Breeding Programme and Infrastructure

– the Case of Red Maasai Sheep in Kenya

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Abstract

The aim of this thesis was to study potential breeding strategies for indigenous livestock in Eastern and Southern Africa under low input production systems. The thesis covered a study of the status of supportive infrastructure for use of animal genetic resources. The case of Red Maasai sheep was studied as a model for design of strategies for improvement of an indigenous breed under threat. Studies [I-II] were performed through participatory approaches by use of structured interviews, while [III] comprised analyses of data collected at a research station, and [IV] was based on simulations.

The infrastructure in the countries studied was weak and organizations needed more farmer involvement [I]. Countries with least university training in animal breeding also had least developed activities for animal genetic resources.

A significant genotype by environment interaction was shown for Red Maasai and Dorper sheep in two different environments in Kenya [II]. Dorper was superior to Red Maasai for live weight in the less harsh environment, whereas breed differences were small in the harsh environment. Body size and milk production were highly ranked for both breeds. Red Maasai was appreciated for reproduction and adaptive traits and Dorper mainly for its larger body size. Dorper ram lambs were heavier live but did not have heavier carcasses than Red Maasai [III]. When basing their payment on assessed live weight, evaluators substantially undervalued Red Maasai lambs economically compared to Dorper.

Opportunities for substantial genetic gain in live weight and carcass weight of Red Maasai sheep were shown in [IV]. When conditions are harsh, purebreeding of Red Maasai was superior to crossbreeding. The use of Dorper as a terminal sire breed to produce crossbred lambs for slaughter may be practised if environmental conditions are favourable and survival rates are high. It was shown that a nucleus breeding programme could sustainably improve the productivity of an indigenous breed, while contributing to biological diversity.

Keywords: Breeding programme, Infrastructure, Red Maasai sheep, Dorper sheep, Crossbreeding, Kenya, Livestock recording, Participatory approach, Carcass merits, Genotype by environment interaction

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Dedication

To all the farmers that shared their time and knowledge, in hope that you will benefit from the results of this thesis.

Får får får? – Nej, får får ej får, får får lamm.
Swedish tongue twister

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Zonabend, E., Okeyo, A.M., Ojango, J.M.K., Hoffmann, I., Moyo, S., Philipsson, J. (2013). Infrastructure for sustainable use of animal genetic resources in Southern and Eastern Africa. *Animal Genetic Resources* 53, 79-93.

II Zonabend König, E., Mirkena, T., Strandberg, E., Audho, J., Ojango. J., Malmfors, B., Okeyo, A.M., Philipsson, J. (2016). Participatory definition of breeding objectives for sheep breeds under pastoral systems – the case of Red Maasai and Dorper sheep in Kenya. *Tropical Animal Health and Production* 48(1), 9-20.

III Zonabend König, E., Ojango, J.M.K., Audho, J., Mirkena, T., Strandberg, E., Okeyo, A.M., Philipsson, J. (2016). Live weight, conformation, carcass traits and economic values of ram lambs of Red Maasai and Dorper sheep and their crosses. (submitted to Small Ruminant Research).

IV Zonabend König, E., Strandberg, E., Ojango, J.M.K., Mirkena, T., Okeyo, A.M., Philipsson, J. Purebreeding of Red Maasai and crossbreeding with Dorper sheep in different environments in Kenya (manuscript).

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Abbreviations

AnGR	Animal genetic resources
DAD-IS	Domestic Animal Diversity Information System
EAC	East African Community
FAO	Food and Agricultural Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
G×E	Genotype by environment interaction
GPA	Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration
ILRI	International Livestock Research Institute
KMC	Kenya Meat Commission
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
SADC	Southern African Development Community
SDG	United Nations Sustainable Development Goals
SoW	State of the World's Animal Genetic Resources for Food and Agriculture
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Units

1 Introduction

Rural people depend on livestock for food security, draught power, fertilizer, energy, economics and social life (Smith *et al.*, 2013). In sub-Saharan Africa, ruminants play an important role by converting forage to high value protein for human consumption. The consumption of meat and milk is expected to increase rapidly in this region (Herrero *et al.*, 2014). Historically an increased demand for food of animal origin has been met by an increased number of animals, rather than by increased productivity from fewer animals. This has lead to negative effects on the environment, with effects such as overgrazing and soil erosion, and excess emissions of green house gases (Gerber *et al.*, 2013).

The Global Plan of Action for Animal Genetic Resources adopted by Food and Agricultural Organization of the United Nations (FAO) member states recognizes the role of animal genetic resources for food security through improved productivity while maintaining genetic diversity (FAO, 2007a). A critical issue for conservation and genetic improvement programmes is the availability of supportive infrastructure. In low to medium input systems functioning infrastructure to support breeding activities is often lacking, or is underdeveloped (Herrero *et al.*, 2013). In order for breeding programmes to succeed, infrastructure such as physical facilities, functioning livestock recording and genetic evaluation systems of some sort, are required.

Notwithstanding the threats posed by increasing animal numbers on many livestock systems, the livestock sector is also facing the risk of losing biodiversity. Nearly 70% of the world's unique livestock breeds are found in developing countries (Hoffmann, 2010), and as many as 20% of the world's ~7,000 farm animal breeds are at risk of extinction (FAO, 2007b). For the developing countries there are two major reasons for this: 1) the genetic potential of many of the indigenous breeds is not well utilized, resulting in low productivity, poor performance in the market place and ecological problems; 2) short-sighted indiscriminate crossbreeding with non-adapted exotic breeds and their crosses, thus unduly replacing the adapted indigenous breeds (FAO, 2007b). An important role for science is to generate and disseminate knowledge for development of more appropriate strategies.

Red Maasai sheep is an example of a threatened breed (Gibson, 2007). It is a transboundary indigenous breed mainly kept by Maasai pastoralists in the semi-arid and arid regions of Kenya and Tanzania (Baker *et al.*, 2003; Wilson, 1991). It has developed considerable genetic resistance to gastro-intestinal parasite infections, is drought and heat tolerant, while also having a substantial traditional and cultural importance (Silva *et al.*, 2012; Kosgey *et al.*, 2008; Preston & Allonby, 1978). Until the mid 1970s, purebred Red Maasai were found throughout the pastoral lands of Kenya. A subsidized dissemination programme for use of the larger-sized Dorper breed from South Africa was then established to increase lamb weight gain. Widespread indiscriminate crossbreeding followed in the absence of advisory services (Gibson & Pullin, 2005). This resulted in a rapid decline in numbers of pure Red Maasai sheep.

The overall aim of this thesis was to study potential breeding strategies applicable to indigenous livestock within Eastern and Southern Africa for their sustainable utilization under low input production systems. The study covered an investigation of the status of supportive infrastructure for use of animal genetic resources. The case of Red Maasai sheep was studied as a model for design of realistic breeding objectives and strategies for sustainable conservation and improvement of an indigenous breed under threat.

2 Background

2.1 Contribution of livestock to livelihoods

Livestock contribute in a number of ways to their owners and the nations where they are kept. Livestock in Africa contribute to approximately 22% of the agriculture gross domestic product (FAO, 2015). They contribute to rural development not just through the provision of food, but also to the general livelihoods (Chagunda *et al.*, 2015a; Godfray *et al.*, 2010). Livestock contribute with manure to be used as fuel, fertilizer and building material, hides and skins, draught power, employment, capital, social and cultural values (FAO, 2009c). Ownership of livestock is also considered a way out of poverty, not least in sub-Saharan Africa (SSA) (UN, 2014). Many groups of people in developing countries, totally depend on their livestock for their livelihoods (Gerber *et al.*, 2013; Homewood *et al.*, 2009). Nevertheless, in SSA it has been estimated that 309 million livestock keepers live on less than 2 USD per day (Staal *et al.*, 2009).

SSA holds large numbers of livestock, almost 25% of the world's sheep and goat population and approximately 20% of the world's cattle population (FAO, 2015). Totally in Africa there are approximately 310 million cattle, 360 million goats, 340 million sheep, 34 million pigs, 23 million camels and 1.9 billion chicken (FAO, 2015). These numbers are very high, but many of these animals are not productive. Due to difficulties to compare animal numbers of different species in relation to their size, production or work potential, an exchange ratio has been established for transforming animal numbers of different species to so-called Tropical Livestock Units (TLU) based on an approximate average metabolic weight of adult animals of each species. In TLU the figures above corresponds to 155 million for cattle, 36 million for goats, 34 million for sheep, 7 million for pigs, 25 million for camels, and 19 million for chicken (conversion ratios: cattle 0.5, goat and sheep 0.1, camels 1.1, pigs 0.2, and chicken 0.01) (Njuki *et al.*, 2011).

Livestock production systems vary in different areas and regions. Consideration must be taken to the ecosystem and that the animals must be adapted to the temperature, humidity and the environment where they are kept. Production systems can be categorised by the integration of crops, the relation to land, the agro-ecological zone, intensity of production and type of products delivered. In SSA the most common system is pastoral or agro-pastoral (Steinfeld *et al.*, 2006b). Most systems are small scaled and family owned (Chagunda *et al.*, 2015a).

2.2 Food security – need to increase productivity and consider climate change

The recently adopted United Nations Sustainable Development Goals (SDGs) aim to end all forms of hunger and malnutrition by 2030 (United Nations, 2015). To enable this, a part goal from 2015 to 2030 is to double the agriculture productivity and incomes of small-scale food producers (United Nations, 2015). At present there are enormous challenges securing food for everyone worldwide. The progress to fight hunger is progressing, but still almost 800 million in the world are undernourished and most of them, 23%, are found in SSA (FAO *et al.*, 2015; Herrero *et al.*, 2014).

Population projections predict the human population of Africa to grow with more than 100% to 2050 (UNDP, 2015). Continued urbanization (UN, 2014) is expected with the highest increase in SSA. In coming years also greater per capita food consumption is expected (Herrero *et al.*, 2014; Godfray *et al.*, 2010). An increasing demand for animal-sourced food in Africa over the coming decades is also projected (Herrero *et al.*, 2014; Herrero & Thornton, 2013). However, projections are that production will not keep pace with consumption and Africa may increasingly become a net importer of animal sourced food (Pica-Ciamarra *et al.*, 2013).

Food security in SSA has been affected by economical and other crises in recent years (Thornton *et al.*, 2011). Food security can be compromised when crops and livestock are destroyed or market chains disrupted, and supplies are cut off leading to abrupt reduction of access to food. Conflicts, fires, floods, droughts, earthquakes, tsunamis and major epidemic diseases do all destabilize food security, sometimes affecting both supply and demand.

Livestock contribute to food supply and nutrition security by converting low-value materials, inedible or unpalatable for people, into meat, milk, eggs and offal and to crop production through the provision of transport and manure (Smith *et al.*, 2013).

In SSA, consumption of protein has since year 2000 to 2010 slowly, but steadily, been increasing from approximately 57 g/capita/day to almost 70 g/capita/day (approximately 22% are from animal source) (FAO, 2015), yet the consumption in Africa remain at less than a quarter of that in the Americas, Europe and Oceania (Herrero *et al.*, 2014; FAO, 2011b). Current population growth requires an increase of food production. When food production and consumption increases, the use of land and waters increases further if following traditional livestock production patterns.

Although SSA holds large numbers of livestock, the agricultural productivity is low (Ehui & Pender, 2005). The increasing need for food of animal origin has largely been met with increasing number of animals while productivity per animal has remained low (FAO *et al.*, 2015). This has led to overgrazing of pastures, and thus degradation of land (Gerber *et al.*, 2013). Furthermore, greenhouse gas emissions per unit of product are high. In order to meet the challenges of increased food production while considering the environmental constraints regarding land use and carbon footprint, productivity of the livestock populations must improve.

2.3 Climate change

Climate change represents a serious threat to food security and the most vulnerable people are already being affected the most (Vigne *et al.*, 2016; Gerbens-Leenes *et al.*, 2010). It presents challenges both for the environment and the livestock keepers but also directly for the livestock. SSA has been predicted to be the most vulnerable region to the impacts of climate change (Kotir, 2011). Different livestock systems are affected in different ways. The role of livestock, especially ruminants, as a major contributor to climate change has been widely discussed (Gerber *et al.*, 2013; Steinfeld *et al.*, 2006a). However, the positive aspects of livestock are also very well recognised (Philling & Hoffmann, 2015).

Climate change multiplies the risk of natural hazards, which in developing regions across the world affected more than 1.9 billion people between 2003-2013 (FAO *et al.*, 2015). Higher temperatures and unforeseeable weather patterns with more extreme droughts and floods are predicted and have the potential to kill large number of livestock. Feed quality, geographical and seasonal distribution of infectious diseases, pathogens and vectors are likely to be affected and higher temperatures may cause heat stress (Philling &

Hoffmann, 2015). These are just a few examples of the negative effects climate change may have on livestock.

To cope with various challenges, animals need to be well adapted to their environments. If animals cope better with the environment and produce more, the productivity increases, and the pressure on the environment decreases. Monogastric animals, as pigs and chickens, have better feed conversion ratios and their digestive processes produce less methane than those of ruminants, although on feeds that largely could be used for human consumption. Locally adapted breeds in low external input systems normally use less fossil fuel and the livestock often provide multiple products.

Mitigating the green house gas emissions from livestock could be done by improving feed and grazing management, and by increasing the feed conversion ratio and thereby decreasing the amount of methane produced during digestion (Thornton *et al.*, 2015). Keeping improved animals better adapted to the environment, and choosing species and breeds more suitable for the environment would be beneficial. By keeping healthier livestock that have better survival, e.g., from droughts and diseases, and are more productive the number of livestock could be decreased while the animal output would still be kept or even increased. Locally adapted breeds developed in harsh production environments are expected to cope better with the effects of climate change than exotic breeds. The livestock keepers of local breeds are also already more experienced with the harsh circumstances (Philling & Hoffmann, 2015).

2.4 Sustainable use of livestock genetic resources

Feeding the world with food of animal origin and to be able to cope with changes in production environments, such as climate, market and disease challenges, requires sustainable conservation, utilization and improvement of the livestock (Boettcher *et al.*, 2010; Hoffmann, 2010; FAO, 2007b).

