Institute of Animal Production in the Tropics and Subtropics

Breeding objectives and selection schemes for Boran cattle in Kenya

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Improved and unimproved Boran cattle of Kenya
(Cover pictures courtesy of Ol Pejeta Conservancy ltd and D. Elsworth, ILRI)

UNIVERSITÄT HOHENHEIM
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Breeding objectives and selection schemes for Boran cattle in Kenya

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LIST OF ACRONYMS AND ABBREVIATIONS

ADC	Agricultural Development Centre
AGTR	Animal Genetic Training Resource
AI	Artificial Insemination
AnGR	Animal Genetic Resources
ASAL	Arid and Semi-Arid Lands
BCBS	Boran Cattle Breeders Society
BLUP	Best Linear Unbiased Predictions
CAIS	Central Artificial Insemination Station
CBOGIL	Community Based Organisation for Genetic Improvement of Livestock
DAGRIS	Domestic Animal Genetic Resources Information System
DB	Databank
DOS	Disk Operating System
EPZ	Export Processing Zones
ET	Embryo Transfer
EXPO	Expanded organisation
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GILMA	Gambian Indigenous Livestock Multiplier Association
ILRI	International Livestock Research Institute
ITC	International Trypanosomiasis Centre
KARI	Kenya Agricultural Research Institute
KBR	Kenya Beef Records
kg	Kilogramme

KSB	Kenya Stud Book
LOW	Low input production system
LRC	Livestock recording centre
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MoARD	Ministry of Agriculture and Rural Development
MS Win	Microsoft Windows
Mt.	Mountain
NAGRC	National Animal Genetic Resources Centre
NARS	National Agricultural Research Service
NBRC	National Beef Research Centre
NM	Natural Mating
PCV	Packed Cell Volume
PEAP	Poverty Eradication Action Plan
TLU	Total Livestock Unit
UAE	United Arab Emirates
UNDP	United Nations Development Programme
ZPLAN	Computer Programme for evaluating livestock breeding programmes
ELISA	Enzyme-Linked Immuno-Sorbent Assay

CHAPTER 1

GENERAL INTRODUCTION

CHAPTER 1: GENERAL INTRODUCTION

1.1 Beef cattle production and genetic improvement

The livestock sub-sector in Kenya is an integral part of the agricultural sector contributing about 12% of the Gross Domestic Product (GDP) mainly from the production of milk, meat, eggs, hides, skins and wool (FAO, 2005). About 80% of all meat consumed locally is red meat (beef, mutton, goat and camel meat) with 67% of all the red meat being produced in the arid and semi-arid lands (ASALs) (EPZ, 2005). The main international markets for meat from Kenya are in the United Arab Emirates (UAE), Tanzania and Uganda while Germany, United Kingdom, Netherlands and Italy are the main markets for hides and skins (EPZ, 2005). The total value of meat and meat products produced in Kenya has been on an upward trend with that of cattle and calves increasing by over 29% during the period of 1999 to 2003 (Table 1.1).

Table 1.1 Total value of meat products marketed in Kenya from 1999 to 2003 in Kenya Shillings ('000)

Livestock and products	1999	2000	2001	2002	2003
Cattle and calves	8,888	8,040 (-10%)	9,079 (+13)	11,824 (+30%)	11,476 (-2%)
Chicken and eggs	1,431	1,540 (+8)	2,075 (+35%)	1,624.5 (-22%)	1,625 (0%)
Other meat products	2,032	2,318 (+14)	2,482 (+7)	3,123 (+26%)	3,032 (-3)

Source: Economic Survey, 2004

Severe droughts between the years 1999 and 2001 were responsible for the -10% drop in beef production that is predominantly produced through extensive grazing in arid and semi-arid areas where annual rainfall distribution is poor. Heath (2001) reported that the continuing drought patterns, coupled with increasing human population, have increased the pressure on beef producers leading to the decline in sustainable stocking rates from 1 Tropical Livestock Unit (TLU)/15 ha to 1TLU/50-100 ha. In the future, improving beef production in Kenya would probably rely not only on pasture availability but also on the inherent potential of cattle to produce under such limitations. Strategic breeding options for sustaining productivity of cattle as well as improving on fitness characteristics to cope with the production environment have been suggested by Wasike *et al*. (2006), who investigated the growth and fertility performance of a rangeland beef cattle breed (improved Boran) under harsh tropical climatic conditions.

Utilisation of beef cattle in Kenya has a relatively long history probably because the East African region was a settling point for migrating cattle herds (Marshall and Hildebrand, 2002). As early as the 15 century, some traditional cattle keepers of Kenya were known to exclusively consume beef (Maasai-Mara, 2009). One of the earlier reports on beef cattle breeding in Kenya dates back to the 1920s when the European ranchers crossed indigenous African cattle with European types (Homann *et al*., 2005). Most of the research interventions in the beef sector since then have focused on feeding management, characterisation and crossbreeding. For example, Creek (1972) and Creek *et al.* (1973) reported on the Kenya feed-lot project in which it was recommended that high energy rations with 53% corn grain or with 67% corn silage and 21% corn were economically feasible for fattening cattle in Kenya. However, feed-lot beef production in Kenya has found difficulty in adoption because beef is valued in quantity rather than carcass quality in the local market (Rewe, 2004). Other research on beef cattle in Kenya included Kimenye and Russel (1975) who compared the crosses of Ayrshire x Sahiwal cows with high grade Ayrshires, and Trail and Gregory (1981a and b) who evaluated the potential of Sahiwal cattle for milk and beef production and further characterised the Boran and Sahiwal cattle for economic characters such as growth, fertility, survival, milk production and cow productivity. During the 1980s, crossbreeding programmes were already in place in some beef cattle ranches in Laikipia and Machakos districts as exemplified by the studies of Gregory *et al*. (1984) and Trail *et al*. (1984). These studies compared purebred Boran to crosses of Boran x Charolais, Ayrshire and Santa Gertrudis breeds. Similarly, Hetzel

(1988) studied the productivity of East and Southern Africa *Bos indicus* breeds to that of the Brahman and some indigenous Sanga. Mwenya (1993) evaluated the impact of introduction of exotic cattle in East Africa and Southern Africa. This study showed that the contribution to meat production of the exotic beef cattle and their crosses was similar or even worse than that from indigenous cattle. In effect, interest to focus on indigenous cattle genetic resources was gradually developed. For example, the Kenya Agricultural Research Institute (KARI) refocused the objectives of the National Beef Research Centre (NBRC) to promote research and genetic improvement of indigenous Boran cattle for specialised beef production. A bull performance testing project was carried out between 1998 and 2001 at the NBRC where three Zebu breeds (Boran, Sahiwal and the East African Zebu) selected from Kajiado, Laikipia, Baringo and Nakuru districts were evaluated with the aim of initiating breed comparisons of bulls between herds with information from performance testing (Indetie, 2001 cited in BCBS, 2008). The objective of breeding indigenous cattle breeds in Kenya was pursued further through the exploration of prospects for genetic improvement programmes not only for the Boran cattle but also for the other Zebu breeds in Kenya (Rege *et al*., 2001).

