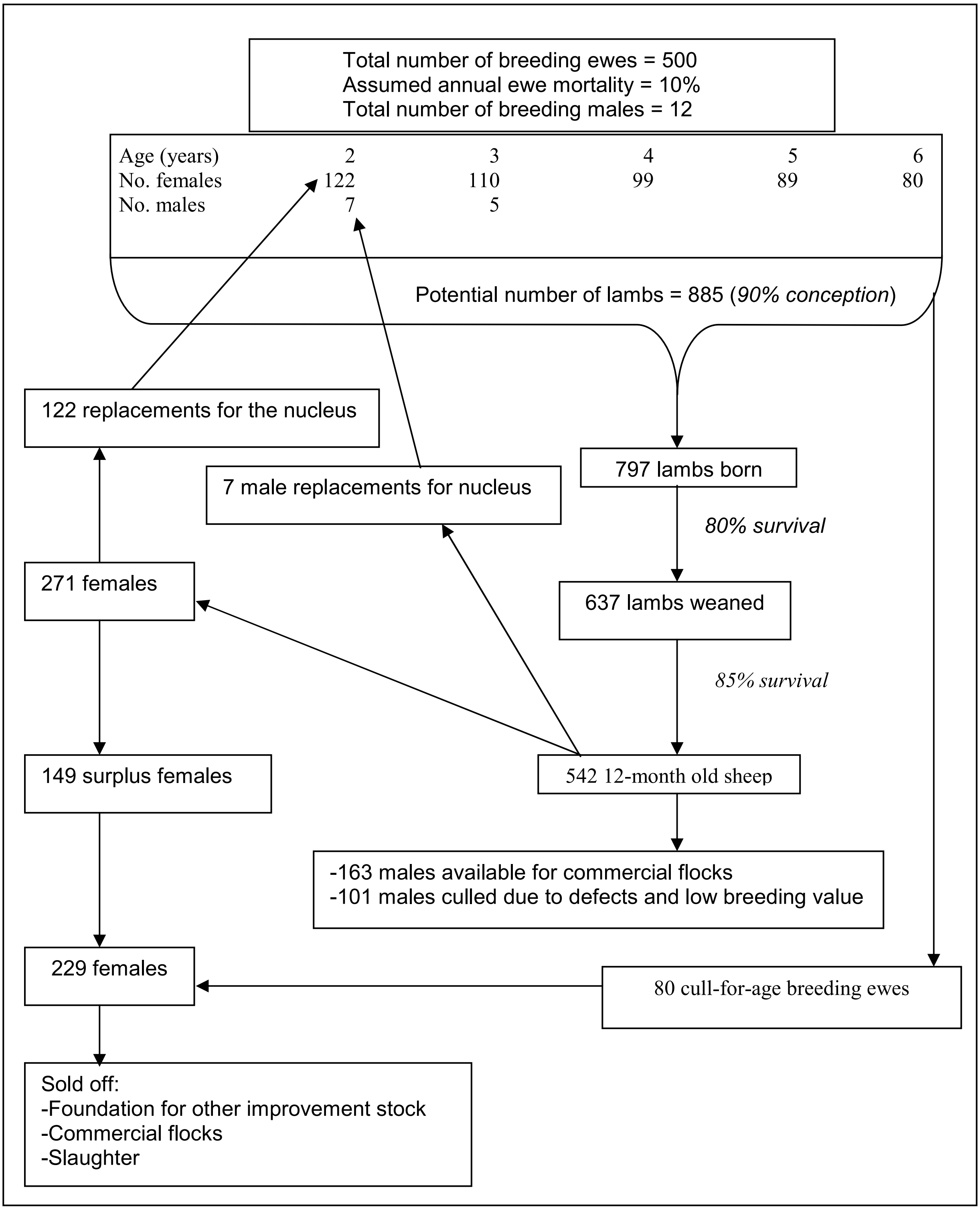

Fig. 8.1. Flock dynamics in a closed nucleus

required with a population of 1,000,000 commercial ewes, and (ii) to determine the size of the commercial population that can be serviced with a nucleus of 500 ewes.

(i) The number of nucleus breeding ewes required to service 1,000,000 commercial ewes

Table 8.4 shows the number of breeding ewes in nucleus flocks required to produce sires for 1,000,000 commercial ewes with different mating ratios. For instance, in a 2-tier scheme (i.e., nucleus and commercial flocks), with a male to female mating ratio of 1:50, the number of new sires needed per year to service the commercial ewes is 10,000 and are produced by 30,675 ewes in the nucleus. This represents about 3% of the total number of ewes in the commercial flocks. The number of nucleus breeding ewes would increase if the mating ratio were decreased and vice-versa.

Table 8.4. Number of breeding ewes in nucleus flocks or in nucleus and multiplier flocks to produce sires for 1,000,000 commercial ewes[a,b,c]

		Ram:ewe mating ratio in commercial flocks		
Structure	Flock	1:30	1:50	1:100
		16,667[d]	10,000[d]	5,000[d]
2-tier	Nucleus	51,126	30,675	15,337
3-tier	Nucleus	490	294	147
	Multiplier	49,020	29,412	14,706

[a]Proportion of sires: 0.326 (i.e., 163/500) in 2-tier and 0.340 (i.e., 170/500) in 3-tier (see Fig. 8.1). [b]Mating ratio 1:50. [c]The multiplier and commercial flocks are assumed to have, respectively, 50%, 35% and 15%, of the sires in age class 2, 3 and 4, i.e., each year one half of all used sires is needed for replacement (e.g., Ponzoni, 1992). [d]Number of sires required for the commercial flock.

The results presented in Table 8.4 demonstrate how in practice a relatively small group of animals in a nucleus would control the genetic change of a large population. Care is therefore required to ensure the breeding ewe population in the nucleus is high enough for long-term genetic improvement. The use of a multiplier (i.e., 3-tier scheme) greatly reduces the number of ewes required in the nucleus. For example, a 3-tier scheme with a male to female ratio of 1:50 contains 294 ewes in the nucleus (only 0.03% of the total number of commercial flock population) compared to 30,675 (31% of the total number of commercial flock population) for a 2-tier scheme. The function of the multiplier tier is to multiply any genetic improvement generated in the nucleus and disseminate it to the commercial population. However, this results in a genetic lag between the nucleus and the commercial population. If lower tiers buy average males (and no females), the lag behind the tier above is 2 generations (about 7 years in sheep) of selection response (chapter 2). Nevertheless, once the scheme is stable the nucleus and the commercial tier will genetically progress at the same rate. In optimizing the breeding strategy, a balance between the cost of running the nucleus, rate of genetic gain and rate of inbreeding is necessary.

(ii) Size of a commercial flock serviced by a nucleus flock of 500 breeding ewes

Fig. 8.1 shows that in a nucleus of 500 ewes 163 males are produced for use in other flocks, implying a potential of serving a ewe population using 326 males per year. Table 8.5 gives the number of commercial breeding ewes serviced by sires

Table 8.5. Number of commercial breeding ewes serviced by a nucleus with 500 breeding ewes[a,b,c]

	Ram:ewe mating ratio in commercial flocks		
Structure	1:30	1:50	1:100
2-tier	9,780	16,300	32,600
3 –tier	978,000	1,630,000	3,260,000

[a]Proportion of sires: 0.326 (i.e., 163/500) in 2-tier and 0.340 (i.e., 170/500) in 3-tier (see Fig. 8.1). [b]Mating ratio 1:50. [c]The multiplier and commercial flocks are assumed to have, respectively, 50%, 35% and 15%, of the sires in age class 2, 3 and 4, i.e., each year one half of all used sires is needed for replacement (e.g., Ponzoni, 1992).

resulting from a nucleus with 500 breeding ewes. For example, with a male to female mating ratio of 1:50 the commercial flock could contain 16,300 breeding ewes. A 3-

tier scheme operating on the same mating ratio would have about 1.6 million commercial ewes serviced by the nucleus.

With a ram rotation scheme, the males could be used longer, and the number of breeding females serviced in the commercial flock increased substantially. For instance, if the average breeding life of a male in the commercial flocks is three years, then the males could be distributed to three flocks in rotation. The number of ewes mated with sires from the nucleus would then be three times as many compared to no rotation. Ideally, this implies that with a male to female mating ratio of 1:50 in commercial flocks only five 3-tier nucleus schemes would be able to service the entire sheep commercial population (≈8 million) in the country. The challenge would be how to effectively organize farmers to make extensive use of the available males. Extension services would be necessary before implementation and during the operation of the breeding programme, to inform farmers of its operations, and the benefits of a farmers' organization in running a breeding programme. Farmers too need to fully understand the benefit of an improved animal to avoid cases of unintentional selection for slow growth rate due to the tendency to first slaughter or sell faster growing male animals (e.g., as sacrifices during religious or special traditional occasions) (chapter 2). Close matings can be avoided through the distribution of males (i.e., avoidance of the use of closely related males in subsequent years).

Training and motivation of the station personnel who are responsible for the animals in the nucleus flock, and extension staff based in the areas where the commercial population is located would be necessary. In addition, constant monitoring and evaluation is needed to ensure the programme services the commercial sector efficiently (chapter 2). In case of an open nucleus (Fig. 8.2) it is important when screening several flocks to always remember that there is a risk of introducing diseases into the nucleus (Ponzoni, 1992). Disease outbreak can result in a serious setback to the breeding programme and precaution is essential to minimize the risk. Veterinary guidance and not having all animals in one location would assist to curb the problem.