FAO has defined sustainable agricultural development as "the management and conservation of the natural resource base, and the orientation of technological change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations. Sustainable agriculture conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (FAO, 2007b; FAO, 1988). It may however be defined in many different ways and in agriculture the emphasis of sustainability is often to consider long-term maintenance of production (Brown *et al.*, 1987).

The concept of conservation of farm animal genetic recourses has been defined by FAO (2007b) and refers to all human activities including strategies, plans, policies and actions undertaken to ensure that the diversity of farm animal genetic resources is being maintained to contribute to food and agricultural production and productivity, now and in the future. Thus, it is important that the animal genetic resources (AnGR) needed for future are sustainably developed to be competitive in potentially changing markets and environments.

2.5 Genetic diversity and its threats

When sustainably conserving, utilizing and improving farm animal genetic resources it is important to consider genetic diversity. Animal genetic diversity is commonly recognised as the observation of different forms and functions *between* species. One may also define the total genetic diversity in a trait *within* species as the variance of the phenotypes between breeds and between individuals within breed. The proportion of genetic variance due to between and within breeds is scarcely documented but a broad estimate indicates that about half of the variation in a trait within a given environment is due to differences between breeds and the other half due to within breed variation (Woolliams & Toro, 2007). The opportunities for genetic improvement of a breed or population are directly proportional to the size of the genetic diversity (which can be seen as the standard deviation of the additive genetic variation of the trait in question).

Genetic diversity comprises, not only variation in production and functional traits, but also the variation in the ability to adapt to different environments, including food and water availability, climate, pests and diseases (FAO, 2007a). For instance, some species and breeds perform better in low input environments while other breeds may perform better in intensive systems, a situation which well describes the concept of genotype by environment interaction. The within breed diversity is usually related to the rate of inbreeding in a breed. To keep a breed vigorous and sustainable it is necessary that the population is not too small or too inbred.

Inbreeding is the result of mating related animals. In a small and closed population, all animals in future generations will be related to each other to some extent and for every generation the level of inbreeding and homozygosity will increase. The rate of inbreeding in animal breeding is related to the effective population size. Declining effective population size leads to increased rate of inbreeding. The effective population size may be approximated as: $(4 \times M \times F) / (M+F)$, where M and F are numbers of reproducing males and females in the population per generation (Falconer & Mackay, 1996). It has been suggested that for persistence of a population, the minimum effective population size should not be smaller than 50 breeding individuals (Rai, 2003). An effective population size of 50 corresponds to a rate of inbreeding of 1.0% per generation (Maijala, 1999).

With future changes in climate and markets, and their changing needs, it is important to ensure that a broad diversity is available. Livestock keepers have diversified species over centuries, into thousands of breeds. However, currently the trend is towards uniformity and large high output monocultures of production systems due to globalization of livestock inputs and markets (FAO, 2009a). Traditional production systems with locally adapted breeds are becoming marginalized compared to high output breeds.

Most breeds may have a potential importance in the future, and should therefore be conserved. They must, however be competitive on the market or contribute to livelihoods in other ways. To cope with the changes and food security it remains vital to maintain and increase the productivity of livestock. More broadly, genetically diverse livestock populations provide society with a greater range of options to meet future challenges (FAO, 2007b).

When breeds are lost genetic diversity declines. For livestock stakeholders to know the status of breeds, the Global Databank for Farm Animal Genetic Resources of FAO classifies breeds into one of the following seven categories: extinct, critical, critical-maintained, endangered, endangered-maintained, not at risk, and unknown (FAO, 2007b; FAO, 2000):

- Extinct. It is no longer possible to recreate the breed. This situation becomes absolute when there are no breeding males or breeding females remaining. In reality extinction may be realized well before the loss of the last animal, gamete or embryo.
- Critical. The total number of breeding females is less than or equal to 100 or the total number of breeding males is less than or equal to five; or; the overall population size is less than or equal to 120 and decreasing and the percentage of females being bred to males of the same breed is below 80 percent.
- Endangered. The total number of breeding females is greater than 100 and less than or equal to 1 000 or the total number of breeding males is less than or equal to 20 and greater than five; or; the overall population size is greater than 80 and less than 100 and increasing and the percentage of females being bred to males of the same breed is above 80 percent; or; the overall population size is greater than 1 000 and less than or equal to 1 200 decreasing and the percentage of females being bred to males of the same breed is below 80 percent.

- Critical-maintained or Endangered-maintained. These categories identify critical or endangered populations for which active conservation programmes are in place or populations are maintained by commercial companies or research institutions.
- Not at risk. The total number of breeding females and males are greater than 1 000 and 20, respectively; or; if the population size is greater than 1 200 and the overall population size is increasing.
- Unknown. Status of the breed is not known.

In the report "The State of the World's Animal Genetic Resources for Food and Agriculture" (SoW) by FAO presented at the first "International Technical Conference on Animal Genetic Resources for Food and Agriculture, Interlaken" in 2007, a first assessment of the global status of livestock biodiversity was reported (FAO, 2007b). Drawing on 169 country reports, contributions from a number of international organizations and twelve specially commissioned thematic studies, an analysis of the state of agriculture biodiversity in the livestock sector was presented. Information on origins and development of the AnGR, their use and values, distribution and exchange, risk status and threats, as well as the capacity to manage these resources (i.e. infrastructure such as institutions, policies and legal frameworks, structured breeding activities and conservation programmes) were presented. The report provides an overview of AnGR in the world.

According to the report approximately 20 percent of all breeds are classified as at risk (a breed that has been classified as either critical, critical-maintained, endangered, or endangered-maintained). It further reports the loss of almost one breed per month. The concept of breed may, however, be defined differently and it is also cultural and geographic. Therefore, a loss of breed may be a change of name or alleles may be introgressed into other breeds (Bett *et al.*, 2013). Breeds may also actually be lost when upgraded with other breeds, but by keeping the original name the breed does not seem to be extinct. In Africa, for instance, a group of animals in one geographical region may have a different name than in another region even though they may be phenotypically and genetically similar (Bett *et al.*, 2013).

Declining genetic diversity is a major threat to farm animal genetic resources in SSA. Historically, epidemics, droughts, crossbreeding, civil conflicts and migration of people caused extinction of breeds or strains of breeds. Indiscriminate crossbreeding and civil conflicts are the major causes of breeds or strains being classified as at risk in Africa (Wollny, 2003). Policies regarding conservation and utilization of genetic resources are key to ensure that the diversity is maintained (Drucker *et al.*, 2001). However, livestock policies have often encouraged short-term solutions, e.g., promoting exotic breeds to improve their indigenous livestock. Planning is often short-term and non-sustainable, often ending up with indiscriminate crossbreeding and loss of genetic diversity.

2.6 Breeding strategies

Animal genetic resources are used to accommodate both short and long term benefits for improved livelihoods. Structured breeding programmes provide a key to increase production levels and product quality, increase productivity and cost efficiency, maintain genetic diversity and support the conservation and sustainable utilization of specific breeds. For sustainable breeding strategies to take place there is a need for long term planning and commitment.

For conservation or improvement of a breed or population for a given purpose the choice of breeding strategy is determined by a number of factors and is giving the framework for design of more detailed breeding programmes for specific populations. There is a fundamental difference between a conservation programme, to only to maintain a breed without improving it, and a breeding programme aiming at improvement of traits in a defined breeding objective.

2.6.1 Conservation programmes

Conservation and utilization of farm animal genetic recourses are important to consider for example as an insurance against changes in environment and market, and against emerging diseases, natural catastrophes, and political instability. Sustainable utilisation can lead to opportunities for development for rural communities, maintenance of agro-ecosystem diversity and maintenance of cultural diversity (Gustavo & Oldenbroek, 2007).

Conservation can be *in situ, ex situ in vivo,* and *ex situ in vitro*. In SSA the most common way for conservation is *in situ*, where farmers, pastoralists and their community maintain their farm animal genetic resources as part of their livelihoods (FAO, 2007b). Maintaining breeds in their traditional production environments (*in situ*) is also considered the most effective way of conservation (even though it is always best to combine it with other means). Only continuous utilization maintains breeds dynamic, adapted to both the needs of the society and the production environment. The key factor for conservation of farm animal genetic resources is to make the breeds self-sustaining (Gustavo & Oldenbroek, 2007). Conservation programmes may be specifically relevant for small breeds threatened with inbreeding, where it is a need to use as many unrelated male and female breeding animals as possible in order to keep inbreeding under control and increase the effective population size.

2.6.2 Improvement programmes

A breeding strategy implemented with the objective of creating genetic change in the livestock population would commonly benefit livestock keepers as well as wider groups of stakeholders (FAO, 2010). Such benefits can be realized only by long-term commitment, if the desired changes are consistent, and with other trends affecting the livestock production systems targeted, and if the resources are available to deliver the planned improvements.

A number of strategies may be available as regards both the type of selection programmes and the way of disseminating the improved animals. The two main selection programmes are based on either purebreeding within a population or on crossbreeding of some sort, usually in addition to purebreeding (Kosgey *et al.*, 2006).

The purpose of crossbreeding may either be to exploit the positive effects of heterosis when crossing two or more breeds, or to incorporate superior genes from one breed into another. This can take many forms. For continuous exploitation of heterosis a two- or three-breed rotational crossbreeding programme may be desired. Crossbreeding can also be used to upgrade one breed with another superior breed that also fits the environment. The issue is what alleles and traits that are transferred to the remaining breed and what alleles are lost.

Crossbreeding is often used to produce a terminal cross, e.g., for production of animals for slaughter and the heterosis is exploited in the end product. If the first generation of progeny, the F_1-animals, are clearly superior to another breed by having a desired mixture of traits or alleles, even without the heterosis effect, and if a consistent crossbreeding programme is not suitable, matings of the crossbred animals may eventually lead to formation of a new "synthetic" breed. However, any breeding programme requires infrastructure for recording of animal identities and pedigrees of the whole population (Mueller *et al.*, 2015). If the crossbreeding is not controlled this may lead to "indiscriminate" crossbreeding with loss of important animal genetic material (Taberlet *et al.*, 2008).

The design of a breeding programme may differ depending on the availability of livestock recording and supportive infrastructure. In SSA there is often a limitation of available infrastructure for keeping records and pedigrees of the animals. If a large part of the population is recorded, the selection programme may include all recorded animals as potential breeding stock. If livestock recording is lacking the selection could for example be organized in specific nucleus herds from where selected animals or genetic material (e.g., semen) are transferred to a lower tier (commercial level) for multiplication of desired genotypes. Livestock recording is in this case limited to the nucleus herd.

As regards reproduction methods natural matings is the most common in SSA, but it may be replaced by artificial insemination, especially in dairy cattle, where a cost effective supporting infrastructure is often available. This will however depend on infrastructure available and the species to be used. In advanced systems, embryo transfers may be an option for use with elite animals. In the very advanced systems, where livestock recording is well developed and genomic selection is being practiced, gene-sequencing results can be related to breeding values based on phenotypic information of large reference populations.

Translating a breeding strategy into practical breeding programmes involves a number of components that need to be considered, for example policies in place, the value of the livestock in the area both socio-economically and culturally as well as the production system and technologies available (Figure 1). Continuous monitoring of the results and changes in the environmental conditions may call for revisions of the breeding programme (Philipsson *et al.*, 2011).

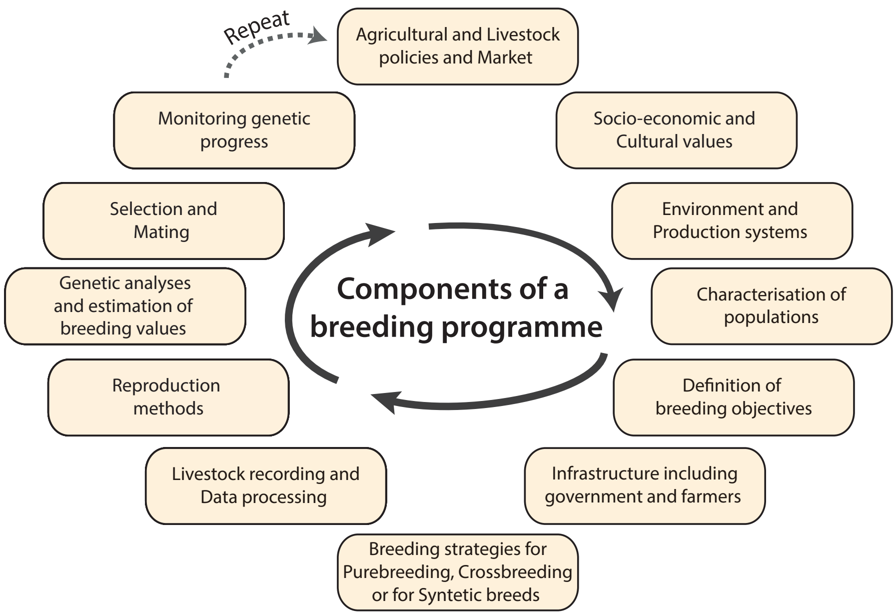

Figure 1. Components of a breeding programme, modified from Philipsson *et al.* (2011).

In areas with limited infrastructure it is extra important to keep the breeding programmes simple, and allow simplifications. The breeding objectives should be appropriately defined for the species or breeds, by the communities and stakeholders, and the strategies laid should be possible to follow in practice (Mueller *et al.*, 2015). To succeed, it is necessary to consider the whole production system and involve stakeholders at every stage in the planning and operation of the breeding programme, integrating traditional behaviour and cultural values (Kosgey, 2004).

In SSA there are mainly indigenous breeds. Improving an indigenous breed can commonly be done by upgrading indigenous breeds with temperate breeds, improving the indigenous breed by purebreeding, progressively substituting the breed with another indigenous breed, or by forming a synthetic breed (Philipsson *et al.*, 2011; Kosgey *et al.*, 2006). The most appropriate strategy differs from case to case.