In the sub-Saharan tropics, the production system, nutritional, socio-economic and breeding constraints are responsible for the variation in production and profitability of beef cattle. The production systems are generally shaped by prevailing biophysical and socio-cultural environments (Steinfeld *et al*., 2006) which determine how cattle are utilised. Subsistence beef production accounts for the nutritional well being of rural households in Africa. Furthermore, trading in cattle as means of livelihood for pastoral communities has continued to be supported by a growing demand for beef in urban centres (Bingsheng 1998; Mwacharo and Drucker, 2005). Figure 1.1 presents the estimated beef offtake in kg/km^2 from sub-Saharan Africa (FAO, 2002). Raising beef cattle based on rangeland pastures to sustain or better the offtake numbers shown is expected to continue in sub-Saharan Africa (Jarrige, 1992). Eastern Africa has a relatively high productivity levels in offtake (Figure 1.1) and will be important in continuing the supply of beef for human consumption, especially for the local and regional populations.

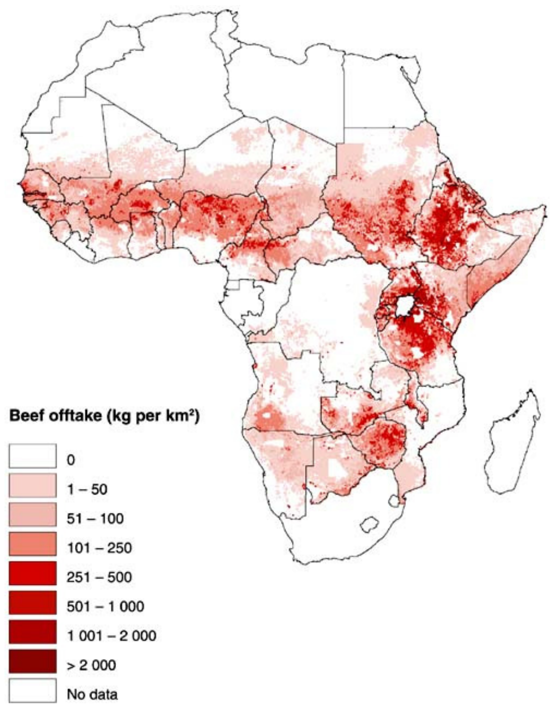

Figure 1.1 Estimated beef offtake (kg/km^2) in sub-Saharan Africa (FAO, 2002).

Improvement in beef production in this region will require integrated approaches to counteract the effects of land degradation, feed scarcity, poor infrastructure and poverty. In almost all strategic development plans for cattle, a breeding component is usually inevitable, be it for conservation of indigenous genetic resources or for genetic improvement of performance (Cardellino, 2005). Genetic improvement aims at optimal use of genetic resources given limited production resources by exploiting genetic variability in important traits to enhance performance (Pirchner, 1983). Cattle selection in this region, however, has for some time concentrated on highly productive genotypes which could lead to the extinction of lowly productive genotypes that harbour fitness genes (Notter, 1999).

Some of these lowly productive genotypes have their ancestry in the first cattle introduced into Africa. These include the humpless Hamitic longhorn (*Bos taurus longifrons*), which arrived about 5000 BC followed by the humpless shorthorn (*Bos taurus brachyceros*) about 2500 years later and the humped Zebu (*Bos indicus*) in about 1500 BC (Mukasa-Mugerwa, 1989). The consequences of further migrations was the heavy concentration of cattle in the highlands of Ethiopia and Kenya (Figure 1.2), currently regarded as one of Africa's original indigenous cattle sites (Marshall and Hildebrand, 2004).

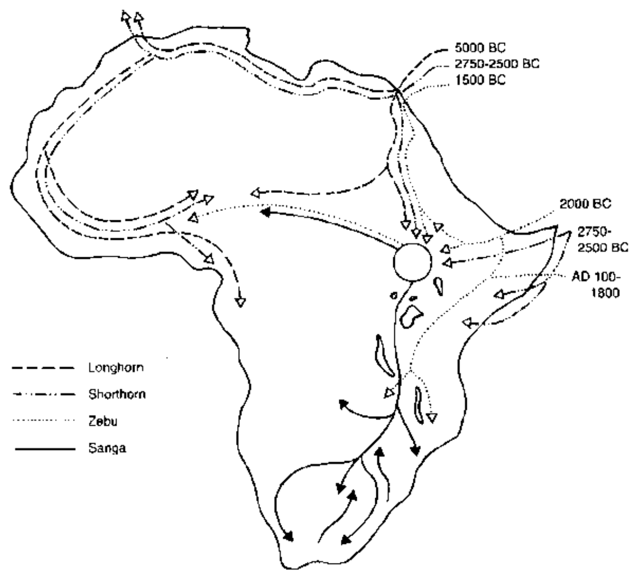

Figure 1.2 Possible migration routes of domestic cattle in Africa (adapted from Mukara-Muregwa, 1989).

The strategic crossing of African cattle with European breeds during the pre-independence era in Africa gave way to the development of some specialised breeds that have continued to be useful in various production systems. Naturally, most of the crossbred cattle were less adapted to the harsh climatic conditions of the tropics leading to backcrossing towards the Zebu. This led to the formation of some of Africa's most productive commercial beef breeds to date (Homann *et al*., 2005). One of these breeds is the improved Boran of Kenya.

1.2 Design of optimal animal breeding programmes

Animal breeding programmes are systematic set-ups of sound selection procedures in the process of influencing genetic change in animals (Harris and Newman, 1994). Selection of animals tends to reflect the preferences of the product market in case of commercial enterprises (Kluyts *et al.*, 2003) or the preferences of the farmer in the case of subsistence production (Sölkner *et al.,* 1998). To account for these preferences, optimisation of animal breeding programmes is important for the efficient utilisation of scarce resources. This is achieved by structuring breeding management of animals into sections that include animal recording, genetic evaluation, selection and mating patterns to obtain genetic improvement at shorter generation intervals in a sustainable way (Hazel *et al.,* 1994). Improvement in animal performance especially for economic benefits has been associated with maximisation of production and profitability, however, scarcity of resources have limited the objective of maximisation (gross production) leading to the concept of optimisation (efficiency) (Olesen *et al.,* 2000). Optimisation aims at achieving sustainable development in the long term (Constaza and Daly 1992).