The likelihood of inefficiency in the performance of government-run nucleus schemes as witnessed previously (chapter 2) would necessitate co-operation between the development agency and the owners of animals required for the nucleus. It may be more productive and successful if the females screened from the commercial population are loaned rather than bought (Hodges, 1990). These females would then enter the test flock for a period of recording and when they are returned to the owner, genetically superior offspring would accompany them as rewards to the owner(s). A co-operative aspect, with legal and financial commitment, which brings the leaders of the local small ruminant owners into discussions and decisions, particularly with regard to the evaluation of the animals and choice of which males are to be used in the commercial population would enhance success of the breeding programme.

In general, it might be prudent, if there is uncertainty and if resources permit, to have several nucleus units, perhaps selected in different ways, as an insurance against loss and as competition to one another (e.g., Smith, 1988). According to Kinghorn (2000), geographically dispersed nucleus schemes offer an option of enjoying the full benefits of an open nucleus without nominating one flock to be the nucleus. It involves creating the elite ‘nucleus’ matings in the flocks of birth of the female partners, with migration of males (or semen) to these flocks. In the proposed scheme, innovative large-scale farmers and ranches would be considered for the launch of such breeding schemes which helps to overcome the financial as well as logistic hindrances indicated in chapter 2, 6 and 7. A point to note is that large-scale farms and ranches may not have the expertise in animal breeding, and where they operate as nuclei, then more technical assistance would be required to help them in estimation of breeding values and selection of animals. This could be arranged in the form of consultancy with experts from the private sector, universities or government. In general, each nucleus would have to have regional (provincial) centres for multiplication of animals to be distributed to the commercial flocks.

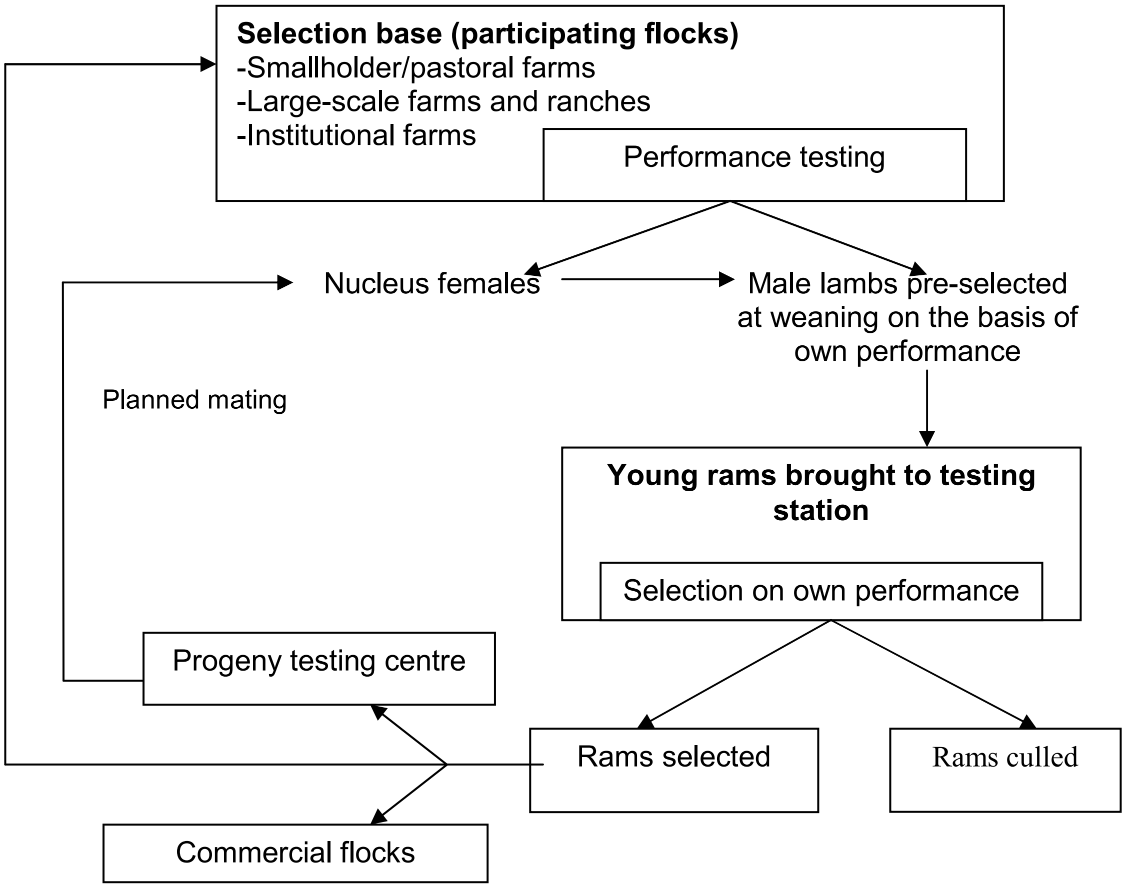

Fig. 8.2. An open nucleus breeding scheme (with progeny testing) for sheep in Kenya (Adapted from Charray et al. (1992))

8.3.2. Use of progeny testing

If progeny testing (PT) is to be used, it is envisaged that the process would involve test rams from the open nucleus (Fig. 7.2). The first stage of the PT scheme entails pre-selection of male rams from participating flocks on the criterion of weight at weaning at 3 months of age. Secondly, the young rams selected are bought from the farms and brought together in a station for individual testing until puberty at 12 months of age. As much as possible the station would try to maintain management conditions similar to the commercial farms to minimize genotype by environment interactions. On a monthly basis, live weight and indicators of worm resistance (i.e., faecal worm egg counts and packed cell volume) would be recorded on the test rams themselves. This implies the performance records on the animals on the traits become available from 5 months of age, and the breeding values (EBVs) of the rams could be estimated, with additional information every month. Rams that obviously are susceptible to worm challenge (see Vatta et al. (2001) for appropriate test) and management stresses, could be independently culled. At puberty, the rams are selected for mating at random to females in the nucleus and participating flocks, to get progeny that would be performance tested. Rams with high EBVs based on progeny information are selected for mating with females in the nucleus and participating flocks to produce the next generation of test males. A minimum of 4-10 offspring per sire would be required for testing (e.g., Wiener, 1994).

The second category rams are sold to commercial flocks. The remaining rams are sold for slaughter. That means the earliest a ram could be allowed for use is at about 24 months of age. To minimize inbreeding, rams are used for 1.5 years in the nucleus. Subsequently, they could be sold to the multiplier or commercial flocks, for pure-breeding or crossbreeding. It is important to note that this is a continuous process and once the programme is running smoothly, rams would usually be available for the breeding scheme. However, given that own performance information is available, the lack of artificial insemination, and the likely high costs and time involved, use of PT is not recommended.

8.3.3. Use of crossbreeding

As indicated earlier, the agro-ecological conditions in Kenya are quite varied (Jaetzold and Schmidt, 1982), and therefore crossbreeding strategies could be adopted to fit the potential of the different target areas (Carles, 1983). A combination of the different crossbreeding strategies in a nucleus set-up is possible. These are discussed next.

Breed substitution: breed substitution by backcrossing (i.e., upgrading) could be attempted in areas where the new breed is clearly more desirable than the indigenous breed and is reasonably more adapted (Baker and Gray, 2003). It would take about 6 to 7 generations at which stage the new breed will effectively have replaced the indigenous breed (Charray et al., 1992). For instance, in the higher potential range areas of the country where it is feasible to produce good quality yearling mutton, it is possible that the indigenous Red Maasai does not contain all the genes that meet this potential, and then the introduction of these by crossbreeding with a breed such as Dorper will be beneficial. The other possibility is in the introduction of the wool breeds such as Merino and Corriedale to the same areas (Kosgey et al., 2004).

Formation of synthetics: two or more breeds could be combined to form a new breed (synthetic), which has the advantage of combining the good attributes of the breeds involved. The disadvantage is that the logistics for creating a synthetic are more complicated than breed substitution or specific and rotational crossing (Baker and Gray, 2003), and requires a large population of animals. During the interbreeding phase, selection would take place to ultimately produce a new breed with desired characteristics, e.g., improved growth and worm resistance. It is proposed that breed formation be restricted to the nucleus where farmers would then buy replacement stock until such a time that the composite has stabilized as a breed. It is important to note that a breeding programme for a synthetic four-way Kenyan Dual Purpose goat by interbreeding the local Small East African and Galla breeds with the exotic Toggenburg and Anglo-Nubian breeds was started in Kenya in the early 1980's (Mwandotto et al., 1992; Rewe et al., 2002). However, its success is doubtful due mainly to lack of sustainable breeding objectives, lack of determination of the optimum level of exotic dairy genes required for efficient production and adaptation in target areas, and lack of funds to sustain the project (Rewe et al., 2002). It is advisable to revitalize the same breeding programme but address the aforementioned setbacks. A possibility is to gradually privatize and decentralize the breeding programme. For the sheep, one option to consider is to combine the indigenous worm-resistant Red Maasai and introduced breeds like Dorper, Corriedale and Romney Marsh to form a four-way synthetic that is worm resistant, hardy and grows faster with good meat flavour. Alternatively, tropical breeds like Damara and Djallonké (chapter 2) could be interbred with Red Maasai and Dorper to get a more tropicalized four-way synthetic cross for the arid and semi-arid areas with extreme feed scarcity and where trypanotolerance is desirable.