In SSA there are still very few structured breeding programmes (Gizaw *et al.*, 2014b; Gizaw *et al.*, 2009). Implementation of nucleus breeding schemes in low-input environments may be difficult, because it requires long-term commitment of the nucleus and involvement of farmers. However, in a nucleus breeding scheme it is usually easier to keep records and keep the structure of it (Kosgey *et al.*, 2006). In many cases the genetic gain and profit is also higher from a nucleus breeding scheme (Gizaw *et al.*, 2014a). An alternative to centrally organized nucleus schemes is community-based or village-based selection schemes, where breeding activities are carried out by communities of smallholder farmers (Mueller *et al.*, 2015; Gizaw *et al.*, 2009). It usually involves less financial support, but requires committed and well-trained farmers involved in the project.

2.7 The role of livestock breeding policies and infrastructure

A livestock breeding policy is an important tool to show the direction of priorities and activities to be conducted in livestock breeding. Policies are supposed to be drivers for the sector, for the current state and for the future. It is also a response to changes in the sector. Many African countries have limited means and inadequate infrastructure to implement legislation on policies for AnGR. Planning and commitments are also too often shortsighted (Boettcher & Atkin, 2010; Wollny, 2003). The Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration (GPA) conclude that policies are often lacking if existing at all in many places in Africa (FAO, 2007a). The lack of policies, often because policy makers do not have enough knowledge about the importance of AnGR (Chagunda *et al.*, 2015a), has also led to a lack of institutional capacity to support and develop farm animal genetic resources (FAO, 2007a). With more informed policies and institutional reforms as well as significant public and private investments the livestock sector could develop much further and more sustainably (FAO, 2007b).

Conservation and genetic improvement programmes are dependent on the availability of supportive infrastructure. Design of sustainable breeding strategies must be thought through and farmers' participation is vital. In low to medium input systems functioning infrastructure to support breeding activities is often limited and underdeveloped (Herrero *et al.*, 2013; Okeyo *et al.*, 2010; Rewe *et al.*, 2009). In order for breeding programmes to succeed, infrastructure such as physical facilities, functioning livestock recording and genetic evaluation systems of some sort, are required (Cardellino & Boyazoglu, 2009). Trained staff, efficient organizations and institutions, long-term financial support and strong links between these components are needed. Absence of required infrastructure is one of the most serious constraints to improve animal genetic resources (FAO, 2011a; Philipsson *et al.*, 2011). Without appropriate support for technological and institutional innovation, many stakeholders, especially smallholders, will be unable to respond to opportunities to supply new markets (FAO, 2009c).

Important infrastructure pillars are animal identification and performance recording. These activities are essential and are the backbone for the continued improvement of AnGR (Scholtz *et al.*, 2010; FAO, 2007a). Public and private breeders, breeding organizations, and market demand, play a crucial role in ensuring recording is maintained. In many developing countries recording is, however, lacking or very limited, resulting in poor animal genetic improvement.

A key issue identified in the GPA (FAO, 2007a) was the lack of information about the status of infrastructure. Kosgey *et al.* (2011) did an assessment of the dairy and beef recording in Kenya and presented the organizations involved and their interrelations. Wasike *et al.* (2011) discussed the factors influencing recording systems in the same country. However, there are still very few studies of countries discussing the state of infrastructure. As the state of infrastructure is rapidly changing reports also need to be kept updated.

For the infrastructure to develop, higher education in the area of animal breeding is important. Ojango *et al.* (2010) points out the lack of trained personnel in animal breeding and limited higher education possibilities in SSA. A recent study, based on an e-conference, discussed future research and developments for AnGR in SSA and how they can be met (Chagunda *et al.*, 2015a). That study concluded that currently most animal breeders and geneticists work at universities and research institutions and that there are very few breeding organizations that implement genetic improvements in Africa.

2.7.1 Strategic priorities of the FAO Global Plan of Action

An International Technical Conference on Animal Genetic Resources for Food and Agriculture was held in Interlaken, Switzerland, to develop a framework for AnGR. The conference adopted GPA (FAO, 2007a). The GPA is the outcome of a country-driven process of reporting, analysis and discussion, which also resulted in SoW (FAO, 2007b), the first comprehensive global assessment of livestock diversity and its management. The GPA spells out the needs for improved productivity and drawing of long term and sustainable breeding programmes, which are currently mostly non-existent especially for the indigenous livestock breeds. Four strategic priority areas were listed:

1. Characterization, inventory and monitoring of trends and associated risks,
2. Sustainable use and development,
3. Conservation,
4. Policies, institutions and capacity building.

A few years after the GPA, FAO presented a report on principles and approaches for sustainable food and agriculture and lists five principles in order to meet sustainable agriculture 1) Improving efficiency in the use of resources, 2) Innovative governance and technologies that sustainably increase agricultural production, 3) Agriculture must protect and improve rural livelihoods, equity and social wellbeing, 4) Enhanced resilience of people, communities and ecosystems is key, 5) Sustainable food and agriculture requires responsible and effective governance mechanisms (FAO, 2014).

For livestock genetic resources these five principles should be taken into consideration and put in appropriate context. After the SoW and GPA, many countries have taken action towards conservation or sustainable use of animal genetic resources, however, there is still much to be done.

2.8 The role of sheep

Sheep are among the most widely distributed domestic species in the world. They are multifunctional, adaptable, and there are no religious restrictions on their use for meat (at least among the dominant faiths) (FAO, 2007b). They provide both tangible benefits, such as blood, meat and milk for home consumptions, manure, fibre, skins and cash income, and intangible benefits, such as savings, insurance against emergencies, cultural and ceremonial purposes (Zygoyiannis, 2006; Kosgey, 2004; Lebbie & Ramsay, 1999). They are especially important to women, children and aged, who are often the most vulnerable members of the society in terms of malnutrition and poverty (Kosgey, 2004).

Small ruminants play a complementary role to other livestock when utilizing feed resources as well as being able to use vast areas of natural grassland where crop production is impossible. They can convert crop residues and fibrous material of no value into high quality protein (Rege & Gibson, 2003). Sheep have lower feed and capital requirements and mature early, have shorter generation intervals, higher prolificacy, are of smaller size and are easier to handle because of the small size compared with larger species (Kosgey & Okeyo, 2007). Compared with cattle, sheep also survive drought and diseases better (Liljestrand, 2012).

The FAO statistical database estimated Africa to hold 340 million sheep (approximately 25% of all sheep in the world) and the number of heads are increasing, with the largest populations in Nigeria, Sudan, Ethiopia, Algeria, South Africa, Morocco, Kenya, South Sudan, Mali and Somalia, in decreasing order (FAO, 2015). The number of sheep and the value of them are also predicted to increase more rapidly than of other species (Herrero *et al.*, 2014). In Africa there are many sheep breeds. They (or their descendants) account for at least eleven of the 29 breeds found in ten or more countries across the world (FAO, 2007b). Especially the indigenous sheep breeds have good possibilities to improve the livelihood of people in low-input, agro-pastoral and pastoral production systems (Kosgey & Okeyo, 2007).

2.8.1 Indigenous sheep breeds

Out of the reported 170 local sheep breeds in SSA, 80% are classified as indigenous (Muigai & Hanotte, 2013). The locally adapted indigenous breeds commonly show low absolute production figures, while productivity may be high when proper input level and required production-lifecycle length are taken into account (Hammond, 2000). Indigenous sheep often have unique characteristics and attributes and are well adapted to the environment and have evolved to survive, produce and reproduce in their environment (Kosgey *et al.*, 2006).

In Kenya the indigenous sheep can be classified as fat-tailed or fat-rumped (Muigai *et al.*, 2009). They are faced with many challenges and need to be hardy to persist droughts, diseases, other catastrophes and poor nutrition. However, indigenous breeds have often not been bred for improved productivity and farmers have therefore been "upgrading" the sheep by crossbreeding with less appropriate exotic breeds to get sheep more attractive to the markets, in many cases leading to loss of diversity and marginalizing of indigenous genetic resources (Chagunda *et al.*, 2015b).

2.9 The Red Maasai sheep

The Red Maasai sheep is an East African fat-tailed sheep (Figure 2). It is a transboundary indigenous breed mainly kept by Maasai pastoralists and neighbouring tribes in semi-arid and arid regions of Kenya and Tanzania (Wilson, 1991). The breed is renowned for its resistance against endoparasites, mainly gastro-intestinal parasites (Silva *et al.*, 2012; Baker *et al.*, 1999; Preston & Allonby, 1979), and relatively good tolerance to trypanosomes (Baker, 1995) and drought tolerance (Kosgey, 2004).

Until the mid 1970s, purebred Red Maasai sheep were the type of sheep kept in most of the southern pastoral lands of Kenya and Tanzania and somewhat also in Uganda, probably numbering several million heads only in Kenya. In the 1970s, however, a population of Dorper sheep was imported to Kenya for research and multiplication purposes.

This resulted in widespread indiscriminate crossbreeding between Red Maasai and Dorper to achieve an increase in weight and body size. The upgrading towards the Dorper later proved unsuitable due to their poor survival rates in areas with a harsh environment (Gibson & Pullin, 2005). Currently there are no available data on the population size of purebred Red Maasai available, and thus the only risk status available is unknown (DAD-IS, 2016; DAGRIS, 2007). Even though the World Watch List or Domestic Animal Diversity Information System (DAD-IS) does not include the Red Maasai among threatened breeds, because of the inability of the system to track dilution and population size, it is evident that the Red Maasai is clearly threatened (Köhler-Rollefson *et al.*, 2012; Yamashiro *et al.*, 2011; Gibson, 2007). Nowadays, it is hard to find purebred Red Maasai in the flocks, which are dominated by crossbreds. However, in 2008-2009 East Africa suffered from a severe drought and millions of livestock died. Interviews with Maasai farmers revealed that during the drought the Red Maasai sheep survived better compared with Dorper sheep and higher grade Dorper crosses (Liljestrand, 2012).

Red Maasai sheep is not only an important breed due to its survival but it has also a high cultural value for the Maasai community (Liljestrand, 2012; Kosgey *et al.*, 2008). The red colour is for example very important. The fat of the Red Maasai is given after a woman has delivered a baby, after a cultural circumcision, and during sickness or injury (Onetu, 2012). The breed is also used as a bride price where the Red Maasai is given to the mother-in-law. If an eagle strikes over a persons head this may in the Maasai culture give very bad luck to that person, but by taking the blood from the Red Maasai sheep and put it on the head of the person it will prevent the bad luck from happening (Onetu, 2009).

Previous research on Red Maasai sheep has mainly been focusing on studying the resistance and resilience of the breed in Kenya and often in comparison with the resistance of the Dorper breed (Mugambi *et al.*, 2005a; Baker *et al.*, 2004; Baker *et al.*, 1999; Baker, 1998; Wanyangu *et al.*, 1997; Mugambi *et al.*, 1996) and somewhat on growth (Inyangala *et al.*, 1992) and genetic parameters (Kiriro, 1994). Later on research on molecular level has been taking place, also focusing on the disease resistance of the Red Maasai (Benavides *et al.*, 2015; Marshall *et al.*, 2013; Silva *et al.*, 2012; Kipanyula *et al.*, 2008).

Figure 2. Red Maasai sheep and lamb.

2.10 The Dorper sheep in Kenya

The Dorper breed was created in South Africa in the 1940's (Milne, 2000). It is a synthetic, non-wolled, meat-type breed that was created and developed by mating Dorset Horn rams and Blackhead Persian ewes, followed by matings between the F_1 progeny (Cloete *et al.*, 2000; de Waal & Combrinck, 2000; Milne, 2000; Baker *et al.*, 1999). Two varieties of the Dorper was created; one fully white and one with a black head, however, they are one breed with the same breed standards (except for colour and pigmentation) (Milne, 2000).

Dorper became a popular breed known for its high quality carcass and relatively early maturing. It is developed to sustain in arid conditions in South Africa (Cloete *et al.*, 2000). Owing to its success it was exported to other African countries and later also to other continents (de Waal & Combrinck, 2000). Today the breed is widespread across the globe, and research both on feeding and breeding, at phenotypic and molecular level has been carried out, but mainly in South Africa (Cloete *et al.*, 2014; Zishiri *et al.*, 2013; Cloete *et al.*, 2000).

To date, Dorper is a common and important breed in many other countries, for example in Kenya (Marshall *et al.*, 2013) (Figure 3). The Dorper sheep was first introduced in a smaller number to Kenya from South Africa in 1952 for its growth potential, better carcass quality and mothering ability (Kariuki *et al.*, 2010; Kosgey *et al.*, 2008; Kiriro, 1994). In the 1970s, however, a subsidized dissemination programme for Dorper rams was established in Kenya. No instruction was provided to farmers about how to maintain a continuous crossbreeding programme and many farmers continued crossing their indigenous flocks of Red Maasai sheep to Dorper, which subsequently proved unsuitable in many production areas. Widespread indiscriminate crossbreeding followed (Gibson, 2007; Gibson & Pullin, 2005). Today it is hard to find purebred indigenous sheep in the field, sheep not crossed with the Dorper.

Figure 3. Young Dorper ram in Kenya.

Since the spread of Dorper in Kenya several comparative studies of Red Maasai and Dorper have taken place, both on the production and performance of crosses (Inyangala *et al.*, 1992; Chemitei *et al.*, 1975). Table 1 show some relevant figures of comparative weights between Red Maasai, Dorper and their crosses in Kenya, most of them at research stations. Resistance to parasites in the two breeds has also been widely studied (Baker *et al.*, 2003; Baker, 1998;

Mugambi *et al.*, 1996) and some relevant survival references are presented in Table 2. Results show that Dorper sheep have a larger body weight than Red Maasai sheep in less hot or dry environments, whereas the smallest differences between breeds were obtained in harsh or humid environments (Mugambi *et al.*, 2005a; Baker *et al.*, 2002). Dorper are less resistant to gastrointestinal parasites (Marshall *et al.*, 2013; Mugambi *et al.*, 2005b). Studies also show that "middleman" at markets often prefer Dorper sheep to Red Maasai sheep owing to its larger body size (Mtimet *et al.*, 2014).