Structured animal breeding programmes, also referred to as breeding designs (Dekkers *et al.,* 2004), are constructed on the basis of farmer production goals that inform the choice of appropriate breeding objective traits. This is the first step of designing breeding programmes achieved through different approaches depending on the animal production system and farmer type (Hazel *et al.,* 1994; Valle, 1996). The production system and farmer type determine whether the breeding objective will be conventional (market oriented) or subsistence. In developing conventional breeding objectives, the prevailing breeding, production and marketing system are specified to allow for the determination of inputs (costs) and outputs (income) from the system (Ponzoni, 1986; Kluyts *et al.,* 2003). Bio-economic models have been utilised in the development conventional breeding objectives, for example, in tropical beef cattle (Rewe *et al.,* 2006a), dairy cattle (Kahi *et al.,* 2004), small ruminants (Kosgey *et al.,* 2004; Bett *et al.,* 2007) and chicken (Menge *et al.,* 2005). The process involves the identification of animal traits that influence income and costs and the estimation of their relative economic worth. Unconventional breeding objectives are more complex to derive because of the lack of market values for such traits, e.g. traits related to aesthetic appeal, cultural preferences and animal welfare. However, tools for defining unconventional breeding objectives that focus on non-market traits have been developed. Olesen *et al.* (2000) discussed the approaches to non-market valuation of animal traits on the basis of the fact that animal breeding impacts genetic diversity, environment and society and that animal science has a significant capacity to address sustainable livestock production. Scarpa *et al.* (2003) and Tano *et al*. (2003) explored the valuation of non-market traits for indigenous animal genetic resources in sub-Saharan tropics using conjoint analysis by ranking animal traits from choice experiments. Drucker *et al.* (2001) presented a summary of methods useful in deriving economic values for non-market traits, namely: the Contingent Valuation Method (CVM) based on willingness to pay (WTP) or willingness to accept (WTA) payment, product loss aversion method based on anticipated losses and opportunity cost method. When selecting for multiple traits, breeding objectives are normally defined as weighted average of traits of economic importance (Hazel *et al*., 1994). In breeding objectives with market and non-market traits, both market values for marketable traits and non-market values for non-market traits are used as weighting factors (Olesen *et al*., 2000). The methodologies for estimating economic values for market and non-market traits are no longer a major limiting factor to the design of optimal breeding programmes.

Choice of selection criteria, animal performance recording, genetic evaluation and selection practiced within designed animal breeding programmes depend on the developed breeding objectives. The application of these steps occurs within varying forms of breeding programme designs, for example, progeny testing, young bull selection and half-sib selection (these three forms in most cases involve recording in the whole population) or nucleus breeding programmes (selection of animals restricted to a separated breeding population) (Syrstad and Ruane, 1998). Recording in whole or parts of a given population for the benefit of a group of farmers would require the consent and participation of the target group to be successful (Sölkner *et al*., 1998). This means that some level of organisation among the farmers is critical in the management of the breeding programme. Livestock farmers could be defined as owners of a common pool renewable resource. Managing the resource for long-term sustainability has been an important subject of research and development. The establishment of strong institutions has been recommended in the management of common pool resources sustainably in the long-term (Scully, 1988; Sun, 2007). The knowledge of how institutions are formed, operate and interact in the management of natural resources is therefore of critical importance in the design of animal breeding programmes.

Historically, institutional framework analysis may have been introduced by the publication of "The tragedy of the Commons" by Hardin (1968) that discussed how deregulation and lack of proper policies could result in conflicts between communities. The main objectives of institutional framework analysis are associated with the need to know the primary and secondary actors in a given system as well as the complexity of interactions between them to allow for the distinguishing between conflicting roles and the possibilities for trade-offs among the key actors (Grimble *et al*., 1995; Grimble, 1998).). Another importance of the institutional framework is observed in the large effects it has on the efficiency and growth rate of local economies and sustainable development (Scully, 1988). Existing frameworks of key actors have profound impact on the sustainable management of common natural resources, for instance, livestock breeding and conservation programmes, which operate under stakeholder partnerships. Institutional analysis is generally varied with respect to the system in question but broadly follows guidelines presented by Messer and Townsley (2003) for analysis of local institutions and livelihoods. These are: a) understanding the key concepts of the system in relation to resources and livelihoods, b) reviewing of background information, c) community profiling, d) understanding household livelihood strategies, e) understanding local institutions and finally f) analysing and understanding linkages between stakeholders. Healthy institutions such as farmer organisations and government agencies have the capacity of running successful breeding programmes through regular evaluation of decisions made and offering alternative responses to systematic changes occurring over time.

The evaluation of breeding programmes can be done pre- and post-implementation. Computer technologies have made it possible for breeding programmes to be simulated with predictions on their genetic and economic merits. Computer programmes available for the evaluation of breeding programmes include ZPLAN (Willam *et al*., 2008) and SelAction (Rutten *et al*., 2002). ZPLAN is basically a complex amalgamation of quantitative genetics equations based on the selection index and gene flow methodologies written in FORTRAN 77 programming language (Willam *et al*., 2008). The development of ZPLAN was done by Karras *et al.* (1997) who reviewed the PhD thesis of Niebel (1974) on "Methodology of planning breeding for pure breed cattle by optimisation of genetic and economic progress" (*Methodik der Zuchtplanung fiir die Reinzucht beim Rind bei Optimierung nach Zuchtfortschritt und Züchtungsgewinn*) together with the study on gene-flow by McClintock and Cunningham (1974). Hocking *et al*. (1983) in the review on computer programmes for teaching animal breeding and genetics, described several programmes designed for the optimisation of genetic and economic responses from animals as shown in Table 1.2. Apart from SelAction, all the other programmes are batch files that require user-defined input statements as required in deterministic approaches of modelling. SelAction is an interactive optimisation tool that uses deterministic simulation with in-built options for users. Modelling is a process of systems analysis that makes use of computer technology to simulate real life situations through exploring interactions between the complex multidisciplinary components of a system and/or predict the systemic responses under a variety of operating conditions (Hervé *et al*., 2002). Deterministic models precisely define outputs which could easily be reproduced; on the other hand, models that produce different outcomes from the same initial conditions by accounting for the dynamic variability of unknown random factors in the system are stochastic (Rosenkranz, 1973; Sorensen, 1990).

Table 1.2 Computer programmes for optimisation of animal breeding programmes

Programme	Description	Type	Language	Reference
BREEDPLAN	Optimisation of genetic and economic response from animal breeding programmes	Batch file	FORTRAN	Petersen, 1974
GFLOW	Gene flow and discounted expressions for any type of population structure	Batch file	FORTRAN	Brascamp, 1978
ZPRI	Optimisation of genetic and economic response from animal breeding programmes (mainly for cattle)	Batch file	FORTRAN	Karras, 1984
ZPSW	Optimisation of genetic and economic response from animal breeding programmes (mainly for pig populations)	Batch file	FORTRAN	Karras, 1984
ZPLAN	Optimisation of genetic and economic response from animal breeding programmes	Batch file	FORTRAN	Karras *et al*., 1997 (Willam *et al*., 2008)
SelAction	Prediction of selection response and rate of inbreeding in livestock breeding programs	MS Win	Borland Delphi 5.0	Rutten *et al*. 2002

Modified from Hocking *et al*. (1983) with additions from Willam *et al*., 2008 and Rutten *et al*., 2002.

Evaluation of animal breeding programmes through modelling allows not only the prediction of genetic and economic performance, but also the assessment of the impact of breeding and investment decisions after years of implementation of the breeding programme. In sub-Saharan Africa, breeding programmes for indigenous livestock have been lacking even though designing optimal breeding programmes has been made increasingly possible by the development of cost-effective technologies. Modelling breeding programmes is a less expensive way of comparing options for sustainable use of animals.

1.3 The Boran cattle

The Boran is a large east African Zebu breed that is now considered to have distinct groups of unimproved and improved Boran (DAGRIS, 2007). The unimproved Boran is utilised in subsistence and semi-commercial systems of production in Ethiopia, Kenya and Somali where it is commonly called Borana, Boran or Awai respectively (AGTR II, 2006). According to the Boran Cattle Breeders' Society (BCBS) of Kenya and Hanotte *et al*. (2000), the improved Boran is a product of the Zebu (*Bos indicus*), near East-European *Bos taurus* and native African *Bos taurus*. The breed is adapted to tropical rangelands. For instance, it possesses high number of sweat glands which enable it to withstand high ambient temperatures and to thrive well in dry and low rainfall areas (AGTR II, 2006).