Specific and rotational crossing: the approaches allow benefits of heterosis each generation without the need to maintain a purebred nucleus. However, they require reasonable flock sizes (about 50 or more breeding females), and thus may not be useful under smallholder production systems (Baker and Gray, 2003). The approaches could be applied with the pastoral communities where the average flock sizes are large (chapter 3). In specific crossing, for instance, the popular Dorper breed could be used as a terminal sire over a proportion of the indigenous Red Maasai flock (30-40%) to produce F_1 progeny (Dorper x Red Maasai) but with the rest of the Red Maasai flock being straight-bred (Red Maasai x Red Maasai) to supply female replacements (e.g., Baker and Gray, 2003). All the F_1 progeny can then be sold or slaughtered for home consumption. Where desirable, rotational crossbreeding may be used to mate the F_1 females to their parental sire breeds. For example, Dorper x Red Maasai F_1 females are alternately crossed back to Red Maasai sires and their progeny to Dorper sires, resulting in a two-way rotational crossing. This rotational crossing system produces its own replacements and would be favourable in the country, especially to avoid the many problems and risks involved in purchasing animals. In addition, there is no need to maintain purebreds at the farms that are needed to produce pure-bred sires. Alternatively, *inter se* mating (e.g., F_1 x F_1 or F_2 x F_2) could be practised in situations where farmers find it difficult to keep buying sires for rotation. A new breed could also be introduced and mated with the Dorper X Red Maasai females to produce a 3-way cross progeny. The resultant crosses are then all sold or slaughtered or included back in the programme. If productive progeny arise, then these can ultimately evolve into new breeds or strains (e.g., Baker and Gray, 2003). However, this is difficult to organize in traditional small ruminant production systems.

In conclusion, the low level of technical know-how and limited resources in the country imply the crossbreeding systems would have to be simple. New breed formation and straightforward F_1 cross or two-way rotational crossbreeding are therefore the most practical systems to adopt. The breed to be used for improvement must be chosen very cautiously, taking into consideration the characteristics of the indigenous breed and stresses caused by the environment. In the arid areas of the country it would be plausible to maintain the existing breed and improve the genotype with a simple selection system, or improve the management.

8.4. New technologies

8.4.1. Current and modern reproductive technologies

Reproductive technologies with potential impact for small ruminant genetic improvement programmes in the tropics are available (Smith, 1984; Ponzoni, 1992; Rege, 1994; Brash et al., 1996; Ishwar and Memon, 1996; Cunningham, 1999; Kinghorn et al., 2000). These include AI (artificial insemination), MOET (multiple ovulation and embryo transfer), embryo cloning, *in-vitro* maturation (IVM) of oocytes, *in-vitro* fertilization (IVF) of oocytes, and sexing sperm and embryos. The techniques can be used to increase reproductive rates in animals, and subsequently increase rates of genetic gain through possible higher selection intensity and accuracy of selection. Despite the potential benefit, few studies exist on optimization of small ruminant breeding schemes using existing reproductive techniques in developing countries (Ponzoni, 1992; Rege, 1994). This is probably due to their limited application now and in the foreseeable future. High expenses and degree of sophistication currently preclude availability of the necessary infrastructure for their common application (Cunningham, 1999). Nevertheless, a brief explanation of the contributions of the techniques that could have immediate application in genetic improvement is helpful. These are AI and MOET. The rest of the technologies are much less likely to be of practical value to developing small ruminant industries in the near future (Udo, 2003).

AI implies that a given number of progeny can be produced from fewer sires, thus allowing greater selection intensity among males, and possible reduction in generation length for males. AI, where feasible, is an effective and powerful tool for dissemination of genetic gain being achieved in nucleus flocks to the commercial sector. AI enables use of progeny testing schemes. Ponzoni (1992) has summarized other contributions of AI as: intense use of superior sires from closed and open nucleus breeding schemes in commercial flocks, thus reducing the genetic lag; the transfer of genetic material from one nucleus flock to another, without actually transferring the sires. If two flocks have sufficient sires in common, this may under some conditions, enable elaborate analysis of the data leading to valid comparisons of the estimated breeding values (EBVs) for individuals in both flocks.

MOET is used to increase the reproductive rate of females, and thus reduce generation interval, to increase the selection intensity without altering the ewe age composition, or to simultaneously do both (Ponzoni, 1992; Simm, 1998). In the tropics, possible application of MOET includes the multiplication of valuable genotypes available in small numbers. For example, a breed introduced from another country or group of 'super-elite' individuals intensely selected for some specific attribute(s) (e.g., disease resistance) from a number of nucleus flocks.

It is important to realize that use of reproductive techniques could have consequences for biodiversity. A careful study of all implications is therefore desirable if conditions would allow their application.

8.4.2. Information technology

Computer software exist for storage, and retrieval of information on performance of animals. An example is the web-based Domestic Animal Genetic Resources Information System (DAGRIS) (http://dagris.ilri.cgiar.org/dagris/) database developed and run by the International Livestock Research Institute (ILRI-Nairobi, Kenya), which has made significant contribution in providing information on existing diversity, characteristics and use of selected indigenous farm animal genetic resources in developing countries of Africa, Asia and Latin America. It is also possible to apply geographical information systems and spatial analysis in decisions regarding small ruminant breeding programmes and conservation of animal genetic resources.

Accuracy of estimation of breeding values can be enhanced with best linear unbiased prediction (BLUP) methodology when there is computing power. Perhaps of immediate benefit in the tropics would be the development of software that meet the information requirements of the smallholders and pastoral farmers and a data flow procedure assuring fluent feedback of information relevant at farm level (e.g., Olivier et al., 2002). For instance, alternative genetic improvement schemes can be simulated and compared before doing the practical work, as was done in chapter 6 and 7. The benefit is that costs and risks are reduced.

With information technology systematic storage and dissemination of valuable information to a larger audience is possible, and therefore reduce the current problem of grey literature prevalent in the tropics (chapter 2). This would enhance research output through direct use of the information and networking and therefore assist development agencies and policy makers in decision making. In general, the computer and information technology can contribute greatly to small ruminant improvement in the tropics, and investment in them is worthwhile.

8.4.3. Disease resistance and use of quantitative trait locus (QTL) information

Diseases and parasites are a huge concern in small ruminants in the tropics. Particularly, gastro-intestinal parasites (predominantly *Haemonchus contortus*) result in losses through mortalities, reduced production and direct costs associated with preventive and curative measures (Baker et al., 2003). Current control strategies for helminthosis include medication with drugs (anthelminthics), isolation of animals from parasites through grazing management (rotational grazing) and improved sanitation in management systems (e.g., housing animals in wet season). Other strategies are improved nutrition, biological control, vaccination and herbal remedies (Baker and Gray, 2003). In developing countries, many control strategies are limited by lack of funds to purchase good quality drugs, inefficiency of veterinary services and poor management. In addition there is the increasing global awareness of anthelmintic chemical residues contaminating the environment and human food. Moreover, widespread and indiscriminate use of drugs has resulted in increasing emergence of drug resistant parasites (e.g., Wanyangu et al., 1996). Fortunately, some of the small ruminants in the tropics are genetically resistant or tolerant to gastro-intestinal parasites (chapter 2). An attractive and sustainable control option would therefore be the development and farming of disease resistant genotypes. Selection and crossbreeding provide means to incorporate gastro-intestinal resistance into small ruminant breeding programmes with the objective of combining resistance and production in an efficient manner.

It is unlikely that parasite control will rely on any single method but will probably be a combination of approaches. Identification of genetic markers linked to parasite resistance genes holds potential for marker-assisted selection (MAS) to improve breeding of disease resistant animals. In addition, this would enable introgression of genes (MAI) to incorporate resistance in other susceptible breeds of small ruminants. The end result would be the possibility of introducing and sustaining more resistant breeds into the smallholder production systems of the humid and sub-humid tropics in the face of high worm challenges, and thus reduce use of chemicals.

To evaluate the effects of a MAS scheme for the degree of parasite resistance in a small ruminant population, knowledge on accuracy of estimates of marker-linked effects plays a crucial role. Selection for improved resistance is partly hindered by lack of good indicators/measurements to identify resistant animals. More importantly, genotyping animals for QTL information may currently be too expensive for small ruminant production systems in the tropics, and is presently not applicable despite the potential benefits (Gibson, 2003). Use of MAS would require a much more organized infrastructure as compared to phenotypic selection, and is not currently feasible in the tropics (van der Waaij, 2001).

In general, if MAS and MAI were to be used, the benefits are many. For example, increased disease resistance leads to improved animal productivity as a result of enhanced feed conversion efficiency and growth rates. Economically, farmers would gain due to reduced costs of drugs as a result of utilization of genetically disease resistant animals that are less reliant on drugs and chemicals. Since most of these are imported or manufactured largely from imported raw materials, the scarce foreign exchange would be saved for other uses. Besides, the risk of the smallholder and pastoral farmers buying low quality drugs would greatly be reduced. The promotion of animal welfare would be enhanced due to reduced mortality, reduced drug use and health control measures. However, breeding schemes involving MAS and MAI might have consequences for genetic diversity within and between breeds. Integration of knowledge on genetic markers for parasite resistance therefore undoubtedly demands a breeding scheme that strikes the optimum balance between different traits and maintenance of genetic diversity. In addition, in the introgression of genes from one breed to another, it is important to first look at its efficiency before large-scale utilization (Visscher and Haley, 1999; van der Waaij, 2001).

In the future transgenic small ruminants might further improve rates of genetic gain, or contribute with specific attributes such as disease resistance (Ponzoni, 1992). Transgenics involves the application of new methods of reproductive biology and molecular genetics for the enhancement of productivity of small ruminants. The possibility to introduce foreign DNA into the germ line of an individual gives rise to transgenic animals. The technique, in combination to quantitative genetic methods, could be used to genetically improve the overall economic merit of small ruminants, but an adequate infrastructure would be required (e.g., Franklin, 1986; Smith et al., 1987; Fennesy, 1990).

8.5. Biodiversity

Biodiversity and sustainable use of breed resources is currently an issue of concern and will remain so for a long time (Anderson, 2003; Drucker and Scarpa, 2003; Rege and Gibson, 2003; Wollny, 2003). Genetic diversity is a requisite for the present and future livelihoods of the rural poor (Anderson, 2003; Wollny, 2003). Small ruminant genetic improvement programmes have to pay special attention to its maintenance both in the short- and long-term. The loss of livestock diversity reduces potential effort to contribute to alleviate poverty, improve food security and promote sustainable agriculture (Drucker and Scarpa, 2003). All stakeholders in small ruminant development therefore have to be aware of the importance of conservation (or the negative consequences of erosion) of farm animal genetic resources (ANGR).