Table 1. *Birth weight (BW), weaning weight (WW), 6 month weight (6W), 12 month weight (12W), and adult weight (AW), per sex (male = m, female = f) and location for Red Maasai (RM), Dorper (D), and their crosses in Kenya*

Breed	Sex	Location	BW	WW	6W	12W	AW	Reference
RM	M+F	Semi-arid	2.9	15.6				(Kiriro, 1994)
½ RM			3.3	17.5				
¾ D			3.6	19.6				
D			3.6	19.5				
RM	M+F	Humid		10.1		18.5		(Baker, 1998)
¾ RM				10.9				
¾ D				11.1				
D				11.2		19.7		
RM	M+F	Semi arid			12.4			(Mugambi *et al.*, 2005a)
¾ RM					14.8			
¾ D					19.9			
D					23.1			
RM	M+F	Semi-arid			13.6			(Mugambi *et al.*, 2005b)
¾ RM					16.1			
¾ D					20.6			
D					23.1			
RM	M	Humid				26.2		(Baker *et al.*, 1998)
D						30.1		
RM	M+F	Semi arid	2.9	15.6				(Kiriro, 1994)
D			3.6	19.5				
D		Semi-arid				36.6		(Kariuki *et al.*, 2010)
RM	M+F	Humid			13.0	17.5	27.7	(Baker *et al.*, 2002)
¾ RM					13.7	18.2		
¾ D					14.3	18.4		
D					14.2	18.4	30.6	
RM	M+F	Semi-arid			15.2	20.0	30.2	
¾ RM					17.1	22.0		
¾ D					22.5	27.0		
D					24.5	30.0	46.1	

Table 2. *Survival rates (%) at 3 and 12 months of age per sex and location (male = m, female = f) for Red Maasai (RM), Dorper (D), and their crosses in Kenya.*

Breed	Sex	Location	3 months	12 months	Reference
RM	M+F	Humid	90.1	95.0	(Okeyo and Baker, 2005)
D			71.7	73.0	
RM		Semi-arid	96.9	93.2	
D			94.6	91.9	
RM	M+F	Humid		84.1	(Baker et al., 2002)
¾ RM				87.0	
¾ D				64.3	
D				55.3	
RM		Semi-arid		98.0	
¾ RM				96.9	
¾ D				92.7	
D				90.0	

2.11 Some conclusions for priorities of the present study

- Infrastructure including policies for support of AnGR activities are insufficiently studied and need to be highlighted in research as well as for development in practice.
- The biological and economic characteristics of Red Maasai sheep in comparison with Dorper sheep under different environmental and commercial conditions need to be clarified.
- The opportunities for conservation and improvement of Red Maasai sheep by developing, in agreement with stakeholders, suitable breeding programmes for increased productivity, need to be investigated. These breeding programmes must handle situations with limited infrastructure resources and cover both crossbreeding and purebreeding.

3 Aims of the thesis

The overall aim of this thesis was to study potential breeding strategies applicable to indigenous livestock within Eastern and Southern Africa for their sustainable utilization under low input production systems. The thesis covered an investigation of the status of supportive infrastructure for use of animal genetic resources. The Red Maasai sheep was chosen as a model for design of realistic breeding objectives and programme for sustainable conservation and improvement of an indigenous breed under the threat of indiscriminate crossbreeding.

More specifically, the aims were to:

- Assess existing and needed infrastructure for the support of sustainable use of animal genetic resources in a sample of countries in Southern and Eastern Africa.
- Investigate traits of preference to be included in the breeding objectives, breed differences of live weights, conformation, carcass traits and economic values for meat production of Red Maasai and Dorper sheep and their crosses in two different low input areas.
- Study opportunities for conservation and improvement of Red Maasai sheep by comparing purebreeding with different levels of crossbreeding with Dorper sheep as a terminal sire breed in the two environmentally different low input areas.

4 Summary of the studies

This thesis comprises one qualitative study [I] conducted on data collected in six countries in Southern and Eastern Africa and three studies [II-IV] based on data from Kenya. All studies have been done in collaboration with the International Livestock Research Institute (ILRI) and the first study was also done in collaboration with the Food and Agricultural Organization of the United Nations (FAO).

Studies [I-II] have been performed through participatory approaches by use of structured interviews with relevant stakeholders, while the third study [III] comprised analyses of data collected at a field experimental station, and the fourth study [IV] was based on simulations.

4.1 Materials and Methods

4.1.1 Infrastructure and institutional capacity

The first paper [I] included a survey of infrastructure for support of the use of animal genetic resources in three countries in Eastern Africa: Kenya, Tanzania and Uganda; and three countries in Southern Africa: Botswana, Mozambique, and Zambia (Figure 4). The countries chosen show a wide variation in production systems, yet were thought to be representative of their respective region.

The study was primarily based on semi-structured interviews carried out at country visits undertaken during 2010. Information was also gathered from the SoW Country reports of the six countries prepared between 2003 and 2004 (FAO, 2007c), and from a workshop with targeted persons in 2009. Furthermore, information was continuously collated on relevant issues through various ongoing projects in the countries studied until submission of the paper. Qualitative research interview methods, as described by Kvale (1996), were used. Interviews focused on a number of thematic issues that relate to livestock policies and infrastructure that support AnGR improvement and conservation.

To study the various networks and organizations involved in a given country, a two-stage snowball method was used (Hanneman & Riddle, 2005). First, the stakeholders in the countries provided a list of all organizations and institutions with any kind of involvement in animal genetic resources. Thereafter, through on-site interviews, representatives of each institution listed, were asked which bodies they were collaborating with, using snowball selection. This method gave the opportunity to successively highlight institutions that were not initially known to the interviewer. The interviews were semi-structured in order to ensure that the same questions were put forward to all interviewees. Each interview lasted 1–2 h and was transcribed, summarized and analysed separately for each country.

Figure 4. Countries of study: Botswana, Kenya, Mozambique, Tanzania, Uganda and Zambia.

4.1.2 Participatory definition of breeding objectives

In the second paper [II], pastoral livestock keepers from two Maasai pastoralist sites, Amboseli and Isinya in Kenya, keeping Red Maasai, Dorper and crosses between the two sheep breeds, were included in the study (Figure 5). The southernmost site, Amboseli, is characterized by arid climate (Kenyan agro-ecozone V and VI) with little or no pastures during certain periods of the year and has small sized flocks (ranging from 20 to 160 sheep per flock) of mixed livestock. There are no permanent rivers in the area. Farmers in Amboseli live in houses made of clay and mud and move their animals over large rangelands. In the other site, Isinya, pastures are more productive. Farmers have more permanent homes and move the animals only if the pasture availability is too scarce. Off-farm jobs are common in Isinya because it is close to the market and main urban centres. The sheep production is more market oriented and flock sizes are larger (ranging from 40 to 850 sheep per flock).

Through a project that started two years ahead of this study, a basic sheep recording scheme was introduced to and supported by participating farmers.

The scheme involved routine measurements of live weight and body size of individual animals with the aim of providing objective information to strengthen the farmers' own qualitative valuation of important traits in their sheep to be used for breeding and management purposes. Farmers included in this study were those identified by the communities at the sites as individuals keen on improving their sheep flocks. This was determined through focus group discussions and using key informants within the target areas (including local leaders, ministry of livestock development officials and non-governmental organizations).

Ten farmers from Amboseli and nine from Isinya participated in the study. Each farmer was asked to identify three ewes per breed group that had lambed at least once, representing one of the best, one average and one of the poorest quality ewes, within each breed group, Red Maasai, Dorper and their crosses. In total 147 ewes were included in the study. The farmers gave three reasons for their ranking and what price they were willing to pay for the specific ewe if it were to be purchased at the market and to be used for breeding purposes. Farmers also told how much milk the ewe was producing per day after the lambs had suckled. Thereafter they also ranked all the selected ewes across breed groups. Body measurements and weights were recorded for all ewes in the study.

A trained local enumerator translated all answers from the local language to English. Answers of reasons from interviews were grouped into seven trait categories based on the most commonly appearing characteristics. Individual farmer's response of reasons was ordered by importance. All traits resembled normal distributions and were analysed with linear models accounting for site, breed, and rank of the ewe. Results were presented as least squares means.

Farmers' assessments of the best ewes were interpreted as being the most preferred traits of each breed group. Results for both the most preferred traits of the best and the most inferior traits demonstrated in the poor quality ewes were interpreted as indicators of the most important traits to improve for each breed and site. The results were used for the pure Red Maasai and Dorper breeds as basis for presenting weighted reasons of traits to be considered in a breeding objective for improvement of those breeds in Amboseli and Isinya.

4.1.3 Live weight, conformation, carcass traits and economic values

In the third study [III], primarily aimed at investigating breed differences in meat production, ram lambs of Red Maasai, Dorper and their crosses were raised at the Kapiti Plains Estate (Kapiti) ranch, belonging to ILRI, Kenya (Figure 5). The lambs were slaughtered at the largest abattoir in the country, Kenya Meat Commission (KMC), on the outskirts of Nairobi. All lambs were raised under natural range conditions. When the natural pasture conditions deteriorated, supplementary feeding was practised, especially to lactating ewes and newly weaned lambs. Dorper lambs and crosses were docked at 1-3 weeks of age, and all animals were routinely provided with basic vaccinations and strategic, but limited, treatments against gastro-intestinal and ecto-parasites. The lambs were weaned at about three months of age and slaughter took place at around one year of age when lambs in the region were normally slaughtered. Morphologic characteristics were recorded before and after slaughter. Prior to slaughter the ram lambs were also subjectively assessed by experienced evaluators for live weight and conformation. In addition, the evaluators were asked to quote the prices that they were willing to pay for each of the lambs intended for slaughter. The carcasses were weighed and graded by butchers for muscle conformation, fat levels and total carcass grade. In total 88 ram lambs from two batches were included of Red Maasai, Dorper, 50% crosses (F_1 and F_2) and 75% Dorper crosses. All traits were normally or close to normally distributed and therefore analysed with mixed linear models. Three different models were used; all including the factors breed group, batch and a regression on age. The first model was used to estimate differences between breed groups and thus also heterosis. The results were presented as least squares means. Effects of heterosis were calculated based on F_1 and F_2 animals compared to parental breed means. A second model additionally included an objective (e.g., body measure) or a subjective live measure (e.g., an assessment score) to estimate how much these measures could explain of the variation in various carcass traits. A third model was used to study the influence of evaluator on the subjectively assessed traits.

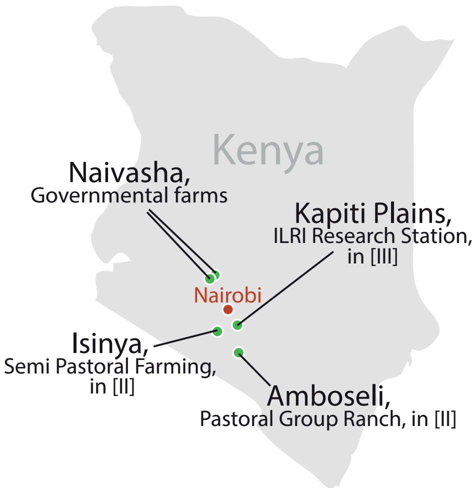

Figure 5. Study sites in Kenya.

4.1.4 Purebreeding of Red Maasai and crossbreeding with Dorper sheep

In paper IV, alternative nucleus breeding schemes with both purebreeding of Red Maasai and crossbreeding with Dorper in two environmentally different areas (A and B) were stochastically simulated. Input data were based on results from [II-III] together with relevant literature. Under the base assumptions, four alternative breeding programme scenarios with moderate genotype by environment interaction (G×E) (genetic correlation of 0.8 between the areas), were simulated. In total there were 5800 ewes, out of which 800 were in the nucleus, and 2500 in each environment. Two scenarios assumed only purebreeding with Red Maasai and two scenarios also included crossbreeding with Dorper. One scenario of each kind included a subnucleus for environment B, in order to better account for the G×E between nucleus and that environment, whereas in the other scenarios, the commercial tier received all their males directly from the nucleus.

In sensitivity analyses the impact of changing some of the assumptions were studied. The genetic correlation across environments was changed to 0.6 and 1.0 (No G×E) (from base alternative 0.8). The percentage of crossbreeding in the commercial tier was 20% in the base alternative and was changed to 40%. In the base alternative there was no recording or selection in the commercial tier. An alternative with recording at the commercial level was studied allowing selection of replacement females. In the base alternative Dorper ewes produced fewer number of lambs at 12 months compared to Red Maasai. An alternative was studied assuming number of produced yearlings was equal for the two breeds within environment. Sensitivity analyses were also conducted based on the assumption that the two pure breeds had almost the same carcass weight within areas (i.e. results from [III]).

Each of the breeding programme scenarios was simulated over 15 years and replicated 20 times. The genetic response for the breeding goal traits carcass weight, milk yield, and survival, were followed for all scenarios as well as the amount of meat and milk produced and income from each scenario.

4.2 Main findings

4.2.1 Infrastructure and institutional capacity

The institutional setup to handle livestock breeding issues differed between countries in stage of development, levels of ambition and success [I]. No complete breeding programmes were in place, but some conservation programmes existed in most countries. Except for a few cases, livestock recording as basis for research, development and breeding practice was lacking. It mainly existed at research stations. Only in Kenya cattle recording being was implemented at a larger scale.

The institutional setup to support animal breeding programmes was fragmented and needed to be better integrated. Farmer organizations with the mandate to improve livestock existed to some degree in most countries, but they were often weakly organized, partly due to shortage of trained staff. Farmers' lack of participation was reported as a constraint in all countries.

Countries with least university training in animal breeding also had the least developed AnGR activities. All countries, except Mozambique and Zambia offered training at M.Sc. and Ph.D. level in animal breeding. All countries reported that shortage of trained and skilled personnel in animal breeding was the single biggest constraint to development and implementation of animal genetic resources improvement programmes. More university training and capacity building in animal breeding was needed.

Since the GPA was agreed upon, many countries have re-casted their policies and make efforts to develop breeding policies. A change in mindsets aiming at closer collaboration among institutions, farmer involvement and capacity development and strengthening at all levels is suggested.

4.2.2 Participatory definition of breeding objectives

In the study of preferred traits of breeding ewes significant effects were observed of site, farmer within site (Amboseli and Isinya), breed (Red Maasai, Dorper and crosses), and rank of the ewe (best, average and poor). For the traits body weight and price the interaction between breed and site was also significant. At the harshest site, Amboseli, differences between breed groups in body weight were small and breeds were more equally preferred. Milk yield and body condition score were highly preferred traits for all breed groups in Amboseli. In Isinya, where environmental conditions are better and farmers are more market oriented, Dorper and crosses had significantly higher body weight. The price the farmer was willing to pay for the sheep was also higher for all breed groups in Isinya, almost twice as much for Dorper and crosses and 22% more for Red Maasai.