The two strains of Boran cattle differ in performance for growth, reproduction and fitness. The improved Boran is heavier at birth averaging 30 kg compared to an average of 26 kg for the unimproved type (DAGRIS, 2007). This translates to heavier sale weights for the improved Boran of up to 419 kg for steers at 36 months of age (Rewe *et al.*, 2006a). In general, the unimproved Boran has relatively longer calving intervals and calves first at an older age than the improved Boran (Okeyo *et al.,* 1998). However, variation in reproductive performance exists also among the improved type. For instance, Okeyo *et al*. (1998) reported a calving interval of 426 days for improved Boran herds in Laikipia district of Kenya while an average of 577 days was reported for an improved Boran ranch located in Nakuru district (Rewe *et al.,* 2006a). This presents an opportunity for within-breed selection among the Boran cattle. Comparison between these two Boran cattle types with respect to milk production is scarce because they are mostly utilised as beef cattle. Freetly and Cundiff (1998) found that the lactation length averages 200 days with a lactation yield of 889kg. Similarly, Ouda *et al.* (2001) reported a lactation length of 203 days and a lactation yield of 849 kg. Figure 1.3 shows some improved Boran cattle in their natural environment.

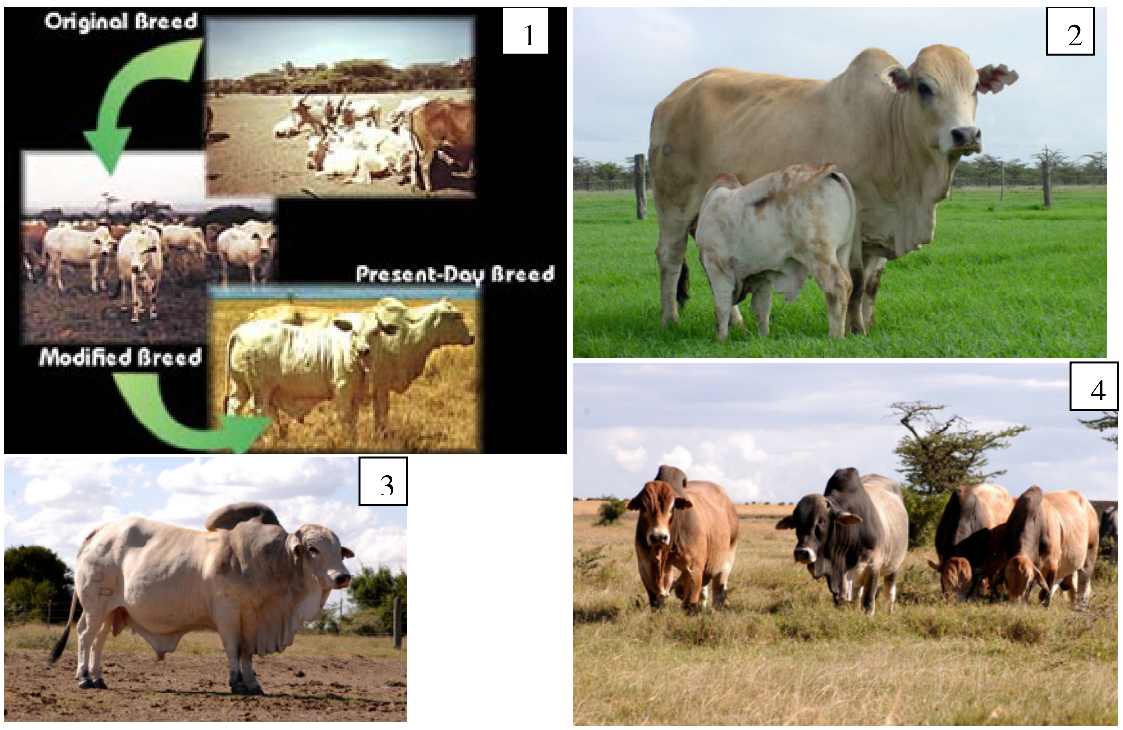

Figure 1.3 (1) Development of the improved Boran, (2) Improved Boran cow and calf, (3) Improved Boran Bull, (4) Herd of young Improved Boran bulls: Source (Ol Pejeta, 2007 and BCBS, 2008)

The trend in performance for growth and reproduction traits has been relatively stable over the last decade with major fluctuations attributable mainly to environmental challenges related to feed availability and climate (Wasike *et al.,* 2006). Roland (1995) reported that the unimproved Boran types such as Orma Boran is hardier and more trypanotolerant than the improved Boran. Years of selecting improved Boran on growth have made the breed more susceptible to tropical diseases than its unimproved counterpart (Hanotte *et al.,* 2003). Since the year 1951, the Boran cattle Breeders Society (BCBS), which is the first breed society in East Africa to create guidelines for improving indigenous cattle (BCBS, 2008), has continued to establish the improved Boran as a recognised breed. The main objective of the BCBS is beef production while retaining the efficiency and adaptation of the breed to harsh conditions.

1.4 Design of study

1.4.1 Study area

The current study focussed on semi-arid Kenya where the Boran breed is raised. Information for the improved Boran was sourced from the Lanet Boran Stud of the National Beef Research Centre and from the Boran Cattle Breeders Society's commercial beef ranches. A majority of these ranches are located in the Laikipia region and its environs where also pastoralism and agro-pastoralism exist. Figure 1.4 shows the Laikipia region of Kenya. Laikipia region of Rift Valley province is located within the central part of the country in the rain shadow of Mt. Kenya.