Erosion of livestock biodiversity in developing countries of the tropics is largely attributable to breed substitution and unsystematic crossbreeding of indigenous breeds with introduced breeds, lack of economic valuation, civil strife and warfare (Wollny, 2003). Concrete strategies are particularly desirable to conserve and utilize the adapted indigenous genetic resources. The first step in conservation and exploitation of genetic resources is to know their current status through their effective and systematic documentation and all aspects of their performance in their harsh environment (Turner, 1978; Lebbie and Ramsay, 1999). Secondly, it depends on the ability of the communities to decide on and implement appropriate breeding strategies (Rege, 1992; Wollny, 2003). In addition to maintenance of peace and political stability, interventions by researchers, governments and other development agencies would be crucial to encourage farmers and breeders in the design of effective breeding schemes. Genetic improvement strategies based on selection within local populations are generally a solution in low-input systems where animals that are well-adapted and reasonably productive are required to preserve the hardiness traits that are supposed to be present in those breeds (chapter 2; Olivier et al., 2002). Since the smallholders and pastoral communities are currently the main custodians of indigenous farm ANGR (Baker and Rege, 1994), community-based genetic improvement strategies are critical for efforts to conserve biodiversity (Wollny, 2003). Breeding schemes presented in this thesis offer an opportunity in the conservation effort by according farmers active participation and a high degree of identification with the breeding programme.

Economic incentives are important in the implementation of strategies for conservation of small ruminant genetic resources (Drucker and Scarpa, 2003). To promote and sustain conservation, the strategy has to be linked with some benefit, which could be economic or adaptation characteristics, and in general fitting the production objectives of the farmer (chapter 2). The demonstration by Baker et al. (2003) discussed earlier in this chapter regarding the comparative efficiency of the indigenous Red Maasai sheep over the introduced Dorper sheep is an effective way to promote conservation of ANGR. It is also gratifying that the majority of the farmers in the tropics still keep the indigenous breeds as seen for the case of Kenya in chapter 3. In general, animal breeders need to face the challenge of how to avoid further erosion of farm ANGR.

8.6. Impact of changing society

Whilst animal breeding plans should be technically sound, their success in the field is overwhelmingly dominated by ruling policy environment (Hammond, 2001). Despite trade liberalization being in vogue, livestock breeding cannot wholly be left to market forces. A coherent and comprehensive animal breeding policy formed in close consultation with the farmers and all stakeholders would assist to guide development agencies in developing countries of the tropics in streamlining animal breeding activities and conservation of animal genetic resources and avoid current haphazard activities (e.g., Nakimbugwe et al., 2002).

In smallholder and pastoral communities, there is basically no retirement age from farming, resulting in denial of land use rights to the younger generation. Alternatively, particularly in agro-pastoral systems, there is sub-division of land especially to the sons resulting in units that are uneconomical for large ruminant keeping. The latter scenario favours the keeping of small ruminants (de Haan et al., 1996). According to the World Bank (2003), grazing systems, particularly those using communally owned land are affected by erosion of traditional grazing rights with a shift to open access and ‘free-for-all’ grazing in the remaining areas. This is a concern in the arid and semi-arid areas of sub-Saharan Africa, India and Central Asia, and is being reflected by declining livestock productivity on a per human capita basis. It is necessary to think about the future of pastoralism in light of changing farming systems and world order vis-à-vis environmental protection. In chapter 3, it was noted that there is encroachment of crop farmers from other communities especially into the medium potential pastoral lands. According to de Haan and Gauthier (2003), there is a decline in the social cohesion at the higher level of group formation and a return to the family, or small groups of families as the main decision making unit. In addition, rising unemployment in other sectors leads to fragmentation of the pastoral societies. To curb these problems, support of off-farm employment for the able members of the community is vital (de Haan, 2003). In addition, the formation and empowerment of pastoral associations, which enable local communities to assume responsibility for, and play an active role in, the management of natural resources is a worthwhile consideration (Shanmugaratnam et al., 1992). Where livestock and wildlife share feed and water resources (e.g., pastoral Maasai community of Kenya), part of the benefits accruing from wildlife (e.g., earnings from tourism, sports hunting and cropping) could be ploughed back into the local community. This would assist in livestock disease control (wildlife often harbour livestock disease vectors and parasites, and predate on livestock (e.g., Makokha, 2002)) and improvement of infrastructure for quick access to socially acceptable livestock and input markets. The additional benefit from this would be reduction in human-wildlife conflict, and hence community participation in wildlife genetic resource conservation.

Natural catastrophes like long drought spells, disease and incidental floods are common in tropical areas, and need to be taken into consideration in breeding programmes. Early warning systems are therefore imperative to enable farmers to prepare and cope with them. According to de Haan and Gauthier (2003), drought preparedness is the key issue in pastoral areas, which requires strategies for rapid de-stocking before the drought and rapid re-stocking when the rains start. However, the issue to ponder is where to de-stock such a large number of animals in a short period, and to get an equally large number for re-stocking. In some areas livestock rustling is a way of life (e.g., Makokha, 2002). Breeding programmes in such areas are prone to risk and careful consideration is required before initiating any. In addition to provision of adequate security by the government, intensive extension work to convince farmers on the negative aspects of the retrogressive practice would be desirable to discourage the activity. Another option is to have large-scale community (village-based) breeding programmes, so that most of the communities have equally better animals and do not see the need to raid stock from their neighbours. An appropriate method of animal identification, for example, by branding with unique numbers for each region would further contribute to reduction of livestock banditry. In extreme circumstances, for example, of insecurity and inaccessibility, it is possible to initiate a breeding programme and leave it to chance that it will be successful and hence sustained. If it formally collapses, at least some genetic progress will have been made, and the effects both genetic and non-genetic, however small will remain. Baker and Gray (2003) have suggested that where animals are exquisitely adapted to fragile conditions after thousands of years under natural selection (e.g., the Bedouin sheep of the middle east deserts), the best strategy is to let natural selection continue without external interference with either their genetic potential or their environment. This thesis shares the same sentiments.

The HIV/AIDS pandemic is currently a challenge in developing countries in the tropics and its impact on small ruminant production needs to be considered in breeding programmes, at least in the short-run. For instance, the incidence is highest in sub-Saharan Africa were an estimated 29.4 million people are infected with the disease (UNAIDS, 2003), with more than two-thirds of the population of the 25 most affected countries living in the rural areas (FAO, 2002). The epidemic is increasing and expected to reach its peak in 15 to 20 years (Goe and Stranzinger, 2002). The extent to which HIV/AIDS impacts the small ruminant sector at the smallholder and pastoral level in the short- and long-term has not been widely studied. However, it has been observed that both smallholder and pastoral farmers turn to livestock as their main resource to cover medical expenses or meet funeral costs (FAO, 1995). The slaughter or sale of animals reduces herd size, resulting in less livestock products available for sale. The disease also causes reduced labour force for taking care of animals (Goe and Stranzinger, 2002). In addition, it makes it difficult for governments to give higher priority to breeding programmes than tackling the disease (Koudandé, 2000). A concerted effort is required to combat the HIV/AIDS pandemic, and enhancing the nutritional and income status of the rural people through increased productivity of small ruminants would be a worthy contribution.

Moreover, governments of developing countries are encouraged to seek alternatives of footing medical bills (e.g., through formal medical insurance cover, and subsidized or free drugs for the afflicted) in order to relief the burden on livestock. In general, the dynamism witnessed in the society would demand relevant knowledge to address emerging issues. In addition to other strategies, this would require continual revision of education (tertiary college and university) curricula in developing countries to make them responsive to the needs of the society. More importantly, is the recognition of indigenous breeds in food production and stability of the environment.

8.7. Conclusion

This thesis has demonstrated that there are good opportunities for sustainable breeding strategies of small ruminants in local farming systems of the tropics. Genetic improvement is a slow and gradual process, which will improve the welfare of the resource-poor smallholder and pastoral communities in the long-term. Within-breed selection and use of adapted indigenous breeds is a viable strategy to both preserve animal genetic diversity, and to consequently alleviate poverty, increase food security and enhance sustainable agriculture in developing countries. The recommendations do not demand a *status quo* but a gradual change to market-oriented small ruminant production utilizing indigenous breeds. To realize full benefit of genetic improvement, simultaneous improvement in the environment (e.g., nutrition, husbandry, marketing and policy) is vital. Viable options for financing and insurance are necessary in order for the farmers to view small ruminants differently, not as a form of saving or insurance, but as an economic activity. It is important to define the goal of small ruminant genetic improvement initiative at the start based on analysis of the anticipated situation. In this regard, a systems and multidisciplinary approach is needed to integrate issues affecting the people in a holistic manner. Vital for success and sustainability of the breeding programme are the support of the overall national development policy, and involvement of the producer at every stage in its planning and execution, while simultaneously incorporating traditional knowledge, practices, behaviour and values.

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Summary

Small ruminants (i.e., sheep and goats) are widespread in the tropics and contribute to the subsistence, economic and social livelihoods of a large human population. They are a source of tangible benefits (i.e., cash income from animal sales, meat for home consumption, manure, fibre and skins) and intangible benefits (e.g., savings, insurance, cultural and ceremonial purposes). The main beneficiaries are the women, children and the aged, who are often the most vulnerable members of the society in terms of under-nutrition and poverty. Besides, small ruminants complement other livestock in the utilization of available feed resources and provide one of the practical means of using vast areas of natural grassland in regions where crop production is impractical, such as arid and semi-arid areas, and hilly and rocky grounds. Despite the large numbers and importance of these animal species in the tropics good definitions of comprehensive breeding objectives are rare. In addition, sustainable breeding programmes using indigenous breeds are scarce. The developing countries in the tropics currently experience high increases in human population, dramatic urbanization, increasing monetarization of their economies and income change. Consequently, there is need to address issues related to under-nutrition, food security, rural poverty, and rates and patterns of agricultural growth that contribute to overall economic development, and protection of the environment. Sustainable breeding programmes can make a significant contribution.