Farmers considered body size and growth as the most important traits irrespective of breed, though more so for Dorper. Milk production was ranked as the second most important regardless of breed. Red Maasai was more appreciated for its good reproduction and mothering ability and was also more appreciated than the other breed groups for its drought tolerance and disease resistance.

Breeding objectives should emphasize growth traits and milk production for both breeds at both sites. Body condition needs to be specifically considered in the breeding objectives for both breeds in Amboseli, whereas adaptive traits need to be generally emphasized in Dorper.

4.2.3 Live weight, conformation, carcass traits and economic values

In the study of ram lambs for slaughter significant, or close to significant, effects were found of breed groups and age for almost all traits. Dorper had a 2.1 kg higher live weight at delivery to slaughter and had better carcass grade but lower dressing percentage and fat levels than Red Maasai. As regards conformation, Red Maasai had significantly shorter body length than the other breed groups, whereas heart girth showed only small differences between the pure breeds. Crossbreds were generally superior to the parental breeds. Positive effects of heterosis were found for all traits, and amounted on average to 8-9%.

Evaluators were willing to pay more for the Dorper lambs for slaughter although carcass weights later were shown not to be higher than for Red Maasai. Evaluators undervalued Red Maasai lambs by 8-13% compared to Dorper lambs according to the prices quoted per kg live or carcass weight by KMC.

Live weight was better than any other live measure in predicting carcass weight. Among the subjectively assessed traits the price the evaluators were willing to pay for the lamb was the most informative predictor of the variation in carcass traits, although much less informative than live weight.

Due to the overall superiority of the crossbred lambs for meat production Dorper may be recommended as a terminal sire breed for crossing with Red Maasai ewes.

4.2.4 Purebreeding of Red Maasai and crossbreeding with Dorper sheep

In general, about 10 kg of carcass weight was produced per ewe in the population in year 15. This was an increase by more than 10% over the 15 years. The annual genetic gain in carcass weight per lamb amounted to 0.17 genetic standard deviations or 0.2 kg per year. For all scenarios genetic gain in the other goal traits, survival and milk yield, was much lower (0.04-0.05 genetic standard deviations per year). The annual genetic gain for all goal traits and for all scenarios tested were highest in the nucleus, and lower further down in the breeding structure, and lowest among the crossbreds. This was because it took several years before the genetic gain became linear, for nuclei about 3-4 years and 2-3 years longer for lower tiers, and longest for crossbred lambs.

With stronger G×E (0.6), the genetic gain in the commercial tier for Red Maasai in the harsher environment B was as expected lower than that under the base assumptions. With no G×E (1.0) the genetic gain in environment B was almost identical to that in the less harsh environment A. Selection of female replacements (by recording) in the commercial tier resulted in slightly higher genetic gain, and also more similar gain in the two environments. The genetic level for carcass weight increased over 15 years with 1.96 kg without selection and with 2.25 kg with selection in commercial tier for Red Maasai in environment A, and from 1.39 kg to 1.63 kg in environment B.

Using the base assumptions, the second scenario with only purebreeding of Red Maasai and a subnucleus in environment B, resulted in the highest amount of income and amount of meat from slaughtered lambs per ewe and year. Environment A benefited from having also Dorper and producing crossbred lambs, and a higher level of crossbreeding resulted in slightly more meat produced. For environment B, on the other hand, less meat was produced with Dorper and crossbreds.

If Red Maasai and Dorper would hypothetically have the same number of lambs at 12 months per ewe and year within a given environment, a crossbreeding scenario with subnucleus in environment B (scenario 4) would be superior and give the highest amount of meat produced in total. Using the carcass weights given from [III] in a sensitivity analysis did not change the ranking of the scenarios, only the actual amount of meat produced.

The main income was from slaughtered lambs (81%), followed by meat from culled adult sheep that contributed to 18% of the income. Milk production contributed with only 1% overall, and was more important in environment B than in A.

The introduction of a breeding programme will be highly beneficial for Red Maasai, especially for carcass weight, and purebreeding is recommended in harsh conditions. In less harsh conditions, or if Dorper were to achieve reproduction and survival similar to Red Maasai, Dorper could also successfully be included as a terminal sire breed.

5 General discussion

The overall aim of this thesis was to investigate the opportunities for sustainable conservation and improvement of indigenous livestock under low input production systems in Eastern and Southern Africa. Research in animal breeding and genetics has been dominated by studies on genetic parameters and characterization of various breeds. However, very little research has been devoted to studies of the infrastructure needed to bring genetic information to be applied in practice. An important reporting system is led by FAO to monitor the risk status of various breeds being threatened by extinction, but little has been done in practice to apply methods to conserve breeds by implementation of sustainable breeding programmes. However, guidelines have been worked out by FAO and others (FAO, 2012; Haile *et al.*, 2011; FAO, 2010; FAO, 2009b). The approach taken in this thesis was therefore to study the infrastructure available for support of sustainable use of AnGR in a number of countries in Eastern and Southern Africa. In order to concretize the opportunities for conserving and improving an indigenous breed declining in numbers, the Red Maasai sheep in semi-arid and arid lands of Kenya was chosen as an example. Red Maasai and the areas studied should be seen as a model and could be applied to other breeds and areas where opportunities allow.

Already before the studies in this thesis, the Red Maasai sheep breed was renowned for its resistance against endoparasites, mainly gastro-intestinal parasites (Silva *et al.*, 2012; Baker *et al.*, 1999; Preston & Allonby, 1979) and drought tolerance (Kosgey, 2004). Only limited information of the values of the breed for its livestock owners has, however, been available. Due to the indiscriminate crossbreeding of the Red Maasai with the Dorper and the increasing importance of the market, comparative studies between these breeds focusing on carcass traits were considered necessary. Moreover, there is still no structured breeding programme in place at farmers' level to improve the breed.

The thesis therefore comprises four studies intended to 1) provide information about the available infrastructure and what the most important constraints for development of sustainable breeding programmes are, 2) map the advantages and disadvantages of actual breeds, the indigenous Red Maasai and the imported Dorper and their crosses, in low input regions of Kenya, 3) define important traits in the breeding objectives for the two pure breeds, and specifically investigate the meat production because growth rate and body size were rated highest in sheep production by the livestock keepers, and 4) investigate the potential of alternative breeding schemes involving both purebreeding and different levels of crossbreeding, as well as genotype by environment interactions.

5.1 Choice of methods

This thesis comprises four studies of rather different character. Owing to the variable nature of the studies conducted, different methods and materials for study and analyses had to be applied. For the first study [I] on the infrastructure for sustainable use of animal genetic resources in a sample of countries in Southern and Eastern Africa, there was no systematically documented information available and few studies were available prior to the present investigation (Kosgey *et al.*, 2011).

The lack of information on infrastructural issues had also been outlined previously in the SoW and the GPA. The study was initially built on fragmented and partly outdated information obtained from the SoW reports and grey literature with information on supportive structures such as policies, institutions and capacity building.

A second source of information was through interviews with targeted people at a joint workshop held by members of the AnGR groups of FAO, ILRI and SLU in collaboration with East African Community (EAC) and Southern African Development Community (SADC), in Arusha, Tanzania, for capacity building on AnGR. To get a deeper understanding of the current state of the infrastructure it was necessary to visit the countries in question. Country visits increased the validity of the responses, when people working in the field could openly and directly explain the situation. In every country visited, representatives of the livestock sector and related institutions were given the same opportunity to present the situation. Allowing each institution to inform about other institutions they work with, i.e. snowball methodology, gave an opportunity to visit more institutions than those initially known to the interviewer. Visiting the countries added an extra understanding and it is believed that it deepened the subjects discussed at interviews.

The study was conducted during a long period of time, which made it difficult to study the "current" state. It would of course have been better to spend even more time with each institution to get a broader and deeper understanding of the situation, however, this was not possible for one person given the circumstances. The study conducted is the first of its kind, with systematic interview materials, which hopefully can be used as background for a follow-up study.

For the study on defining breeding objectives [II], participatory approaches and analytical procedures were used. The participatory approach enabled information to be gathered on the farmers' views on the sheep. There are several ways this type of participatory rural appraisal can be conducted (Duguma *et al.*, 2010). Farmers' ranking of their *own* ewes allowed the farmers to rank the ewes not just based on appearance, but on the whole life history of the animal. Recalled memory regarding the performance and pedigree of their animals is incorporated, instead of only current phenotypic appearance. A deeper insight about the animals is therefore obtained compared to if farmers are valuating unknown animals (Duguma *et al.*, 2010). As the outcome is to benefit the stakeholders it is important to include them also in the research phase of development (Gizaw *et al.*, 2010). The results of the subjective assessments by the farmers were well supported by the objectively collected information on live weights. Thus, farmers' evaluation of their sheep is well worth exploiting for breeding and flock management purposes, if objective measures are lacking.

The study would have benefitted from having more ewes included. However, because it was difficult to find farmers with three ewes for all three breed groups studied, it was hard to increase the size. It should also be noted that the two village sites used in the study were chosen because they previously had been known to keep large numbers of sheep of all three breed groups.

The use of interpreters instead of direct communication may also be a weakness of the study. However, in this case the farmers already knew the enumerators, which might have been beneficial. In participatory approaches with farmers, the interpreters must be experienced to limit language barriers as much as possible. To keep the interest of the interviewee, questions should not be too complex or too many. In a workshop aimed at presenting the results from study [II] and discussing the farmers' sheep recording, the proficiency of the enumerators was demonstrated in their interaction with farmers, most of which were illiterate.

Study [III] was initiated to give more detailed information on the meat production potential of Red Maasai and Dorper sheep and their crosses because body size and growth rate were highlighted in the breeding objective study [II] to be the most important traits. Thus, an experimental study using two batches of ram lambs at the Kapiti ranch was designed. Prior to slaughter, experienced evaluators were subjectively assessing weights, grades and prices of the ram lambs, based on the phenotypic appearance of the lambs. This procedure mimics the way evaluators rank animals at a market ground, where the buyer does not know the animal beforehand. Live weight and conformation measures were recorded prior to slaughter and carcasses were weighed and graded at the abattoir. The analytical analysis made it possible to later quantify the results with regards to breed group differences in both live measures and carcass traits including the economic revenue.

Results are dependent on both the size of the material and that representative animals were chosen for the study. Kapiti, where the ram lambs were raised and evaluated, mainly sources rams from within its own flocks, but also from other research farms in the country and directly from farmers in villages keeping Red Maasai and Dorper. The animals at Kapiti not needed for replacement are normally sold to any farmer interested to buy live animals for breeding. Thus, the genetic material from Kapiti is widespread in the country including in Amboseli and Isinya. Ram lambs used in this study may, therefore, be considered representative for lambs raised in the region.

This study, although comprising a limited number of purebred lambs, was the first one reporting a comparison of carcass traits of Red Maasai and Dorper sheep, and thereby adding valuable information. Because carcass weights unexpectedly did not differ between the breeds, even though live weights did, further studies on slaughter lambs of Red Maasai and Dorper lambs are, however, warranted. This should preferably be done using a larger number of animals and also with more evaluators grading the animals, both live and as carcasses.

The last study [IV] on alternative breeding programmes for conservation of the Red Maasai sheep by genetic improvement with or without use of crossbreeding was based on simulations. Simulations may be preferable when many alternatives are to be compared and relevant data are not readily available or too expensive to collect. Stochastic simulations, as used in this study, unlike deterministic simulations, mimic breeding programmes on the individual animal level. They hold some inherent randomness and the same set of parameter values and initial conditions will lead to an ensemble of different outputs, just like under natural circumstances. Given the results presented in [IV], where due to space limitations only average outcomes were presented, a deterministic simulation could have been used instead. However, there are some advantages with the stochastic simulation. The variation in outcome, both for amount of carcass weight and genetic gain could be observed.

Deterministic programmes such as the software ZPLAN (Willam *et al.*, 2008) were however considered, but the programme had limited abilities to handle different breeding goals for the two breeds and also for two environments with genotype by environment interaction.

The four base scenarios of breeding programmes presented were considered to be the most realistic for the regions. Each scenario was run for 15 years and replicated 20 times. This produced stable and close to linear average values of genetic gain and amounts of meat produced. The parameters chosen were based on information obtained through [II-III] together with relevant literature information and selection was based on an assumed selection index. With more literature available, the accuracy of the input parameters would be strengthened. Most of the selection pressure was put on live weight among the index traits: live weight, survival, and milk yield. Even though there were differences in the economic weights in the breeding goal between breeds and environments, the actual genetic gain in the goal traits was not much affected by that.

Simulation results are by nature sensitive to the parameters chosen. Thus, sensitivity analysis was conducted to see the effects of varying some of the assumptions for the study. None of the changes done in the sensitivity analysis changed the ranking of the four scenarios, except if the number of lambs at 12 months of age was increased for Dorper. However, this situation is currently very unlikely to be true, and therefore the conclusions about purebreeding of Red Maasai being superior to crossbreeding with Dorper, especially in extreme environments, seem to be robust.

5.2 Infrastructure and institutional capacity – the basis for sustainable breeding programmes

Well-organized institutions and organizations are important for the development of the livestock sector. A basic principle to follow should be based on the assumption that there is no better way to conserve a breed than to consistently keep the breed or population viable by using a demand-driven long-term breeding programme suitable to the needs of the farmers (Leroy *et al.*, 2016; Philipsson *et al.*, 2011). While it may be wise to start a recording scheme and breeding programme in a simplified manner, addition and application of more advanced strategies may be done as infrastructure and industry develops.

The first study [I] pointed to the importance of trained and skilled personnel. With more trained staff the quality of infrastructure is also advanced. Without adequately trained people in charge of potential animal breeding activities, it will be difficult to formulate relevant breeding policies and develop appropriate breeding objectives, livestock recording schemes or evaluation systems of livestock. Politicians and policymakers must be made aware about the importance of sustainably improving livestock. Shortage of trained human resources was seen as one of the most serious constraints in the first study [I] and that was also confirmed later by Chagunda *et al.* (2015a) for the case of SSA.