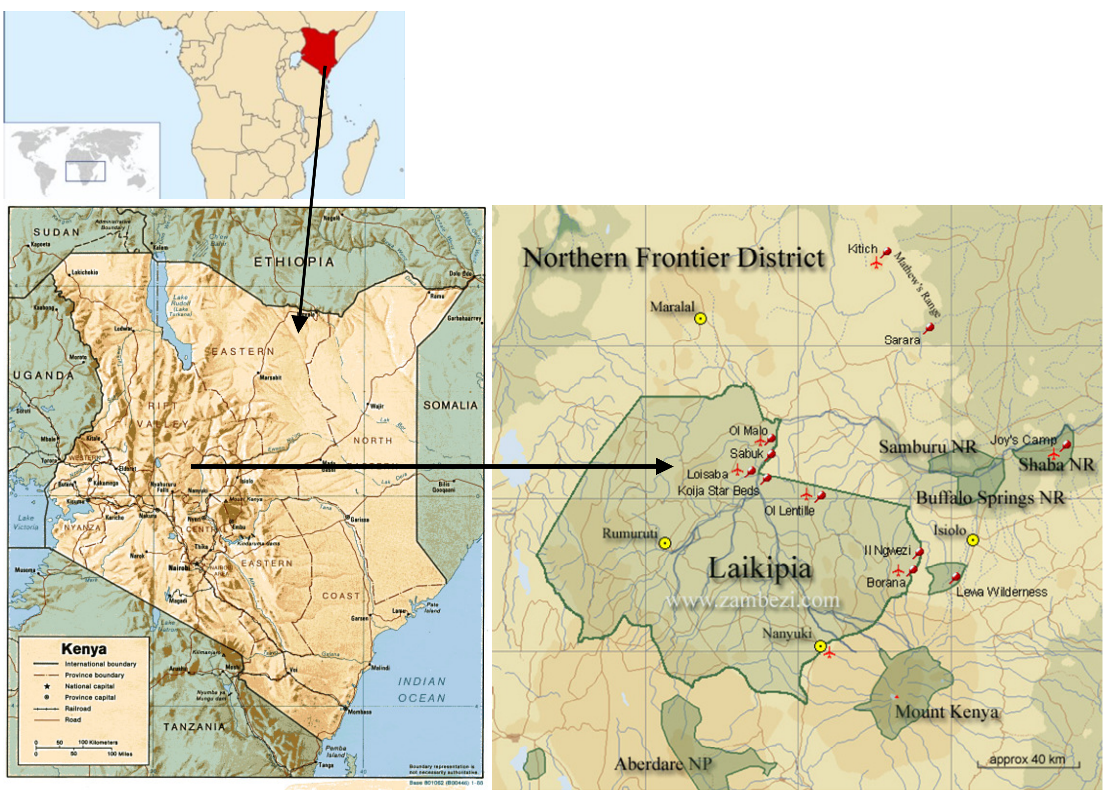

Figure 1.4 Laikipia region of Kenya (AGTR II, 2006)

The rainfall is between 400 and 800mm per annum and the altitude ranges between 1600 and 2300 m above sea level. The district has a diverse population consisting of pastoralists in the Northeast and agro-pastoralists in the rest of the district. Seventy five percent of the total land area is devoted to livestock production and game parks/reserves. Over 50 percent of the total land area is occupied by large-scale beef ranches while the rest is the unsettled smallholdings and group ranches owned by the pastoral Laikipia Maasai (Laikipia District Development Plan, 2002).

1.4.2 Justification and objectives of the study

Currently, a harmonised genetic improvement programme to fulfil Boran cattle farmers' breeding objectives is lacking. This has contributed to the inability of commercial beef ranches to inform their choices with respect to purchasing quality breeding stock. Rangeland beef production is dependent on rain-fed natural pastures. The climatic conditions which impact on pasture availability in the semi-arid areas also impacted negatively on growth and fertility performance of the Improved Boran (Wasike *et al*., 2006). Irregular trading between low-input farmers keeping unimproved Boran and the commercial beef farms keeping the improved Boran has been reported despite these limitations (Mwacharoa and Drucker, 2005). There is the need to put in place organised breeding programmes for the Boran in Kenya to harmonise the genetic improvement strategies. It is upon this background that the present study was envisaged to design optimal and sustainable breeding programmes for Boran cattle, the results of which are presented in this thesis.

The overall objective was to design optimal breeding programmes for an indigenous beef cattle breed reared in the semi-arid tropics. The focus was on the improved Boran cattle of Kenya with considerations of the existing populations of unimproved Boran cattle raised by market oriented low-input pastoralists and agro-pastoralists that interact with large scale commercial ranches. The achievement of this objective was undertaken by addressing the following research questions:

1. What is the potential for beef cattle genetic improvement in sub-Saharan Africa?
2. What is the state of institutional support, the structure of Boran cattle farm types in Kenya and the genetic and economic merit of a basic breeding programme based on Boran breeders who register with the Kenya Stud Book?
3. What are the genetic and economic merits of alternative breeding programmes based on: a) the improved Boran incorporating all embers of BCBS? b) the low-input Boran cattle population? c) an expanded and inclusive breeding programme capitalising on the interactions between these two Boran populations?
4. How does an optimal cost-effective breeding design for the Boran cattle work in the context of the prevailing institutional, infrastructural and socio-political environment?

1.4.3 Structure of thesis

The thesis is set up into seven chapters that account for the various research questions raised in this study as well the bibliography. The chapters have been presented as follows;

- Chapter 1: General introduction: Outlines the situation of beef cattle in sub-Saharan Africa and the Boran cattle of Kenya. It provides an overview on the methods used for designing optimal breeding programs. The chapter also identifies the background of the current study, the objectives of the study and a chapter by chapter structure of the thesis.
- Chapter 2: Beef Cattle in the sub-Saharan region: Presents a historical and statistical background with respect to beef production while identifying the

potential for commercial beef production and genetic improvement strategies using indigenous animal genetic resources from sub-Saharan Africa.

- Chapter 3: The Boran cattle of Kenya: Identifies the institutional framework supporting Boran breeding in Kenya alongside a basic breeding programme based on a section of elite breeders from the Boran Cattle Breeders Society (BCBS) who record with the Kenya Stud Book (KSB).
- Chapter 4: Alternative breeding programmes: Analyses the feasibility of establishing breeding programmes for the entire BCBS membership as well as one based on the low-input beef producers. The chapter also explores an expanded programme for BCBS and low-input producers. The sensitivity of the breeding programmes to changes in biological and technical circumstances is also discussed.
- Chapter 5: General Discussion: Integrates all previous results together with findings from the literature in consolidating a working example for a nucleus breeding programme suitable for the improved Boran cattle under the present production, marketing, breeding and socio-political circumstances.
- Chapter 6: General summary: a comprehensive summary of the concept of the thesis, material and methods, results and the implications of the results of the study written in English, Deutsch and Kiswahili.
- Chapter 7: References: includes all the cited publications from all chapters.

CHAPTER 2

BREEDING BEEF CATTLE IN SUB-SAHARAN AFRICA:

A REVIEW

CHAPTER 2: BREEDING BEEF CATTLE IN SUB-SAHARAN AFRICA

Breeding indigenous cattle genetic resources for beef production in sub-Saharan Africa

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Abstract:

The objective of this paper was to review breeding technologies vital for breeding programme development in sub-Saharan Africa while considering indigenous cattle genetic resources for beef production. The importance of beef cattle was highlighted considering the globally and regionally growing demand for meat and the fact that Sub-Saharan Africa is home to a large population of indigenous cattle, for whom however, few examples of successful breeding programmes exist. Examples were analysed including the N'Dama pure breeding programme in western Africa, Boran improvement programme in eastern Africa, Nguni cattle breeding in southern Africa and Ankole cattle of Uganda. The characteristics of sub-Saharan Africa with respect to livestock production systems, livestock breeds and socio-political aspects have mostly not permitted a successful breeding technology transfer from developed countries. Technological adjustments and increasing consideration of target group involvement in livestock breeding programmes may offer better possibilities for raising production by breeding in low- and medium-input livestock production systems. Recognising differences in the characteristics of livestock keepers allows for differentiation into breeder groups and commercial groups. Breeder groups are important as targets for genetic improvement programmes via community-based genetic improvement organisations. Breeding programmes are suggested in sub-Saharan Africa within the concept of regional genetic improvement programmes under the control of stakeholders comprising of breed societies, government, and national agricultural research systems.