The thesis basically had two main aims: (1) to identify breeding objectives for tropical small ruminants, and (2) to develop appropriate small ruminant breeding strategies for tropical small ruminants. Most of the research in this thesis can be termed as system analysis research in which statistical modelling played an important role. The focus was on traditional smallholder and pastoral production systems in developing countries of the tropics. Production circumstances in Kenya for sheep are used for illustration, but the methodology, and where possible the findings, are generalized.

For genetic improvement, replacement of indigenous genotypes by exotic breeds, and crossbreeding with exotic germplasm have been widely used but have in most cases been unsuccessful in the low-input traditional production systems in the tropics. Within-breed selection of the adapted indigenous genotypes is a viable alternative. However, little information is available on within-breed selection programmes utilizing indigenous breeds in the tropics. **Chapter 2** reviews within-breed selection programmes in the tropics, highlighting aspects contributing to their success or failure. The aim was to better understand opportunities for genetic improvement of small ruminants by the resource-poor farmers in traditional smallholder and pastoral farming systems. It was found that dismal performance of breed substitution and crossbreeding programmes involving breeds from temperate regions have triggered a recent re-orientation of breeding programmes in tropical countries to use native breeds, and most programmes are developing. Definition of comprehensive breeding objectives incorporating the specific, immediate and long-term social and economic circumstances of the target group as well as ecological constraints was found lacking in some projects which failed. The success rate of some breeding schemes involving indigenous breeds is encouraging. It is concluded that it is necessary to look at the production system holistically, and involve the producer at every stage in the planning and operation of the breeding programme, integrating traditional behaviour and values. The most promising breeding strategy to improve and sustain the native small ruminant population is probably to address the issue of risk aversion through management measures and sire exchange rather than setting selection criteria for output-oriented traits, which cannot be matched without additional external inputs.

When it was evident that the definition of appropriate breeding objectives for the low-input traditional production systems in the tropics was a problem, and that probably the role of small ruminants in smallholder and pastoral farming systems was poorly understood, the need for more information to better understand these farming systems arose. Subsequently, a field survey was carried out in Kenya, covering smallholder and pastoral/extensive sheep and goat farming systems. **Chapter 3** presents the results from the survey. The findings assist in the definition of breeding objectives and design of appropriate breeding schemes. It was found that 58% of pastoral/extensive farmers and 46% of the smallholders indicated livestock as their main activity. Small ruminants were ranked closely to cattle in their importance. Among the reasons for keeping small ruminants, regular cash income and an insurance against emergencies were the highest priorities. Income from small ruminants was spent on school fees (32%), purchase of food (22%), farm investment (18%), medical expenses (10%), off-farm investment (9%), social activities (5%) and re-stocking (4%). Indigenous genotypes were predominant among pastoralists and mixed crosses predominant among smallholders. A range of traits: growth rate, size, shape, drought tolerance, meat quality, fertility, disease and heat tolerance, prolificacy and temperament were all considered important for both sheep and goats in both farming systems and across the different genotypes. Compared with other pure breeds Red Maasai sheep and Small

East African goats were rated poorly in terms of size, shape, growth and fertility but highly in terms of drought and (Red Maasai) heat tolerance by both smallholder and pastoralist farmers. In general, crosses were perceived less favourably than indigenous pure breeds. Size and performance ranked as the most important traits in the choice of breeding males. Approximately half the farmers inherited their males, reared them on the farm and kept them for an average of 2-3 years. Constraints to small ruminant productivity included low levels of management, disease and parasite challenge, inadequate feed and poor marketing. For instance, uncontrolled mating within the household's flock was predominant in both farming systems. Over 98% of the farmers reported incidence of disease, mainly pneumonia (in pastoral/extensive areas), tick-borne diseases, helminthosis, diarrhea and foot-rot. Over 95% of farmers fed supplements in both dry and wet seasons. Respectively 74% and 76% of smallholder and pastoral/extensive sheep farmers did not have a preference for a particular season for selling their animals. Corresponding percentages for goats averaged 84%. The remainder either sold animals in the wet or dry seasons only. It is concluded that it is necessary to look at the production system in a holistic way and involve target groups in devising effective small ruminant breeding programmes. An integrated systems approach to small ruminant improvement is likely to be the best option. In the traditional smallholder or pastoral/extensive environment emphasis of genetic improvement of the indigenous genotype may prove to be the best option.

In **Chapter 4**, economic values were derived for important traits of meat sheep in medium to high potential areas. A deterministic bio-economic model that assumed no variation in characteristics among animals was used for calculation of economic values for important traits of an indigenous meat sheep population reared under smallholder farming, taking production circumstances in Kenya as a working example. The calculations were based on a profit function (US$ per ewe per year) including the specification of revenue and feed, and other costs of production. Poor climatic years were not modelled. The traits considered were litter size, lambing frequency, pre-weaning, and post-weaning lamb survival to 12 months, ewe survival, lamb live weight at 12-month, mature ewe live weight, consumable meat, kg of manure dry matter sold per ewe per year and residual dry matter feed intake. Three evaluation situations were considered: (i) base with constant number of ewes, (ii) fixed feed resource and (iii) setting feed costs to zero. Sensitivity analysis of economic values to price levels of inputs and meat production was carried out. Situation (ii) appropriately describes smallholder production circumstances in the tropics. A profit of $–34.16 was obtained for this production scenario. Meat accounted for 88% of revenue and

manure 12%. Variable costs represented about 95% of the total costs. Litter size and lambing frequency were the most important traits in a breeding objective for smallholder production. All the traits considered were sensitive to changes in price levels of inputs and meat production, except kg of manure dry matter sold per ewe per year and residual dry matter feed intake.

The apparent net economic loss observed in the preceding chapter implied that the intangible roles of animals (e.g., as savings and an insurance against emergencies) could substantially influence the economic values of traits. The idea necessitated the examination of the impact of tangible as well as intangible benefits in the breeding objective. In **Chapter 5**, the model developed in chapter 4 was extended to include intangible benefits (i.e., savings and insurance), and used to derive economic values for an indigenous tropical sheep breed under pastoral production circumstances. Five scenarios were studied: (i) base accounting for both tangible and intangible roles of sheep, (ii) accounting for manure, skins and intangible roles, (iii) accounting for 20% of animals sold, insurance, manure and skins, (iv) accounting for intangible roles only and (v) accounting for tangible roles only. Sensitivity analysis to different levels of financing and insurance benefit factors, reproduction, survival and live weight traits was performed for the situation accounting for both tangible and intangible roles, and with a constant number of ewes. The same traits as in chapter 4 were considered except residual dry matter feed intake that was not relevant to pastoral production. It was found that profit was positive when both tangible and intangible benefits were taken into account. Situation (v) accounting for tangible benefits only had a profit that was about 35% lower than situation (i) accounting for both tangible and intangible benefits. For the base situation, financing and insurance benefits accounted for 13% and 6% of the total revenue, respectively. The economic values indicated that litter size, lambing frequency and 12-month lamb live weight were likely to be important traits in pastoral production. Sensitivity analysis showed that future economic values for all the traits considered except kg manure dry matter sold per ewe per year might change dependent on levels of intangible benefit factors. Economic values for ewe survival and mature ewe live weight were not responsive to changes in reproductive traits, and pre- and post-weaning survival traits, and vice-versa. It is concluded that it is important to include the intangible roles of sheep in tropical breeding programmes.

The dilemma in small ruminant improvement programmes is how to involve farmers in genetic improvement in order to have successful and sustainable breeding programmes. In **Chapter 6**, stochastic simulation was used to analyze alternative pure-breeding structures for sheep in the tropics. Attention was paid to genetic gain, degree of inbreeding and the level of interaction between the nucleus breeding flocks and the commercial farmers. Motivation of farmers to participate and contribute to the breeding scheme was considered. The breeding schemes considered were: (I) a single closed nucleus providing seed-stock to village flocks, (II) a group of commercial flocks running a co-operative ('ram circle') breeding programme with no nucleus, (III) an interactive two-tier open nucleus breeding scheme, comprising a nucleus and a commercial tier - the best males are used within the nucleus while the remainder migrate to the commercial flocks, with no female migration, and (IV) as scheme III but with female migration between tiers. The findings indicate that running one closed nucleus had a 6-24% advantage over a 'ram circle' in terms of genetic gain. Relative to a two-tier nucleus (scheme I), interactive cyclic screening of commercial animals for use in the nucleus gave an almost optimum genetic response, and the villagers would acquire superior breeding stock in return as an incentive to participate in genetic improvement. Participation of farmers offers them a sense of ownership of the breeding programme, and is likely to make it sustainable in the long-term. Decreasing the dam to sire ratio was a simple way to avoid inbreeding in breeding schemes of small size, with very little compromise towards genetic gain or even an increase in the longer term. In general the chapter provides insight into the advantages and disadvantages of designed breeding structures, especially the 'interactive breeding schemes', which would be useful in deciding breeding programmes to adopt for small ruminants in the tropics.