Trained lecturers in SSA are few and most lecturers have heavy teaching schedules leaving them with little or no time to explore opportunities for research, development activities, and further training. In many cases most research tends to be carried out at research institutions with limited linkages to higher education systems (Ojango *et al.*, 2010). Access to relevant teaching materials is also often limited. Better collaboration between the universities and higher education institutions in the region should be prioritized to better make use of the teachers and materials available. Some collaboration of this kind is already available, but it has potential to be increased where for example the few MSc and PhD students in the region could join together for joint course work where teachers are available. Regional platforms already in place, such as the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), Forum for Agricultural Research in Africa (FARA), ASARECA and SADC could further be utilized and facilitate better information sharing. A project targeted for developing country regions, including SSA on "Capacity Building for Sustainable Use of Animal Genetic Resources in Developing Countries" was implemented by ILRI and SLU (Ojango *et al.*, 2011). That project aimed to strengthen subject knowledge and skills, as well as teaching and communication skills, of animal scientists teaching or supervising BSc, MSc and PhD students in developing countries. The project has been promoting the development of individual scientists and creating regional networks among people working with AnGR-related issues. More such initiatives are desired.

Among the countries studied in [I], information about the organizational structures had previously been presented only in Kenya. Kosgey *et al.* (2011) and Wasike *et al.* (2011) had reported on the organizational framework for dairy and beef cattle recording in Kenya, which is very related to the broader study [I] conducted in this thesis. However, even though the study by Kosgey *et al.* (2011) was only published two years prior to [I], the organizational structure had already partly changed, for example, the Central Artificial Insemination Station (CAIS) was changed into Kenya Animal Genetic Resource Centre and had received a broadened mandate to include also conservation of the national AnGR. The status of the infrastructure is constantly changing and animal breeding activities should be constantly monitored to align with the current status.

The countries studied in [I] are all rather different and with different strategies and setups for their institutional and organisational frameworks for AnGR. There is not a single best practice, but the organizations and institutions in all countries studied would benefit from better collaboration across the institutions. In most cases the market is still to a large extent informal, however, current market developments may constitute a driver for better organizational setup and stronger policies for livestock breeding.

5.3 Recording and breeding objectives

A key for development of breeding programmes is the function of livestock recording. Most countries report that they do have some sort of recording system available, at least for large ruminants. The recording is, however, often limited to registration of pedigrees, whereas continuous recording of animal traits are often lacking. Recording should, however, not be seen as an activity only for breeding purposes, but for all types of animal improvement, for feeding, management and health purposes. Whenever trait recording is carried out, feedback about the records to the farmers is crucial. The feedback should add value to the farmers by, for example, comparisons of own performance in relation to other farmers at regional or national level. Responses from interviews in [I] indicated that much needs to be done in this respect, as feedback was seldom given and if given, it was often already outdated.

Depending on the infrastructure available, the production system and the choice of species and breed, the desired system may be very different. As an example presented in [I], the Botswana Meat Commission has set up a very specific and advanced recording system. Opportunities to serve the global export market has driven the setup of having identification and traceability of cattle with electronic implants that can easily be scanned and the animal can be traced “from farm to table”. Such an advanced recording system may, however, only be needed in cases of very strict traceability regulations. Opportunities for use of such a system for breeding purposes are obvious, although most scenarios relevant for improvement programmes in SSA could be much simpler. However, new information technologies are nowadays available and could be used also in simple systems, provided traits for recording are well defined and easily accessible.

For the recording system and breeding programme to be sustainable, traits to be recorded for breeding purposes should be decided together with the farmers in the relevant area. In Isinya, body size and growth were identified as more important and adaptation traits as less important in the breeding objective compared to the situation in Amboseli. This may be because Isinya is lush enough to support the needs also for Dorper sheep. Owing to the closeness to markets, selling animals may therefore be more important and thus also the larger body size. In [IV] crossbreeding by using Dorper as a terminal sire breed was beneficial, although marginally, in the less harsh area (environment A). The ability for Dorper to survive in Isinya (environment A) may have been underestimated in [IV] based on the popularity of the breed as expressed in [II]. In [IV] the importance of good reproduction and for animals to be well adapted, which could mean for animals to keep good condition, was clearly demonstrated. For the breeding objectives in Amboseli (environment B in [IV]) reproduction and mothering ability, as well as condition, could perhaps have been further emphasized based on the farmers' preferences in [II]. The genetic gain and the phenotypic levels could thus have been further increased. In [IV] the genetic gain was, however, very low for this type of low heritability traits, and mainly a correlated selection response. The importance of these traits may not be only for the increase in genetic gain but for the acceptability of the programme by the farmers. The above discussion shows the importance of defining breeding objectives relevant to the breed, the environment and in understanding with the farmers.

5.3.1 Example of a simplified recording system for sheep in Kenya

It is possible to start up recording rather easily, also with limited means. In 2010-2013 a pilot recording scheme was initiated by ILRI and SLU and managed by ILRI. Two Maasai villages, Amboseli and Isinya, the ILRI ranch Kapiti, and a national government sheep and goat station in Naivasha participated in the recording (Figure 5). The scheme was started by involving villages and its stakeholders, without any infrastructure for sustainable genetic improvement in place in Amboseli and Isinya. Through collaboration with local authorities, ranch leaders, eldermen, village farmers and non-governmental organizations in the areas, the sheep recording and collaboration with the villages were approved. Baseline interviews with farmers willing to participate were carried out, and sheep were eartagged. The primary objective was to recruit interested farmers for the research project and thereby provide essential data for study of their sheep. It also provided an opportunity for the farmers to initiate structured recording of traits as a basis for selection of ewes within their flocks and promote the use of well selected rams.

A basic recording scheme was introduced to participating farmers. Because many farmers were illiterate, trained enumerators kept all records, one enumerator for each village. Records of sheep were continuously kept. Body weight, body length and heart girth were continuously measured from birth and every three months up till one year of age (Figure 6. Sheep recording measures). In case of diseases, the animal was further weighed and type of treatment was noted, reproduction and fertility was also recorded. Similar records were obtained also from the research stations. Records collected were partly used to confirm background information in [IV].

Farmers accepted the explained pilot recording scheme very well. When the recording scheme was introduced to the farmers, and when the farmers were more acquainted with the system, workshops explaining the benefits of keeping records and showing results from the farmers own farms were presented. Farmers could then also compare results of their own farms with those of others. This has led to a larger interest, some of those literate farmers continued keeping records on paper, and not just by head as traditionally, and selecting animals for breeding based on the records. Collaboration between the farmers became stronger with a positive effect on exchange of genetic material. There were even examples where the sheep were marketed for export. Enumerators also became more interested in recording and in some cases continued keeping records. For continuation of this recording scheme it is suggested for the recording system to be integrated into a larger national recording system with continuous supervision and aligned extension services.

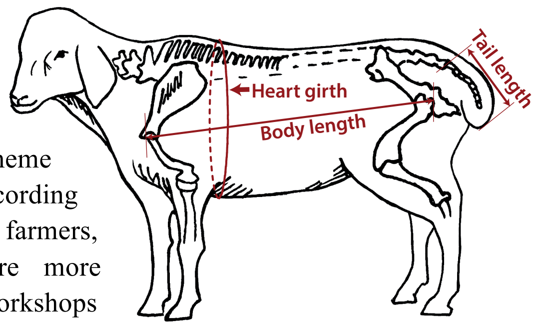

Figure 6. Sheep recording measures.

5.4 Economic aspects on Red Maasai and Dorper in Kenya

Sheep in the tropics provide meat, milk, manure and skins; they are also culturally important and act as insurance (Kosgey, 2004; Lebbie & Ramsay, 1999). With modernization and infrastructure development the sale of lambs and sheep to generate direct cash income may become more important, as farmers become more market-oriented and the whole value chain from farm to carcass becomes more important.

In the last few years, a few studies looking at preferences of farmers, middlemen and butchers have been conducted in Kenya (Mtimet *et al.*, 2014; Katiku *et al.*, 2013). Middlemen were noticed as being key players in the value chain (Katiku *et al.*, 2013). Farmers need to be aware of how middlemen value the sheep in order to access the highest price. The price of the animal must also be decided in relation to the environment where it is sold and for what purpose the animal is to be used, i.e. as breeding animal or for slaughter. The second study in this thesis [II] showed that the price farmers were willing to pay varied depending on the environment they were in. In the less harsh area, which had better infrastructure and was closer to markets, farmers were willing to pay significantly more for the sheep, more than twice as much for a Dorper sheep to be used for breeding purposes, compared to in a very harsh area far from infrastructure and market. The high price of the Dorper was, however, overvalued in terms of income from the breed, even if Dorper were to be used in crossbreeding programme, based on the assumptions and results in [IV] for environment A. In Amboseli the farmers were willing to pay approximately the same for Dorper as for Red Maasai in [II], even though the use of Dorper in harsh environments as Amboseli was proven unsuitable [IV]. It may be that the assumed input values for survival in [IV] were too low for Dorper especially in environment A to mimic Isinya, but to pay twice as much for Dorper breeding animal still seems too much in relation to the price of Red Maasai.

The farmers in Isinya, an area with very similar environmental conditions as Kapiti, were also undervaluing Red Maasai breeding ewes [II], which weighed approximately 2 kg more than the ram lambs at Kapiti to be used for slaughter in [III]. Farmers were willing to pay only 240 KES more for the Red Maasai breeding ewes compared to what the evaluators were willing to pay for the lambs for slaughter. The breeding worth of Red Maasai was thus highly underrated.

Based on the price evaluators were willing to pay for the slaughter lambs in [III], the Dorper ram lambs were highly overvalued. This price differentiation confirms earlier findings by Mtimet *et al.* (2014), where Dorper were better priced at markets. Evaluators in [III] were willing to pay approximately 7 KES more per kg live weight at evaluation, or 36 KES per kg more for what later was shown to be the carcass weight, for Dorper compared to Red Maasai. The evaluators are thus losing more income on the Dorper when sold to the abattoir compared to the Red Maasai.

The routinely used prices paid at the abattoir were based on two different payment systems. The abattoir either paid a fixed price per kg live weight or a flat rate per kg carcass. If payment by the abattoir is based on live weight they buy Red Maasai for 361 KES per kg carcass weight and Dorper for 383 KES per kg carcass weight, due the differences in dressing percentage between the breeds. If evaluators are seen as pure middleman they received 1132 KES more if paid by live weight for one Red Maasai lamb and 921 KES more for one Dorper lamb compared to the price middlemen were willing to buy the animals from the farmers for. If they instead were paid per kg carcass weight the earnings were 590 KES for Red Maasai and almost none, 45 KES for Dorper. Middlemen earn more if payments are made based on live weight at the abattoir and if payments were based on carcass weight the middlemen are probably losing money on buying and selling Dorper, if including additional costs for market and transport to abattoir.

If the sheep are only for slaughter and the flat payment per kg carcass with no premiums continue at the abattoir, farmers and middlemen must learn to see beyond the more popular white colour of Dorper and focus on the weight of the animal. They would benefit from using a scale to measure the weight and not just rely on visual inspection, which is generally the case in the region. If the market is willing to pay, there is also room for different payments based on different grading, muscle formation and carcass fat level. Payment by such premiums would change the price setting per breed as the Red Maasai and Dorper have different qualities. The leaner carcasses of Dorper may attract customers close to cities, whereas Red Maasai carcasses with more fat may be more suited for rural local markets (Katiku *et al.*, 2013).

5.5 Aspects on a potential breeding programme for conservation and improvement of Red Maasai sheep

The Red Maasai sheep is valuable for its tolerance to drought, resistance to diseases, and also for its high cultural value. The purebred sheep among commercial farms are, however, few compared to how it used to be. A breeding strategy for the Red Maasai needs to be established in order to develop the breed to avoid further decline in numbers. Livestock policies need to support a sustainable breeding programme. The success of such a breeding programme is highly determined by the compatibility with actual farming conditions and the involvement of the farmers.

Among the countries studied in [I], Kenya was the best resourced in terms of trained staff holding a PhD degree in animal breeding. The organizations and institutions have primarily been developed for improvement of cattle, but less so for small ruminants. Nevertheless, recording systems for small ruminants could be integrated into the same system as for large ruminants, and number of recorded traits could be kept to a minimum.

Through the simplified recording scheme that was set up, farmers in those areas are already aware and used to the procedure of pedigree and trait recording. Owing to the knowledge of these farmers it would be suitable to continue having these two village sites, Amboseli and Isinya, as start-up flocks for recording at commercial level for an introduction of a breeding programme for the Red Maasai. Amboseli represents a site with little available infrastructure, far from markets, and the environment is harsh and arid. Isinya is less harsh, a semi-arid area closer to Nairobi, infrastructure and markets. These two areas would therefore be representative of the situation for commercial flocks in Kenya as a whole. Continued collaboration between the flocks and sites should be encouraged, as it may lead to a stronger farmer's voice and eventually also farmer's cooperative or organization. Mobile phones are now available and connected in most parts of SSA and applications for early warming of disease outbreaks are already available. Increased usage of mobile phones and computer technology attached to solar panels for power can be used to collect and transfer animal records, send pictures of animals for veterinary support or sales, and may decrease costs. The commercial levels do not need to keep records to benefit from a breeding programme. It would, however, improve data for management decisions, e.g., for choice of lambs for slaughter. If selection of female replacements takes place in the commercial tier, genetic gain can also be increased [IV].

Breeding programmes can be structured in many different ways, with crossbreeding or only purebreeding, with one or more tiers, community-based (Mueller *et al.*, 2015) or including larger areas, and with an open or closed nucleus system. All options should be carefully considered. In low input systems with limited infrastructure, a breeding programme with a closed nucleus may be the best option (Kosgey, 2004). Inbreeding in the nucleus may, however, become a concern and needs special attention to be managed. Trait and pedigree recording can, if needed, be carried out only in the nucleus with limited costs and organizational resources. If available, the nucleus can be an experimental or government station or institutional flock, or comprise a few coordinated farmer flocks. A closed nucleus reduces the risk of spreading diseases, unwanted material and semen may be easier to transport than animals, but is dependent on reliable infrastructure (e.g., cryopreservation and cold storage during transport) and skilled labour for insemination. Dissemination of genetic material may for some species be done successfully by artificial insemination. In the case of a breeding programme for the Red Maasai sheep, natural mating and sale of selected ram lambs from a nucleus flock seem most realistic.