Key words: sub-Saharan Africa, Beef cattle, breeding programmes, genetic improvement

2.1 Introduction

Livestock production plays an important role in agro-based economies in both developed and developing countries. The demand for livestock products is growing faster than other agricultural products and human nutritional demand indicators reveal an eminent direction towards a "Livestock Revolution" especially in developing countries (Delgado, 2003; Tambi and Maina, 2003). For this revolution to be realised in the beef production sector, stakeholders need to prepare strategic long-term plans to accommodate the challenges of limited resources such as land, labour and capital as well as non-resource challenges related to socio-cultural characteristics of farmers. Animal breeding is a vital component of livestock production that addresses future direction and gives importance to the need for long-term planning to prepare the livestock industry for potential benefits of genetic improvement (Hammond, 2006). In line with the objective of long-term planning, reviewing predictive research studies that provide informed suggestions on the direction of livestock breeding with respect to technological advancement, adoption and application are considered to be useful.

Indigenous cattle are worth noting when considering livestock production in sub-Saharan Africa, as they are mostly utilized for beef production unlike dairy production, which has relied mainly on imported genetics (Madalena *et al.,* 2002; Valle Zárate *et al.,* 2006). Despite the importance of indigenous cattle for beef production in tropical countries, only few examples of successful breeding programmes for them exist. In Brazil, for example, breeding programmes for indigenous cattle have been successful because of the cooperation between breed societies, groups of breeders or private firms and universities and research institutions (Madalena *et al.,* 2002). This shows the importance of cooperation in solving livestock production challenges. There is potential of developing countries for beef production, especially in the regions where large populations of beef cattle exist (Scholtz *et al.,* 2002; Rewe *et al.,* 2006b).

A major drawback in improving productivity especially in response to future demands for livestock products in sub-Saharan Africa is the absence of organised breeding programmes. The eminent potential of community-based breeding programmes (Galal *et al.,* 2000), that counteract infrastructural bottlenecks and the realisation that the definition of "community based" does not necessarily mean "resource poor" (Kahi *et al.,* 2005), presents new possibilities for breeding programme development in sub-Saharan Africa.

The objective of this paper is to review breeding technologies vital for breeding programme development in sub-Saharan Africa while considering indigenous cattle genetic resources for beef production. Livestock breeding programmes are described based on the general definition modified here to refer to a procedural combination of technologies aimed at genetic improvement of performance, conservation or maintenance of breed integrity while considering biological and socio-economic aspects of the production system. This takes into account the definition of appropriate breeding objectives, determination of selection criteria, performance recording and evaluation. Optimal mating systems that take advantage of available infrastructural capacity as well as socio-economic aspects of the production systems are also discussed (Valle Zaráte, 1996).

2.2 Beef demand and production trends

In sub-Saharan Africa, the demand for food protein (especially meat) is increasing as a result of increasing population size, income and urbanisation (Tambi and Maina, 2003; Delgado, 2003). Delgado (2003) reported an increase in the demand for meat of 70 million metric tons in developing countries in the period beginning 1970s to the mid 1990s, more or less tripling the demand levels in developed countries. The projected demand for meat from

1997 to the year 2020 is expected to be higher (65%) in developing countries, a majority of which are found in sub-Saharan Africa. The relevance of beef cattle populations both in numbers and breed formations is brought to light, since production targets must be carefully matched with both type and number of available beef cattle genetic resources.

Figure 2.1 shows the output of beef and veal from major producers. In the tropics, Brazil, India and Mexico represent some of the major producers. Noticeably, the major producers are either large countries (e.g. USA with over 11, 000,000 metric tonnes and Brazil with over 6,000,000 metric tonnes) with vast land holdings for beef production or trading blocks (e.g. The European Union). Africa as a block has the potential to yield over 3,717,000 metric tonnes of beef with east Africa alone producing approximately 1,310,000 metric tonnes (Tambi and Maina, 2003).

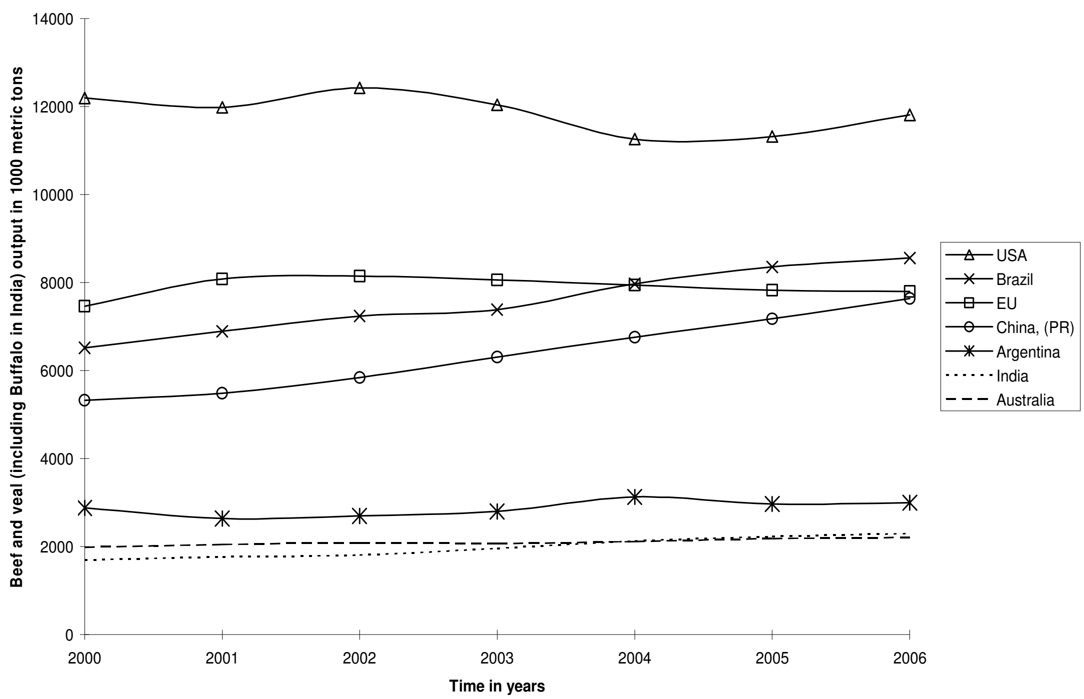


Figure 2.1 Beef and veal output from major producers in the world: (extracted from USDA 2002; 2005):

Sub-Saharan countries, which are home to 146 cattle breeds/strains (Rege and Tawah, 1999), have the potential to contribute highly to the world beef trade. Factors identified as possible determinants of beef output include 1) herd size, 2) off-take (proportion slaughtered), 3) individual productivity and 4) the interaction of the above three factors (Tambi and Maina, 2003). However, analysis of beef output in 1978 and 1998 in Africa reveals a general increase in average output for Africa as presented in Figure 2.2. In 1978, southern Africa had the highest production levels (992,000 metric tonnes) whereas in 1998 eastern Africa was the highest producer (1,310, 000 metric tonnes). The increase in beef output in eastern Africa was attributed mainly to expansion of herd sizes rather than increase in individual productivity of animals. Considering the rate of population growth *vis a vis* the demand of extra land for settlement and alternative use, increasing cattle populations is expected to face stiff challenges in the future (Tambi and Maina, 2003).