Scarce resources – financial, infrastructural and human - hinder effective implementation and operation of small ruminant genetic improvement programmes in the developing countries of the tropics. To overcome these bottlenecks the use of nucleus breeding schemes is a good option. However, studies on multi-trait evaluation of nucleus schemes in the tropics are rare. Previous studies have mainly focused on single trait evaluation, making it unclear if one or more breeding programmes are applicable for the range of production circumstances in the tropics. The key question in **Chapter 7** is whether a single nucleus breeding programme could be used for both smallholder and pastoral production circumstances in the topics. In this chapter, multi-trait evaluation of nucleus pure-breeding scheme for sheep under smallholder and pastoral production circumstances was performed, using stochastic simulation. Productive, reproductive and survival traits were considered simultaneously. The effects of sire to dam mating ratio, age structure, survival rate and type of mating on genetic gain and average inbreeding were examined. In this study, the difference between the smallholder and pastoral production circumstances were only in the economic values of the traits. Firstly, direct responses ($) were calculated for each scenario. Secondly, the correlated responses for the alternative production system were evaluated. The latter is presented as a ratio to the direct response. Optimal schemes in terms of breeding structure were those operating at 50 dams per sire, and 5-10 sires in the flock. For sire to dam mating ratio, the correlated responses for smallholder production ranged from 16% lower to 9% higher than direct responses. A similar trend was observed for pastoral production. Age structure indicated optimal schemes to be those having animals drop their first progeny at 2 years of age and last progeny, respectively, at 3 to 4 and 3 to 7 years for males and females. With regard to age structure, the correlated responses for smallholder production were, on average, the same with direct responses, and varied between 9% less to 11% more than the direct responses for pastoral production. Generally higher survival rates increased genetic responses, but like type of mating (random or assortative), do not necessitate different schemes for smallholder and pastoral production. It is concluded that the factors affecting genetic responses in closed nucleus breeding schemes should be valuable in making decisions regarding the operations of closed nucleus breeding schemes for sheep in the tropics. A single nucleus could serve both smallholder and pastoral production. However, further studies would be necessary when genetic parameters differ for the two production systems or when genotype by environment interaction is present.

In **Chapter 8**, the results presented in chapters 2 to 7 are used to discuss possibilities to improve the genetic potential of small ruminants in the tropics, with special reference to smallholder and pastoral farmers. Firstly, an approach to the design of a breeding programme, including the definition of the breeding objective, the choice of the breed and the organization of a breeding programme are discussed. Subsequently, factors influencing marketing and off-take of small ruminants and/or their products are discussed. The various elements on alternative breeding plans (i.e., nucleus, progeny testing and crossbreeding) are presented and their possible applications elaborated. Lastly, the relevance of new technologies to small ruminant breeding programmes, contribution of the breeding programme to conservation of biodiversity, and impacts of changing society on small ruminant breeding programmes are discussed.

In general, it can be concluded that there is great scope for sustainable breeding strategies of small ruminants in local farming systems of the tropics. Genetic improvement is a slow and gradual process which will improve the welfare of the resource-poor smallholder and pastoral communities in the long-term. It is important that breeding programmes are compatible with the needs of the farmer and the production system - be relatively simple, relatively cheap and above all involve relatively low risks. Market incentives are necessary drives to justify the farmer's investment in the breeding programme. Within-breed selection and use of adapted indigenous breeds is a viable strategy to both preserve animal genetic diversity, and to consequently alleviate poverty, increase food security and enhance sustainable agriculture in developing countries. To realize full benefit of genetic improvement, simultaneous improvement in the environment (e.g., nutrition, husbandry, marketing and policy) is vital. Viable options for financing and insurance are necessary in order for the farmers to view small ruminants differently, not as a form of saving or insurance, but as an economic activity. It is important to define the goal of small ruminant genetic improvement initiative at the start based on analysis of the anticipated situation. In this regard, a systems and multidisciplinary approach is needed to integrate issues affecting the people in a holistic manner. Vital for success and sustainability of the breeding programme are the support of the overall national development policy, and involvement of the producer at every stage in its planning and execution, while simultaneously incorporating traditional knowledge, practices, behaviour and values.

Samenvatting

Kleine herkauwers (i.e., schapen en geiten) komen veel voor in de tropen en leveren een wezenlijke bijdrage aan het levensonderhoud, en aan de sociale en economische leefomgeving van een groot aantal mensen. De voordelen zijn zowel materieel (zoals inkomsten uit verkoop van dieren, vlees voor eigen consumptie, mest, wol en huiden) als immaterieel (financiële reserves, verzekering, culturele en ceremoniële doeleinden). Deze voordelen komen vooral ten goede aan de meest kwetsbare groepen in de samenleving (met name vrouwen, kinderen en ouderen) qua ondervoeding en armoede. Verder vormen de kleine herkauwers een aanvulling op ander vee bij het gebruik van de aanwezige voedselbronnen, en worden bijvoorbeeld gebruikt om uitgestrekte gebieden met natuurlijke graslanden te benutten, waar het verbouwen van gewassen onmogelijk is, zoals in aride, semi-aride, heuvelachtige of rotsachtige gebieden. Ondanks de grote aantallen en het belang van kleine herkauwers in de tropen, is er zelden een goed gedefinieerd fokdoel voor deze diersoorten aanwezig. Bovendien zijn duurzame fokprogramma's voor lokale rassen zeldzaam. De behoefte hieraan groeit, omdat de ontwikkelingslanden in de tropen geconfronteerd worden met grote bevolkingsgroei, enorme verstedelijking, een steeds meer op geld gebaseerde handel en inkomensfluctuaties. Hierdoor is er meer aandacht nodig voor zaken als ondervoeding, voedselvoorziening, armoede op het platteland, en aard en snelheid van de groei van agrarische productie. Deze zaken spelen een rol bij de totale economische ontwikkeling, en beïnvloeden tevens de omgeving. Duurzame fokprogramma's kunnen hieraan een wezenlijke bijdrage leveren.

De doelstellingen van het in dit proefschrift beschreven onderzoek waren: (1) opstellen van fokdoelen voor kleine herkauwers in de tropen, en (2) ontwikkelen van passende fokkerij strategieën voor kleine herkauwers in de tropen. Een groot deel van het hier beschreven onderzoek bestaat uit systeem analyse, voornamelijk gebaseerd op statistisch modelleren van alternatieven. Het ging hierbij met name om de traditionele productiesystemen, zoals een systeem met kleine gemengde bedrijven en een extensief houderijsysteem waarin voer beperkt beschikbaar is, en aangevuld moet worden door met de kuddes rond te trekken. Dit laatste systeem wordt hierna aangeduid als semi-pastoraal productiesysteem. De productie omstandigheden voor schapen in Kenia zijn gebruikt als illustratie, maar de methodes en de resultaten worden zoveel mogelijk vertaald naar andere omstandigheden en diersoorten.

Voor het verbeteren van de erfelijke aanleg van dieren in traditionele productiesystemen in de tropen, is tot nu toe vooral gebruik gemaakt van import van niet-lokale rassen ter vervanging van de lokale rassen, en van kruisen van de lokale rassen met niet-lokale rassen. In de meeste gevallen was deze aanpak niet succesvol. Selectie binnen de aan de omstandigheden aangepaste, lokale rassen is mogelijk een alternatief. Er is echter weinig informatie beschikbaar over binnen-ras selectie programma's in de tropen die gericht zijn op lokale rassen. **Hoofdstuk 2** geeft een overzicht van binnen-ras selectie programma's in de tropen, met speciale aandacht voor de factoren die bijdragen aan het succes of het mislukken van deze programma's. Het doel was inzicht te krijgen in de mogelijkheden voor verbetering van de erfelijke aanleg van kleine herkauwers in de traditionele houderijsystemen. Hieruit bleek, dat de slechte resultaten van vervanging door of kruisen met niet-lokale rassen recent heeft geleid tot heroverweging van fokprogramma's in tropische landen. Er wordt nu meer gebruik gemaakt van de oorspronkelijke rassen, hoewel de meeste van deze programma's nog in ontwikkeling zijn. In enkele van de mislukte programma's bleek een duidelijke omschrijving te ontbreken van het fokdoel, met daarin opgenomen de relevante sociale en economische omstandigheden en de ecologische beperkingen. Het succes percentage van de programma's gebaseerd op lokale rassen is bemoedigend. De conclusie is dat het noodzakelijk is om alle aspecten van het productiesysteem te beschouwen, en de veehouders in elke fase van de planning en uitvoering van het fokprogramma te betrekken, waarbij traditionele normen en waarden worden meegenomen. De meeste kansen om de oorspronkelijke populaties van kleine herkauwers te verbeteren worden mogelijk geboden door een fokkerij strategie die aandacht besteed aan het vermijden van risico door management maatregelen, en via uitwisseling van mannelijke fokdieren. Dit is te prefereren boven het opstellen van selectiecriteria, waar niet aan voldaan kan worden met de beschikbare rassen en middelen.