Kapiti has since long shown its capacity in keeping pedigree and trait records and have for many years supplied farmers with breeding stock at a rather low cost in order to support the genetic base of the breed also in commercial flocks. Kapiti is also using regular weighing scales, usually not available for farmers, but shown in [III] to be very important. It is therefore suggested for Kapiti to expand its role as a nucleus flock, if this is possible from an organizational and legal point of view. National research herds, such as Naivasha sheep and goat station (Figure 5), may also be used.

Farmers were participating in the decisions on their breeding objectives in [II]. The drought tolerance and disease resistance of Red Maasai sheep and the larger body size of the Dorper breed were already well known (Kosgey *et al.*, 2008; Baker, 1998), but the importance of milk production was unknown from before. Owing to the better collaboration between farmers through the pilot sheep recording, women in Isinya started to collect milk for sale through a small business enterprise. The milk was sold to a processor producing cheese for export (Audho *et al.*, 2015). By allowing the farmers to set their own breeding objectives for their sheep it is now evident that milk production is important and should be included in any breeding programme. A higher milk production could perhaps also better meet the higher requirements of Dorper or crossbred lambs, thus potentially increasing the survival of these lambs. However, this can not be at the expense of the survival of the ewe. Therefore, it is important to have as balanced production goal as possible.

The current breeding objectives in the Kapiti research flock are currently to increase growth, survival and reproductive traits (ILRI, 2016). As a nucleus in a larger breeding programme it would be recommended that the current objectives are updated to also include milk records. Trait recording would benefit from being as simple as possible and initially milk production records may be sufficient if recorded a few times per lactation as it is highly correlated with total milk production. However, Abegaz *et al.* (2008) suggested recording every once per week. Even though the genetic gain in [IV] was low for milk yield it was positive and should therefore preferably be included to align with the farmers wish.

Based on the information above, strategic scenarios for a breeding programme were presented in [IV]. All scenarios showed that it was possible to increase the genetic gain in all three breeding goal traits, carcass weight, survival and milk yield. Substantial genetic gain was possible in carcass weight, but the gain was low in the low heritability traits survival and milk yield. It was also seen that there was a delay until the improvement in the nucleus was stable and in addition there was a lag period until any improvement could be seen in the commercial tier. This must be explained to the farmers when starting a breeding programme to avoid overly optimistic expectations leading to disappointment and potentially lack of trust in the programme.

The importance of genotype by environment interaction on the breeding objective level became evident in [II]. The same breeding goal traits could be used, but with different economic weights. Therefore, and owing to assumed

G×E also for the traits in question, breeding scenarios with a subnucleus keeping animals bred for that environment were successfully tested in [IV]. The main issue would be how to start a subnucleus. It may be based on one of the more prominent and literate farmers in the area. The subnucleus may, however, not benefit from the programme if only counting meat produced or genetic gain in that specific population [IV]. The commercial tier must be prepared to pay the subnucleus for the breeding animals in order for anyone to be willing to start a subnucleus. The price of breeding animals bought from the nucleus must also be harmonized with those sold from the subnucleus, it cannot be cheaper for a commercial farmer to buy directly from the nucleus than to buy from the subnucleus. It is necessary that the subnucleus can make a profit selling breeding animals rather than sending the animals to slaughter. A functioning market for breeding animals is thus important. This is though difficult to achieve because it basically requires a functioning genetic evaluation system, accounting for the G×E. Thus, establishment of a supporting extension service with administrative leadership is essential. Such a system, if based on modern technologies for recording, transfer and analysis of data, including a feedback system to the farmers, would be beneficial to all stakeholders. In the meantime, farmers must be made aware of the value of good breeding animals tailored for their specific environment, especially in Amboseli (environment B).

Owing to the harsh climate and with lower number of lambs at 12 months per ewe and year assumed in environment B, crossbreeding was overall unsuccessful. However, in environment A, crossbreeding can still be an option. Environment A in [IV] could be seen as Isinya and environment B as Amboseli. As stated in [III], it may consequently be worth keeping Dorper as a terminal sire breed in Isinya and other less harsh and more productive areas, which is also in agreement with conclusions by Leroy *et al.* (2016).

Based on the above, and if conditions permit, Kapiti is suggested to expand its role as a closed nucleus tier for a sustainable breeding programme keeping Red Maasai in Kenya. If in agreement with stakeholders, a national research herd such as the one in Naivasha may also be used. Either way, one of these herds could act as a backup for the other, with exchange of breeding animals, to lower the risk that a disease outbreak would destroy the nucleus and thus much of the genetic gain achieved. Amboseli and Isinya are suggested as the initial areas in which to disseminate the improved genetic material to the commercial flocks. For commercial flocks, with similar production systems and environmental challenges as the nucleus, such as Isinya, economic weights for selection indexes can be kept the same. For commercial flocks in more harsh and arid regions, such as Amboseli, it is suggested to have a subnucleus to strengthen and support that the animals are bred for the right environment, i.e., accounting for G×E. In less harsh and more productive areas it may be beneficial to use Dorper as a terminal sire breed for production of crossbreds for slaughter. In arid regions, only purebreeding of the Red Maasai is suggested. In both commercial areas the female flocks are suggested to comprise only pure Red Maasai ewes to capitalize from their better adaptability to the environments and to support a structured system of selection.

6 Conclusions

The most serious constraint for the development of sustainable animal breeding programmes in Eastern and Southern Africa was the shortage of skilled personnel in animal breeding at all levels and in all types of institutions. More university training and capacity building in animal breeding was needed. It is important to have clear national policies and institutions that are appropriately mandated and that support sustainable use of animal genetic resources. Increased collaboration and communication between existing organizations and institutions are needed. For any improvement strategy to be successful farmers' involvement is necessary and their organizations need to be empowered.

As regards the case with Red Maasai and Dorper sheep in two different environments in Kenya a significant genotype by environment interaction was shown. Large differences in live weight between the breeds were found, showing the superiority of Dorper over Red Maasai in the semi-arid and less harsh environment, whereas differences between the breeds were small in the arid and more harsh environment.

Body size and milk production was highly ranked for both breeds when farmers ranked the traits for the breeding objective. Red Maasai ewes were appreciated for their reproduction and adaptive traits and Dorper mainly for its larger body size. The same breeding objective traits could be suggested for the two breeds and areas but with different weights.

In the study of meat production of ram lambs slaughtered at about one year of age, live weight was superior to any other live conformation measure in predicting carcass weight, which underpins the use of weighing scales when selecting lambs for slaughter and breeding purposes.

Carcasses of Dorper lambs at a given live weight were not heavier than those of pure Red Maasai but had better carcass grades and higher scores for muscle formation. Red Maasai lambs had a higher dressing percentage and carcass fat level. Crossbreds were generally superior to the parental breeds.

When basing the payment on assessed live weight, evaluators substantially undervalued Red Maasai lambs economically compared to Dorper.

When conditions are harsh, with low litter size and survival, it would be best to use purebreeding of Red Maasai, using a nucleus in that area, or alternatively a subnucleus if there is a genotype by environment interaction with the nucleus area. If the environmental conditions are more favourable and survival rates are higher, it would be possible to use also crossbreeding with Dorper as a terminal sire breed to increase meat production. However, crossbreeding of Red Maasai with Dorper sheep cannot be recommended as a way to improve meat and the livelihoods when the environment is harsh.

With a nucleus herd of Red Maasai, and Dorper if needed, it would be possible to make substantial genetic gain in live weight and carcass weight of Red Maasai, but expected gain in the low heritability traits survival and milk yield is low, however, still positive. With selection of female replacements, based on recording also in the commercial tiers, the genetic gain can be somewhat improved and the lag period for the gene flow to the commercial tier decreases.

The case of the Red Maasai sheep demonstrated that a nucleus breeding programme could sustainably improve the productivity of an indigenous breed, while contributing to biological diversity.

7 Future research

Since the GPA, many countries have increased their efforts in strengthening their resource base as regards animal genetic resources. There is, however, still a great need for both research and implementation in form of development of animal breeding strategies including supportive structures.

A second report on the State of the World's Animal Genetic Resources for Food and Agriculture has just been launched. There is need for new in-depth follow-ups to get a better background for research priorities as regards methods of conserving and improving various breeds under threat, and the choice of these breeds.

The study conducted on lamb carcasses of Red Maasai and Dorper and their crosses was the first of its kind. The number of sheep included in that study was rather small and an extended study including both harsh and more productive environments is warranted. It should comprise sheep of both pure breeds and their crosses and include the slaughter of both ram and ewe lambs and evaluation of carcass weights, grading of various sorts and also recording amounts and types of parasites.

Good resistance against parasites in Red Maasai has been known since decades, but research on survival in general is still limited, including comparative studies with Dorper and their crosses. It has been stated that Red Maasai show some tolerance against trypanosomiasis, this would need further investigation. Other survival traits under harsh conditions, such as drought tolerance, feed and water requirements and disease resistance, would need further research, both on phenotypic and genetic levels.

Milk production has been shown to be unexpectedly important. Production levels under different environmental conditions are needed as well as genetic parameters, both for Red Maasai and Dorper. Further comparative studies of these breeds on reproduction and fertility measures such as litter size, lambing interval and survival at various ages are requested, preferably under different production systems and environmental challenges.

As Red Maasai seemed economically undervalued at the market, it would be desirable to follow up on the current cultural and socio-economic values of the Red Maasai sheep for the livelihood of the farmers. What is the relative role of income versus other assets in the pastoral systems?

Further studies on breeding programmes and strategies are needed to better choose the best option for implementation under variable environmental and infrastructural conditions. Currently drought periods happen at certain intervals; it would be interesting to simulate what would happen to the relative merits of different breeds if droughts appear, e.g., every fourth year.

Could formation of a synthetic breed with the same adaptive traits as Red Maasai and large size of Dorper be created and implemented with success? This question requires more research on crossbred populations (F_1, F_2 and further). If the research would be successful it would require long-term commitment and large resources for development of the new breed.

8 Avelsprogram och infrastruktur – exemplet med Red Maasai-får i Kenya

8.1 Bakgrund

Människor på landsbygden är beroende av husdjur av många anledningar: för att säkra tillgången på mat, som dragdjur, för gödsel, bränsle och byggnadsmaterial, som ekonomisk trygghet och att de även fyller en social funktion. I Afrika söder om Sahara spelar idisslare en viktig roll genom att de omvandlar grovfoder och betesgräs till människoföda i form av högvärdigt protein. Konsumtionen av kött och mjölk väntas öka drastiskt i detta område. Historiskt sett har man mött en ökad efterfrågan på mat av animaliskt ursprung genom att öka antalet djur, snarare än genom att öka produktiviteten hos de befintliga djuren. Detta förfaringssätt har lett till en negativ miljöpåverkan med till exempel överbetning, jorderosion och ökade utsläpp av växthusgaser.

Den globala åtgärdsplanen för husdjursgenetiska resurser, ”The Global Plan of Action for Animal Genetic Resources”, som antagits av FAO:s medlemsstater, belyser vikten av husdjursgenetiska resurser för att säkra matförsörjningen genom ökad produktivitet, samtidigt som man bevarar den genetiska mångfalden. En viktig faktor för hållbara avelsprogram och för bevarandet av mångfalden i djurraser är tillgången på stabil infrastruktur. För mindre intensiva produktionssystem saknas ofta en väl fungerande infrastruktur eller så är den otillräcklig. För att ett avelsprogram ska vara framgångsrikt krävs en fungerande infrastruktur med lämpliga anläggningar, tillförlitlig datainsamling över både djurs identiteter och härstamningar samt en rådgivningsservice med ett genetiskt utvärderingssystem av något slag.

Trots det hot som det utgör att öka antalet djur inom många djurhållningssystem så riskeras också biologiska mångfalden inom sektorn. Närmare 70 % av världens unika husdjursraser finner man idag i utvecklingsländer, och upp till 20 % av världens cirka 7 000 husdjursraser riskerar utrotning. I utvecklingsländerna finns två huvudorsaker till detta: 1) djurets potential är dåligt utnyttjad inom många inhemska raser, vilket ofta ger låg produktivitet, lågt ekonomiskt värde på marknaden och miljömässiga problem, 2) kortsiktig och okontrollerad korsningsavel med exotiska raser med deras korsningar som inte är anpassade för miljön, vilket utarmar genpoolen inom de inhemska raserna. Forskningen har en viktig uppgift i att ta fram och sprida kunskap om utvecklingen av mer passande avelsstrategier.

Red Maasai är ett exempel på en hotad fårras. Det är en inhemsk ras som främst hålls av masajpastoralister i torra områden i Kenya och Tanzania. Rasen har utvecklat mycket god motståndskraft mot infektioner av tarmparasiter, är tålig mot värme och torka samtidigt som den har ett högt kulturellt och traditionellt värde för masajfolket. Fram till mitten av 1970-talet var renrasiga Red Maasai-får vanliga och kunde ses överallt på landsbygden i Kenya. Ett subventionerat program för spridning av den större fårrasen Dorper från Sydafrika etablerades för att öka lammens vikt. Frånvaro av kvalificerad rådgivning för bönderna ledde dock till okontrollerad och ohämmad korsningsavel, vilket resulterade i en kraftig minskning i antalet renrasiga Red Maasai-får.

Syftet med den här avhandlingen var att studera möjligheterna för avel med inhemsk boskap i södra och östra Afrika för hållbart nyttjande under extensiva produktionsförhållanden. Avhandlingen omfattar en studie över vilken stödjande infrastruktur för husdjursgenetiska resurser som finns tillgänglig. Red Maasai-fåret studerades som modell för utformning av realistiska avelsmål och avelsprogram, för att hållbart bevara och förbättra en inhemsk ras hotad av ohämmad korsningsavel.