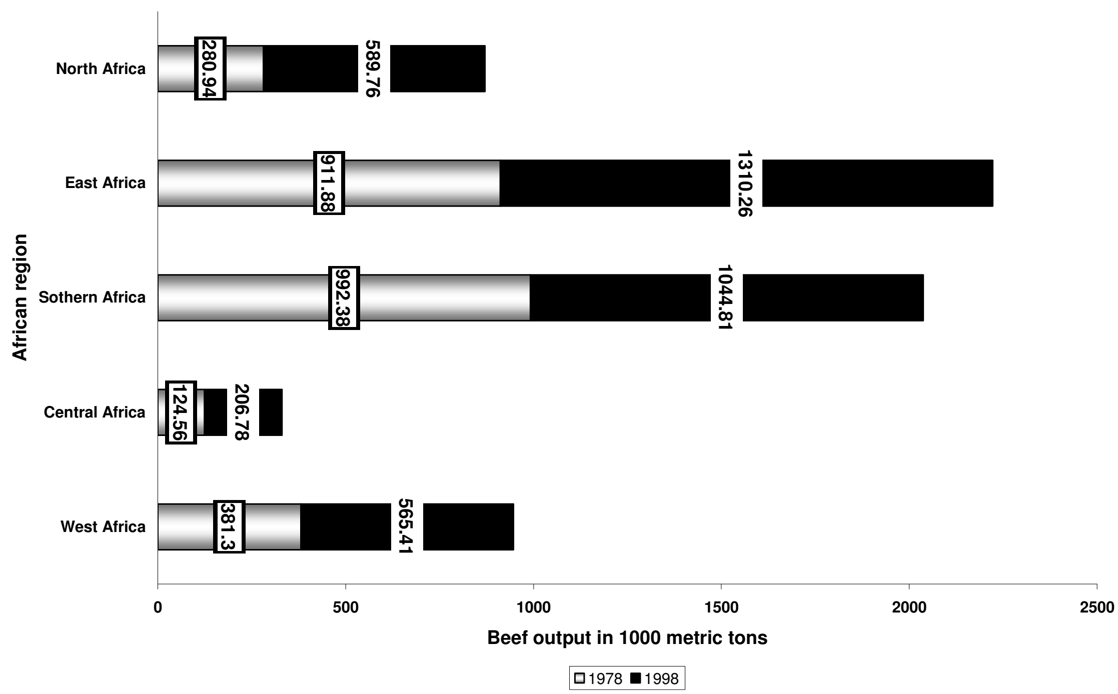


Figure 2.2 Regional beef output for Africa in 1978 and 1998: (extracted from Tambi and Maina 2003):

2.3 Distribution of beef cattle in sub-Saharan Africa

African cattle, their origin, characteristics and distribution are well documented in the literature (Rege and Tawah, 1999; DAGRIS, 2006). In this review, the focus is on commercial types of cattle in sub-Saharan Africa and recent developments in breeding are presented. Table 2.1 summarizes single line breeds and composite breeds of cattle in sub-Saharan Africa. These breeds can be broadly classified into five main groups based on genetic origins, two of these comprise of single line breeds and the other three are line combinations and commercial composites. The two main morphological classes are *Bos indicus* (humped cattle commonly referred to as Zebu) and *Bos taurus* (humpless cattle) while the three combinations are Sanga (stable crosses of *B. indicus* x *B. taurus*), Zenga (stable crosses of Sanga x Zebu) and the composite lines (recent derivatives between and within breeds including crosses with exotic temperate breeds) (Hanotte *et al.,* 2000).

Among the single line origin groups, the Kuri (west/central Africa), Kenya Boran, (east/central Africa), Sokoto (Nigeria), White Fulani (Nigeria) and Maure (Mali) represent heavier types while among the combined origin groups, the Nguni (southern Africa), Tonga (Zambia), Baroste (southern Africa), Tuli (Zimbabwe) and Afrikaner (South Africa) are heavier types (Rege and Tawah, 1999). The combined origin group must have undergone some strategic breeding. This has contributed to the current existence of breeding activities within these groups and also the presence of breed societies that govern the integrity of these breeds. Among the combined origin groups are the commercial composite cattle (e.g. Bonsmara) that have strong breed societies that manage the breeding and trade in breeding stock. The Kenya Boran cattle are classified within the Large East African Zebu (*B. indicus*), however, recent evidence shows presence of taurine blood (Hanotte *et al.,* 2000) indicating a long history of crossbreeding with exotic genotypes. Crossbreeding was also practiced with other Zebu breeds in the Tropics that were reared by settlers during the colonial era (Madalena *et al.,* 2002). The presence of breeding activities as well as organised breed societies for some of the indigenous sub-Saharan cattle breeds is promising.

Table 2.1 Specialised indigenous cattle in sub-Saharan Africa, their unique characteristics, utilisation and origin

Breed	Native Location	Unique Features and Key Functions	Current Breeding activities	References
Single origin				
Barka	Eritrea/ Ethiopia	▪ Good milk production ▪ Dual Purpose	-No organised genetic improvement programme	DAGRIS, 2006
Boran (improved)	Kenya	▪ Tolerant to heat, ticks, ▪ good mothering ability Primarily for beef production	-Breeding activity present Pure breed, strategic crossbreeding as maternal line for beef, dual purpose and dairy ranching	*www.borankenya.org*
Butana	Sudan	▪ Good milk production ▪ Typically for dairying	-No organised genetic improvement programme	DAGRIS, 2006
Kenana	Sudan	▪ Good milk production ▪ Typically for dairying	-No organised genetic improvement programme	DAGRIS, 2006
Kuri	West Africa	Excellent swimmers, poor heat and draught tolerance ▪ General purpose	-No organised genetic improvement programme	DAGRIS, 2006
N'Dama	West/central Africa	▪ Trypano-tolerant ▪ Beef production	-Breeding activity present	http://www.itc.gm/html/purebreeding_programmes.html
White Fulani	West/central Africa	▪ Favourable for both milk and meat production	-No organised genetic improvement programme	DAGRIS, 2006
Mixed origin				
Ankole	Great Lakes region (East Africa)	▪ Favourable tick resistance ▪ General purposes ceremonial functions ▪ Conspicuously large horns	-Used in the development of Ankole-Watusi in the USA -Crossbreeding with *B. taurus* for milk production	DAGRIS, 2006 Nakumbugwe *et al.* (2005)
Afrikaner (Afrikander)	South Africa	▪ Good resistance to heat and ticks. ▪ Primarily for meat production	-Crossed with Shorthorn to develop Bonsmara -Crossed with Holstein to develop Drakensberger	*http://studbook.co.za/society/afrikaner/index.html*
Bonsmara	South Africa	▪ Functional efficiency for beef production	- Breeding activity present	*www.bonsmara.co.za* Rege and Tawah (1999)
Drakensberger	South Africa	▪ Functional efficiency for beef and milk production	- Breeding activity present	*http://studbook.co.za/society/drakensberger/index.html*
Mpwapwa	Tanzania	▪ Dual purpose animal	-No organised genetic improvement programme	DAGRIS, 2006
Nguni	South Africa	▪ Multicoloured beef and draft animal has potential for milk production	- Breeding activity present	*http://studbook.co.za/society/nguni*
Tuli	Zimbabwe /southern Africa	▪ Docile, naturally polled ▪ Primarily for beef production	- Breeding activity present	*http://tuli.co.za/*

Systematic breeding programmes with operational subsections are not entirely in place due to organisational and infrastructural disadvantages. The establishment of such programmes seems increasingly possible in the foreseeable future with the advancing knowledge on community-based breeding programmes (Kahi *et al.,* 2005; Wurzinger *et al*., 2008).