Toen duidelijk was dat de definitie van fokdoelen voor de traditionele productiesystemen met beperkte middelen in de tropen een probleem was, en dat mogelijk de rol van kleine herkauwers in deze systemen minder duidelijk was, ontstond er behoefte aan meer informatie om deze houderijsystemen te begrijpen. Daarom is er vervolgens een veldonderzoek verricht in Kenia, om het systeem met kleine gemengde bedrijven en het semi-pastorale productiesysteem in kaart te brengen. In **Hoofdstuk 3** worden de resultaten van dit onderzoek gepresenteerd. Deze resultaten zijn van belang voor het opstellen van fokdoelen en het opzetten van passende fokprogramma's. Veehouderij werd door 58% van de semi-pastorale bedrijven en 46% van de kleine gemengde bedrijven gezien als belangrijkste activiteit. Kleine herkauwers werden bijna net zo belangrijk gevonden als rundvee. Kleine herkauwers werden vooral gehouden vanwege een gelijkmatig inkomen en als verzekering tegen noodgevallen. Het inkomen van kleine herkauwers werd vooral gebruikt voor schoolgeld (32%), aankoop van voedsel (22%), investering in het bedrijf (18%), uitgaven van medische aard (10%), investeringen buiten het bedrijf (9%), sociale activiteiten (5%) en aankoop van vee (4%). Semi-pastorale bedrijven gebruikten vooral lokale rassen, terwijl de kleine gemengde bedrijven vooral diverse kruisingen gebruikten. Een breed scala aan kenmerken werd belangrijk geacht, in alle schapen- en geitenrassen, en in beide bedrijfssystemen: groeisnelheid, ontwikkeling, type, tolerantie tegen droogte, vleeskwaliteit, vruchtbaarheid, tolerantie tegen ziekte en hitte, reproductiecapaciteit, en gedrag. In vergelijking met andere rassen werden Red Masaai schapen en Small East African geiten slecht beoordeeld voor ontwikkeling, type, groeisnelheid en vruchtbaarheid, maar goed beoordeeld voor tolerantie tegen droogte (beide soorten) en tolerantie tegen hitte (Red Masaai). In het algemeen werden kruisingen minder gewaardeerd dan de lokale, zuivere rassen. Bij het kiezen van mannelijke fokkerijdieren werd vooral gelet op ontwikkeling en prestatie. Ongeveer de helft van de veehouders verkreeg mannelijke dieren als geschenk van hun ouders bij de start van hun bedrijf en hield deze aan gedurende 2-3 jaren. Beperkend voor de productiviteit van deze systemen waren onder andere laag management niveau, ziektes en parasieten, onvoldoende voer en slechte marketing. Op het paren van dieren werd bijvoorbeeld geen controle uitgeoefend. Meer dan 98% van de veehouders meldde het vóórkomen van ziektes, vooral longontsteking (in extensieve gebieden), ziektes overgebracht door teken, worminfecties, diarree, en kreupelheid. Meer dan 95% van de veehouders paste bijvoedering toe in zowel droge als natte seizoenen. Bij bedrijven met schapen was er geen voorkeur qua verkoopseizoen bij 74% van de kleine gemengde bedrijven en 76% van de semi-pastorale bedrijven. Deze percentages waren bij bedrijven met geiten gemiddeld 84%. De overige bedrijven verkochten de dieren uitsluitend in het droge seizoen of in het natte seizoen. De conclusie is dat het noodzakelijk is om het productiesysteem als geheel te beschouwen, en doelgroepen te betrekken bij het ontwerpen van effectieve fokprogramma's voor kleine herkauwers. Een geïntegreerde systeem benadering is hiervoor waarschijnlijk de beste optie. Voor het productiesysteem met kleine gemengde bedrijven en voor het semi-pastorale productiesysteem is nadruk op erfelijke verbetering van het lokale ras mogelijk de beste oplossing.

In **Hoofdstuk 4** zijn economische waarden afgeleid voor belangrijke kenmerken van vleesschapen in gebieden met redelijke tot veel mogelijkheden. Een deterministisch bio-economisch model is gebruikt, waarbij geen variatie in kenmerken tussen dieren werd verondersteld. De economische waarden werden berekend voor belangrijke kenmerken van een lokaal vleesras gehouden op kleine gemengde bedrijven, waarbij uitgegaan werd van de productie omstandigheden in Kenia. De berekeningen werden gebaseerd op een opbrengstfunctie (US$ per ooi per jaar), met daarin opgenomen een specificatie van de opbrengsten, voerkosten, en overige productie kosten. Slechte jaren qua klimaat werden niet meegenomen. De onderzochte kenmerken waren worpgrootte, frequentie van lammeren, overleving voor spenen, overleving van spenen tot een leeftijd van 12 maanden, ooi overleving, levend gewicht van lammeren op leeftijd 12 maanden, levend gewicht van volwassen ooien, vleesproductie, hoeveelheid verkochte mest per ooi per jaar (droge stof), en residuele voeropname (droge stof). Drie situaties werden onderzocht: (i) basissituatie met een vast aantal ooien, (ii) vaste hoeveelheid beschikbaar voer en (iii) voerkosten gelijkgesteld aan 0. De gevoeligheid van de economische waarden voor prijsniveaus van input en vlees productie werd getest. Situatie (ii) is een passende beschrijving van het productiesysteem voor kleine gemengde bedrijven in de tropen. Dit scenario leidde tot een winst van $ -34.16. Vlees productie was verantwoordelijk voor 88% van de opbrengsten en de overige 12% was afkomstig uit de verkoop van mest. De variabele kosten vormden 95% van de totale kosten. Worpgrootte en frequentie van lammeren waren de belangrijkste kenmerken in een fokdoel voor kleine gemengde bedrijven. Alle economische waarden waren gevoelig voor prijsniveaus van input en vlees productie, met uitzondering van de hoeveelheid verkochte mest per ooi per jaar (droge stof) en de residuele voeropname (droge stof).

Uit het voorgaande hoofdstuk bleek dat het onderzochte productiesysteem leidt tot een netto economisch verlies. Dit houdt mogelijk in, dat de immateriële voordelen van dieren (bijv. financiële reserves en verzekering tegen noodgevallen) een substantiële bijdrage zouden kunnen leveren aan de economische waarde van kenmerken. Dit maakt onderzoek naar de invloed van zowel materiële als immateriële baten op het fokdoel noodzakelijk. In **Hoofdstuk 5** is het in Hoofdstuk 4 ontwikkelde model uitgebreid met immateriële baten (financiële reserves en verzekering), en gebruikt om economische waardes af te leiden voor een lokaal tropisch schapenras in een semi-pastorale houderijsysteem. Vijf scenario's werden onderzocht, waarbij rekening gehouden werd met de volgende factoren: (i) materiële en immateriële voordelen van schapen (basissituatie), (ii) mest, huiden en immateriële voordelen, (iii) verkoop van 20% van de dieren, verzekering, mest en huiden, (iv) uitsluitend immateriële voordelen, en (v) uitsluitend materiële voordelen. De gevoeligheid van de economische waarden voor verschillende niveaus van financiële reserves en waarde van de verzekering, reproductiecapaciteit, overleving en gewichtskenmerken werd getest voor situatie (i), en bij een vast aantal ooien. Dezelfde kenmerken als in Hoofdstuk 4 werden onderzocht, met uitzondering van residuele voeropname (droge stof). Dit kenmerk is niet relevant in semi-pastorale houderijsystemen. Een positieve winst werd behaald wanneer rekening gehouden werd met zowel materiële als immateriële baten (i). De winst in situatie (v), met uitsluitend materiële voordelen, was ongeveer 35% lager dan de basissituatie. De voordelen uit financiële reserves en verzekering waren verantwoordelijk voor respectievelijk 13% en 6% van de totale opbrengst. De economische waardes geven aan dat worpgrootte, frequentie van lammeren en levend gewicht van lammeren op leeftijd 12 maanden waarschijnlijk de belangrijkste kenmerken zijn in het semi-pastorale productiesysteem. Uit de gevoeligheidsanalyse bleek dat de toekomstige economische waardes voor alle onderzochte kenmerken, met uitzondering van de economische waarde voor hoeveelheid verkochte mest per ooi per jaar (droge stof), zouden kunnen veranderen bij verschillende niveaus van de immateriële voordelen. Economische waardes voor ooi overleving en levend gewicht van volwassen ooien waren niet gevoelig voor veranderingen in vruchtbaarheidskenmerken, overleving voor spenen en overleving na spenen. Het omgekeerde bleek eveneens. De conclusie is, dat het belangrijk is om de immateriële voordelen van schapen op te nemen in fokprogramma's voor kleine herkauwers in de tropen.

Een belangrijk vraagstuk in fokprogramma's voor kleine herkauwers is hoe de veehouders betrokken kunnen worden bij die programma's, ten einde een succesvol en duurzaam fokprogramma op te kunnen zetten. In **Hoofdstuk 6** zijn alternatieve fokkerijstructuren voor zuivere schapenrassen in de tropen geanalyseerd met behulp van stochastische simulatie. Hierbij is aandacht besteed aan de erfelijke vooruitgang, niveau van inteelt, en de mate van interactie tussen kernfokbedrijven (nucleus bedrijven) en productie bedrijven. De gemotiveerdheid van veehouders om deel te nemen in en bij te dragen aan het fokprogramma werd hierbij eveneens meegenomen. De volgende fokprogramma's werden onderzocht: (i) één gesloten nucleus die fokmateriaal levert aan productie bedrijven, (ii) een groep van productie bedrijven die een coöperatief fokprogramma vormen ("rammencirkel"), zonder nucleus, (iii) een interactief open nucleus fokprogramma, bestaande uit twee lagen, te weten een nucleus en een groep productie bedrijven – de beste rammen worden binnen de nucleus gebruikt, terwijl de overige rammen naar de productie bedrijven worden verplaatst, zonder uitwisseling van ooien, en (iv) als schema (iii), maar mét uitwisseling van ooien tussen verschillende lagen. De resultaten laten zien dat met het nucleusschema (i), een 6-24% hogere erfelijke vooruitgang bereikt kan worden dan met het rammencirkel-schema (ii). De beide schema's met uitwisseling van dieren tussen de beide lagen gaven een bijna optimale erfelijke vooruitgang. Als beloning voor deelname aan het fokprogramma, en om deelname te stimuleren, ontvangen de veehouders superieur fokmateriaal vanuit de nucleus. Deelname aan het fokprogramma geeft de veehouders een soort aandeel in het fokprogramma, en vergroot de kansen op een duurzaam fokprogramma. Inteelt in kleine fokprogramma's kon eenvoudig worden beperkt door het aantal ooien per ram te verlagen, resulterend in slechts een beperkt lagere erfelijke vooruitgang. Wanneer de fokprogramma's over een langere termijn geëvalueerd werden, was een dergelijk schema zelfs beter qua erfelijke vooruitgang. In het algemeen kan gesteld worden, dat dit hoofdstuk inzicht geeft in de voordelen en nadelen van dergelijke fokprogramma's, vooral van de interactieve fokprogramma's. De resultaten kunnen gebruikt worden bij de beslissing welk fokprogramma het meest geschikt is voor kleine herkauwers in de tropen.