De mer specifika syftena var att:

- Studera den infrastruktur som finns och behövs för att stödja hållbart nyttjande av husdjursgenetiska resurser i ett urval av länder i södra och östra Afrika.
- Undersöka vilka egenskaper som bör ingå i avelsmålen, rasskillnader i levande vikt, hull, slaktegenskaper och ekonomiska värden för köttproduktion av Red Maasai- och Dorper-får och deras korsningar i två olika miljöer.
- Studera möjligheter till bevarande och förbättring av Red Maasai-fåret genom att jämföra renrasavel med olika nivåer av korsningsavel med Dorper-får som en faderras i två olika extensiva områden.

8.2 Sammanfattning av studierna

8.2.1 Infrastruktur och institutionell kapacitet

Situationen i de sex länder, Botswana, Kenya, Moçambique, Tanzania, Uganda och Zambia, som ingick i studien var väldigt olika och de hade hanterat frågor gällande husdjursavel på olika sätt. De var alla i olika utvecklingsstadier och hade olika ambitionsnivå.

Inget av länderna hade ett fullständigt avelsprogram i bruk men bevarandeprogram av något slag fanns i de flesta länderna. Registrering av djurens härstamning och produktion är basen för såväl forskning, utveckling och avelsarbete, men tyvärr saknades det i många fall helt, förutom på försöks- och forskningsstationer. Kenya var det enda land som tillämpade produktionsregistrering av nötkreatur i större skala.

Organisationer och institutioner som har till syfte att stödja avelsprogram visade sig vara få, och de behövde bli bättre integrerade. Bondeorganisationer med mandat att förbättra husdjuren fanns i de flesta länder, men de var ofta dåligt organiserade, delvis på grund av avsaknad av tillräckligt utbildade anställda. Böndernas begränsade medverkan i olika organisatoriska sammanhang rapporterades som ett hinder för utvecklingen i alla länderna.

De länder som erbjöd minst möjligheter till universitetsstudier i husdjursavel hade också de minst utvecklade systemen och aktiviteterna för husdjursgenetiska resurser. Alla länder, utom Moçambique och Zambia, erbjöd dock avelsstudier på både master- och doktorandnivå. Alla länder rapporterade avsaknad av tillräckligt utbildad personal som det absolut största problemet för att utveckla avelsprogram. Mer universitetsutbildning och kompetensutveckling behövs.

8.2.2 Avelsmålen bestämdes tillsammans med bönderna

Bönderna i två olika områden medverkade själva aktivt när avelsmålen för fårraserna Red Maasai och Dorper bestämdes. I det mer extrema området, som låg långt ifrån fungerande infrastruktur och där det var väldigt torrt, var det inte så stora skillnader mellan varken storlek på de olika raserna eller vilken av raserna som var mest omtyckt. I det området ansågs mjölkproduktion och djurens kondition vara väldigt viktiga för alla rasgrupperna. I det mindre extrema området som låg närmare städer och hade bättre betesmöjligheter, var bönderna mer intresserade av den ekonomiska marknaden. Priset en bonde var villig att betala för ett avelsfår var också betydligt högre för alla rasgrupper, nästan dubbelt så mycket för Dorper och korsningar och nästan en fjärdedel mer för Red Maasai, i jämförelse med det torrare området. Bönderna tyckte storlek och tillväxt på djuren var allra viktigast oavsett ras, och än mer så för

Dorper-fåren. Mjölkproduktion rankades som näst viktigast oavsett ras. Red Maasai-rasen däremot uppskattades framförallt för sin goda reproduktionsförmåga och sina modersegenskaper. Rasen uppskattades också mer för sin motståndskraft mot torka och sjukdomar.

Avelsmålen bör betona tillväxtegenskaper och mjölkproduktion för både Red Maasai och Dorper i båda områdena. Djurens hull och att de är i bra kondition bör särskilt beaktas i avelsmålen för båda raserna i det torraste och mer extrema området. För Dorper bör man särskilt beakta egenskaper för bättre anpassning till torrare klimat och bättre resistens mot sjukdomar.

8.2.3 Levandevikt, kroppsform, slaktegenskaper och ekonomisk värdering

I en studie av bagglamm hade Dorper 2,1 kg högre levandevikt än Red Maasai vid cirka ett års ålder då djuren gick till slakt. Dorper hade också bättre klassade slaktkroppar, men lägre slaktutbyte och fettansättning än Red Maasai-lammen. Dessa var även något kortare men hade samma bröstomfång som Dorper och korsningarna. Korsningarna var generellt bättre än båda föräldraraserna, i medeltal noterades 8-9 procent i korsningseffekt (heterosis) för alla egenskaper som undersöktes.

Livdjursbedömare var villiga att betala mer för Dorper-lammen, trots att Dorpers slaktkroppsvikt senare inte visade sig vara högre än den för Red Maasai. Bedömarna undervärderade Red Maasai-lammen ekonomiskt med 8-13 % jämfört med Dorper-lamm enligt det prissystem per kg levande- eller slaktkroppsvikt som användes av slakteriet.

Levandevikt var det bästa sättet av levandemåtten för bedömning av slaktkroppsvikt. Av de subjektivt bedömda måtten var priset för vad bedömarna var villiga att betala det mest informativa måttet för att skatta slaktkroppsvikt, dock betydligt mindre informativt än levandevikt.

Tack vare korsningslammens överlägsenhet gällande storlek och egenskaper för köttproduktion, skulle Dorper kunna rekommenderas som faderras vid korsningsavel med Red Maasai-tackor.

8.2.4 Renrasavel med Red Maasai-får och korsning med Dorper-får

I den fjärde artikeln i avhandlingen, simulerades alternativa avelsprogram för både renrasavel av Red Maasai och även med korsningsavel med Dorper i två olika produktionsmiljöer. Avelsprogrammen baserades på en större avelsbesättning, så kallad, kärnbesättning. Från denna distribuerades utvalda bagglamm för avel på den lägsta nivån i avelsstrukturen, i de kommersiella besättningarna som fanns i två olika produktionsmiljöer (miljö A och B). På grund av att miljö B ansågs vara annorlunda än miljö A där kärnbesättningen var, simulerades också scenarier med en sub-kärnbesättning i miljö B anpassad för den miljön, en mellannivå för produktion av avelsbaggar för de kommersiella besättningarna i B.

I genomsnitt producerade tackorna ungefär 10 kg kött per år. Efter 15 års avelsarbete hade slaktvikten per lamm ökat med mer än 10 %. Det genetiska framsteget för kött per lamm uppgick till 0,2 kg kött per år. Det genetiska framsteget för de andra två egenskaperna man avlat för, överlevnad och mjölkproduktion, var relativt sett betydligt lägre (0,04-0,05 genetisk standardavvikelser per år jämfört med 0,17 för kött). Det årliga genetiska framsteget, för alla tre avelsmålsegenskaper och scenarion som undersöktes, var högst i kärnbesättningen och lägre ju längre ner i avelsstrukturen man kom, lägst för korsningarna. Det berodde på att det tar flera år för det genetiska framsteget att nå ut och bli stabilt och linjärt, 3-4 år för kärnbesättningen och 2-3 år längre för de lägre skikten.

Genotyp-miljösamspel innebär att det inte är exakt samma gener som är viktiga i olika miljöer. Rent praktiskt betyder det att det inte är samma djur som är bäst i miljö A som i miljö B. Detta mäts ofta som en genetisk korrelation mellan två miljöer för en och samma egenskap, ju svagare korrelation, desto starkare genotyp-miljösamspel. Vid starkare genotyp-miljösamspel (0,6) försämrades Red Maasai på den kommersiella nivån i den mest extrema och torra miljön (miljö B) jämfört med basalternativet som hade ett genotyp-miljösamspel satt till 0,8. Utan genotyp-miljösamspel (1,0) var det genetiska framsteget i miljö B mer likt det i det mindre torra och kärva klimatet med bättre betesmöjligheter (miljö A). Selektion av tacklamm, genom att man registrerar produktionsnivån, även på den kommersiella nivån, ledde till något högre genetiskt framsteg och mer lika framsteg i de båda miljöerna. Den genetiska nivån för de kommersiella besättningarna steg på 15 år med 1,96 kg slaktkroppsvikt utan selektion av tacklamm och med 2,25 kg slaktkroppsvikt med selektion, för miljö A, och från 1,39 till 1,63 kg i det extremt torra området, för miljö B.

När grundalternativen för olika avelsprogram jämfördes så var renrasavel i hela avelsstrukturen och en sub-kärnbesättning i miljö B det bästa alternativet. Det resulterade i högst inkomst och mängd producerat kött från lamm och äldre djur per år. Det mindre extrema området med bättre betesmöjligheter, miljö A, gynnades något av att också ha Dorper och producera korsningslamm. En högre andel korsningslamm resulterade för det området i något högre köttproduktion. För miljö B å andra sidan resulterade användningen av Dorper och korsningar i mindre mängd producerat kött än renrasavel med Red Maasai.

Skulle Red Maasai-fåren och Dorper-fåren rent hypotetiskt ha samma antal lamm vid 12 månaders ålder per tacka och år inom en viss miljö så skulle ett korsningsavelsprogram med en sub-kärnbesättning i miljö B vara det alternativ som gav högst mängd producerat kött totalt. Att använda slaktkroppsvikter beräknade i tidigare egna studier (artikel III) förändrade inte rangordningen av scenarion utan bara den faktiska mängden producerat kött.

Huvudinkomsten från avelsprogrammet var från slaktade lamm (81%), följt av kött från slaktade äldre djur (18% av inkomsten). Mjölkproduktionen bidrog bara med en procent av inkomsten totalt sett men bidrog med högre inkomst i den extrema miljön än den andra miljön, vilket inte var fallet för mängd kött.

Ett avelsprogram för Red Maasai-fåren skulle vara väldigt gynnsamt, speciellt för ökad slaktkroppsvikt. Renrasavel rekommenderas under torra klimatförhållanden. Under mindre extrema och torra förhållanden, eller om Dorper-rasen får bättre överlevnad och reproduktionsförmåga, kan även den framgångsrikt ingå i avelsprogrammet som faderras med produktion av korsningslamm för slakt.

8.3 Kortfattade slutsatser

Den allvarligaste begränsningen för utveckling av hållbara avelssystem i de länder som studerats i södra och östra Afrika är bristen på kunnig personal inom husdjursavel på alla nivåer och för alla typer av organisationer. Mer universitetsutbildning, fortbildning och kapacitetsuppbyggnad krävs inom sektorn. Det är viktigt med tydliga nationella riktlinjer och institutioner med mandat att stödja husdjursgenetiska resurser. Ökat samarbete och kommunikation mellan existerande organisationer och institutioner behövs. Böndernas delaktighet krävs för att avelsprogram ska bli framgångsrika.

Det var uppenbart att både Red Maasai- och Dorper-fåren har styrkor såväl som svagheter och att båda raserna skulle gynnas av avelsarbete genom renras-selektion. Kroppsstorlek och mjölkproduktion rankades högst i avelsmålet för alla tre rasgrupper, Red Maasai, Dorper och deras korsningar. Red Maasai-tackor uppskattades för deras reproduktionsegenskaper och anpassningsförmåga och Dorper uppskattades främst för sin större storlek.

Levandevikt var den objektiva mätegenskap som bäst skattade slaktkroppsvikt. Det här visar hur viktigt det är att använda vågar för vägning vid val av djur både till slakt och avel.

Slaktkroppar från Dorper-lamm var inte tyngre än för Red Maasai trots att Dorper hade högre levandevikt. Dorper hade dock bättre slaktkroppsklass och hade mer muskler. Red Maasai-fåren hade högre slaktutbyte och mer fett. Red Maasai-lammen var tydligt ekonomiskt undervärderade jämfört med renrasig Dorper vid utvärdering av livdjursbedömare jämfört med det av slakteriet tillämpade betalningssystem för slaktkroppsvikt.

Hänsyn till genotyp-miljösamspel måste tas när hållbara avelsstrategier ska utvecklas. Raserna måste vara välanpassade till sin miljö. Vid torrt klimat, med låg kullstorlek och överlevnadsgrad, som det ofta är i Kenya, är det bäst att använda Red Maasai för renrasavel. Att använda en kärnbesättning och vid behov en sub-kärna, speciellt vid starkt genotyp-miljösamspel, rekommenderas. Om miljöförhållandena är mindre svåra och överlevnaden högre skulle det vara möjligt att även använda Dorper som faderras för ökad produktion av kött. Korsningsavel mellan Red Maasai-får och Dorper-får kan dock inte rekommenderas som ett sätt att förbättra böndernas försörjning, speciellt inte när miljön är svår med torrt klimat.

Med en kärnbesättning för Red Maasai och, om nödvändigt för Dorper, skulle det vara möjligt att öka det genetiska framsteget märkbart för levande- och slaktkroppsvikt för Red Maasai, men framsteget i egenskaper med låg arvbarhet såsom överlevnad och mjölkmängd skulle fortfarande vara mycket lågt, om än positivt. Med selektion av tackor baserat på registrering av djuren även på den kommersiella, lägsta nivån, kan det genetiska framsteget öka något.

Exemplet med Red Maasai visade att ett kärnavelsprogram på ett hållbart sätt skulle kunna förbättra produktiviteten för en inhemsk ras och samtidigt bidra till att bevara den biologiska mångfalden.

8.4 Framtidsfrågor

Fler studier behövs för att kartlägga både forskning och utveckling om hållbara avelsstrategier, både avseende stödjande funktioner som infrastruktur satsningar för registrering av husdjurens identiteter och produktion men också ifråga om alternativa avelsprogram för bevarande och utveckling av raser.

Större komparativa studier över slaktkroppsegenskaper mellan Red Maasai, Dorper och korsningar under olika miljöförhållanden är angelägna.

Det råder brist på fenotypiska och genetiska parametrar för överlevnadsegenskaper och mjölkproduktion både för Red Maasai och Dorper men även för andra fårraser i tropiskt klimat och under extensiva produktionsförhållanden. Kunskap om lamningsintervall, kullstorlek, och lammöverlevnad är också bristfälliga för dessa raser och mer forskning skulle behövas.

Fler studier över alternativa avelsprogram principiellt, och speciellt för Red Maasai i Kenya, vore lämpligt för att bättre kunna implementera bästa möjliga scenario i fält.

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