Beperkte middelen – financieel, infrastructureel en humaan – verhinderen de effectieve inpassing en uitvoering van fokprogramma's voor kleine herkauwers in ontwikkelingslanden in de tropen. Nucleus fokprogramma's bieden mogelijk kansen om deze beperkingen te overwinnen. Studies naar nucleus schema's in de tropen die zich richten op meerdere kenmerken zijn echter beperkt. Reeds uitgevoerde studies hebben zich met name gericht op evaluatie van één enkel kenmerk, waardoor het onduidelijk is of één of meerdere fokprogramma's noodzakelijk zijn voor het brede scala aan productie omstandigheden in de tropen. De belangrijkste vraag in **Hoofdstuk 7** is of één enkel nucleus programma gebruikt zou kunnen worden voor zowel de kleine gemengde bedrijven, als de semi-pastorale bedrijven in de tropen. In dit hoofdstuk zijn nucleus fokprogramma's voor schapen geëvalueerd met behulp van stochastische simulatie. Deze fokprogramma's richtten zich op selectie binnen het ras, en op meerdere kenmerken, voor zowel kleine gemengde bedrijven als semi-pastorale bedrijven. Zowel productie, reproductie als overlevingskenmerken werden gelijktijdig geëvalueerd. Het effect van fokkerij structuur, leeftijdsopbouw, overleving en paringsschema op de erfelijke vooruitgang en op de gemiddelde inteelt werden onderzocht. In dit onderzoek verschilden de productiesystemen voor de kleine gemengde bedrijven en de semi-pastorale bedrijven uitsluitend qua economische waardes van de kenmerken. In de eerste plaats werd de directe respons ($) bepaald voor elk scenario. Ten tweede werd de gecorreleerde response in een productiesysteem bepaald, als gevolg van selectie in het andere productiesysteem. Dit wordt gepresenteerd als fractie van de directe response voor dat productiesysteem. Optimale fokprogramma's qua fokkerij structuur hadden 50 ooien per ram, en 5-10 rammen per bedrijf. De gecorreleerde respons op het fokdoel voor kleine gemengde bedrijven varieerde van –16% tot +9% ten opzichte van de directe respons. Een vergelijkbare trend werd gevonden voor het semi-pastorale productiesysteem. In het optimale schema qua leeftijdsopbouw werden de eerste nakomelingen geproduceerd op een leeftijd van 2 jaar, en kregen rammen de laatste nakomelingen op leeftijd 3-4 jaar, en ooien op leeftijd 3-7 jaar. Hier was de gecorreleerde respons op een productiesysteem met kleine gemengde bedrijven gemiddeld gelijk aan de directe respons. De gecorreleerde respons voor het semi-pastorale productiesysteem varieerde van –9% tot +11% ten opzichte van de directe respons. In het algemeen leidde een grotere kans op overleving tot een grotere erfelijke vooruitgang, maar hierbij kon hetzelfde fokprogramma gebruikt worden voor beide systemen. Hetzelfde gold voor alternatieve paringsschema's (willekeurige paringen, dan wel paring van "gelijke" dieren qua niveau van de kenmerken). De conclusie is, dat de factoren die de erfelijke vooruitgang in gesloten nucleus schema's bepalen, van belang zijn bij het besluit welk fokprogramma geschikt is voor schapen in de tropen. Eén enkele nucleus kan gebruikt worden om zowel een productiesysteem met kleine gemengde bedrijven, als een semi-pastoraal productiesysteem van dieren te voorzien. Verder onderzoek is echter noodzakelijk indien de erfelijkheidsgraad of de erfelijke correlaties tussen kenmerken verschillend zijn voor de twee productiesystemen, of wanneer de erfelijke aanleg verschillend tot uiting komt onder verschillende omstandigheden (genotype-milieu interactie).

In **Hoofdstuk 8** worden de resultaten van de Hoofdstukken 2 tot en met 7 gebruikt om de mogelijkheden ter verbetering van de erfelijke aanleg van kleine herkauwers in de tropen te bediscussiëren. De nadruk ligt hierbij op productiesystemen met kleine gemengde bedrijven en met semi-pastorale bedrijven. In de eerste plaats wordt ingegaan op het opzetten van een fokprogramma, inclusief de definitie van het fokdoel, de keuze voor het ras en de organisatie van het fokprogramma. Vervolgens worden de factoren die van invloed zijn op de marketing en afzet van kleine herkauwers en/of hun producten bediscussieerd. De diverse elementen die verschillen tussen fokprogramma's bepalen (i.e., nucleus, nakomelingen onderzoek en kruisen van rassen) worden gepresenteerd en er wordt ingegaan op de mogelijke toepassingen hiervan. Als laatste wordt ingegaan op de relevantie van nieuwe technologieën voor fokprogramma's voor kleine herkauwers, de bijdrage van het fokprogramma aan het behoud van biodiversiteit, en op de gevolgen van maatschappelijke veranderingen op fokprogramma's voor kleine herkauwers.

De algemene conclusie is, dat er enorme mogelijkheden zijn voor het opzetten van duurzame fokprogramma's voor kleine herkauwers in de locale veehouderijsystemen in de tropen. Erfelijke verbetering is een langzaam en geleidelijk proces, dat op de lange termijn een positief effect zal hebben op de welvaart van de betrokken bevolkingsgroepen. Het is belangrijk dat de fokprogramma's passend zijn voor de veehouders en hun productiesystemen – relatief simpel en goedkoop, en vooral gepaard gaand met weinig risico. Een vorm van beloning is noodzakelijk om de individuele veehouder te laten investeren in het fokprogramma. Selectie binnen rassen en het gebruik van aan de omstandigheden aangepaste, lokale rassen is een levensvatbare strategie om zowel de biodiversiteit te garanderen, als de armoede te verlichten, voedselvoorziening te waarborgen en een duurzame landbouw in ontwikkelingslanden te versterken. Om de erfelijke vooruitgang volledig te benutten, is tevens een gelijktijdige verbetering van de omstandigheden (bijv. voeding, houderijsysteem, marketing en beleid) van vitaal belang. Levensvatbare alternatieven voor financiële reserves en verzekering zijn noodzakelijk, zodat het houden van kleine herkauwers door de locale bevolking niet meer gezien wordt als kapitaalreservering of verzekering, maar als een economische activiteit. Het is belangrijk om vooraf het doel van de erfelijke verbetering van kleine herkauwers goed te omschrijven, gebaseerd op een analyse van de gewenste situatie. Daarom is een multidisciplinaire en systeem benadering noodzakelijk, waarbij alle factoren die van invloed zijn op de bevolking geïntegreerd worden. De steun van de nationale overheid, en betrokkenheid van de veehouders bij ieder stadium van planning en uitvoering van het fokprogramma is noodzakelijk voor het succes en de duurzaamheid van het fokprogramma. Hierbij moet gelijktijdig rekening gehouden worden met traditionele kennis, gebruiken, normen en waarden.

Autobiography

Isaac Sanga Kosgey, a second son to Mr. and Mrs. Lucas Komingoi Koskey, was born on April 5th 1961 in Lessos, Nandi District in the Rift Valley Province of Kenya. After his primary education at Lessos Primary School and high school education at Kapsabet Boys High School (Nandi) and Wahundura High School (Murang'a) (1970-1982) he was employed in 1983 as a teacher at Lelwak Secondary School, Nandi District. In 1984, Isaac joined Egerton University College for a Diploma in Animal Husbandry and graduated with Distinction in December, 1987. Subsequently, he joined the Ministry of Livestock Development and was posted to Mweiga Division of Nyeri District, Kenya, where he was in charge of extension activities and rural dairy projects. In April, 1989, Isaac was employed by Egerton University (Njoro, Kenya) as a Senior Technician in Livestock Management at the Department of Animal Science. A year later he qualified for a staff development programme and joined the same university for a Bachelor of Science degree in Animal Production, for which he graduated with First Class Honours in November, 1994. Isaac won a World Bank Scholarship in 1996 for a Masters degree at Wageningen University, The Netherlands and graduated with Distinction in Animal Science (Breeding Option) in August, 1997. His M.Sc. thesis was entitled: 'Potential Benefit and Implementation of Nucleus Breeding Scheme for Milk Production from Crossbred Cattle in Kenya'. After the M.Sc., he re-joined Egerton University as an assistant lecturer, mainly teaching courses in animal breeding and livestock production, in addition to other departmental duties. In 1998, Isaac attended an 'International Course on Intensive Poultry Production' in Israel. In 1999/2000 he competed for and won two Ph.D. scholarships, Commonwealth Canadian, and The Netherlands Foundation for the Advancement of Tropical Research (WOTRO). He opted for the latter, which involved Wageningen University (The Netherlands) in collaboration with the International Livestock Research Institute (ILRI-Nairobi, Kenya), and The University of New England (UNE) (Armidale, NSW, Australia). He started his four-year Ph.D. programme in April, 2000. At UNE in July-November, 2001, Isaac attended courses in Statistics and Genetics, and Genetic Evaluation and Breeding Program Design, and passed with a High Distinction and Distinction, respectively. He has done other short courses at Wageningen University and ILRI. Upon completion of his Ph.D. study, Isaac goes back to teach at the Department of Animal Science at Egerton University. His hobbies and interests include reading, teaching and research, creative writing, computer programming, farming, sports, dancing and charity work.

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