2.4 Technological advancements for breeding objective development

Technological adjustments and increasing considerations of the human factor (target group involvement) in livestock breeding programmes have brought new perspectives for integration of regionally prevalent low- and medium-input livestock production systems (Galal *et al.,* 2000). In this regard, the principles of breed improvement in relation to breeding objective development are hereby briefly discussed.

Hazel (1943) described a breeding objective as the aggregate genotype. This definition already referred to the advantages of multi-trait selection over single-trait selection. Since then, a series of modifications to the definition of a breeding objective have been proposed. Harris and Newman (1994) reviewed these developments comprehensively noting the shift from breeding objectives of appearance to those involving performance. However, the economics of animal production require that the breeding objective achieves optimal genetic progress towards a stated economic goal (Kluyts *et al.,* 2003). Therefore, breeding objectives need to be defined in economic terms. Breeding objectives can be generally defined as optimal combination of breeding values (performance) weighted by appropriate economic values (Hazel, 1943).

Beef cattle in sub-Saharan Africa are reared under varied conditions that require target-group-specific breeding objectives. The difficulty of defining appropriate breeding objectives for the various groups is compounded by the existence of different relationships between livestock and humans (Neidhardt *et al.,* 1996). In this region, not all cattle are reared traditionally with higher importance of non-commercial objectives because of the presence of large scale ranches that specialise in beef production (Scholtz *et al.,* 2002; Rewe *et al.,* 2006b). The breeding, production and marketing systems that characterise beef cattle production in sub-Saharan Africa, based on the level of organisation are presented in Table 2.2.

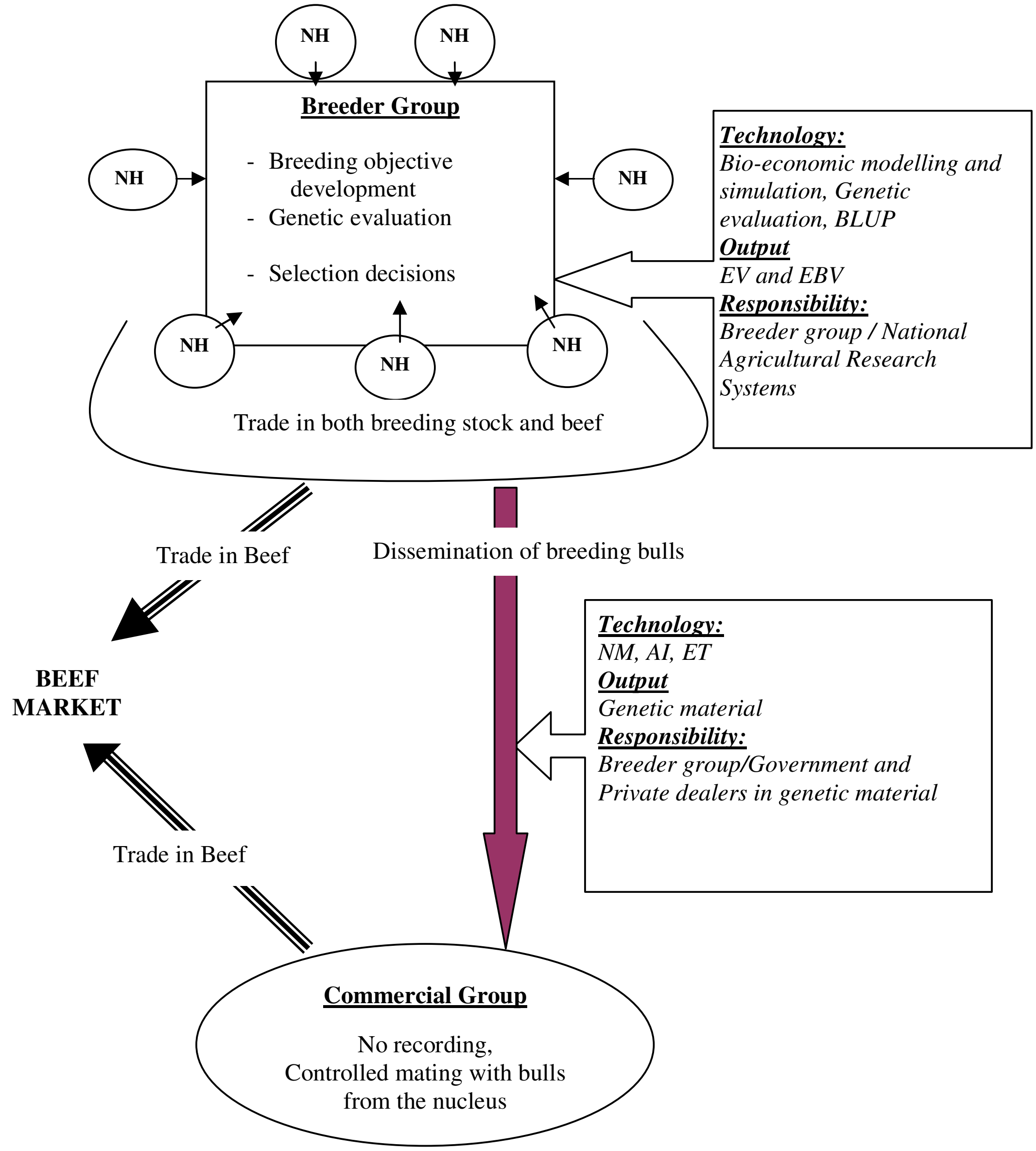
Table 2.2 Cattle production systems with a beef component in sub-Saharan Africa

Production system	**Descriptors**	**Potential breeding objective**	**Reference**
Nomadic/Pastoral	- Indigenous cattle (mostly) - Traditional settings - Migratory - Basic animal health services - Irregular marketing - Rangeland grazing - Large (mixed) herds - Low-input	Multipurpose objective Milk, meat, draft, social security, savings and animal by-products	Neidhardt *et al.* (1996)
Farm Integrated	- Indigenous and crossbreds - Animal husbandry practiced - Utilisation of crop residues - Peri-urban - Animal health services - Strategic marketing - Small herds - Low to medium input	- Dual-purpose objective - Meat and milk	Neidhardt *et al. (*1996)
Market oriented	- Purebreds indigenous/exotic and crossbreds - Integrated herd management - Record keeping - Ranch grazing - Animal health services - Regular marketing - Farmer organisations - Large herds - Medium-input	- Single-purpose objective - Meat production	Madalena *et al.* (2002) Kahi *et al. (*2005)

The approach towards developing appropriate breeding objectives must consider that the relationship between man and livestock is not always the same even in relatively similar production systems. Neidhardt *et al.* (1996) distinguished between livestock users, livestock keepers, livestock producers and livestock breeders. Briefly, livestock users were defined to have a purely exploitative relationship with the animal, livestock keepers as those that perform basic husbandry practices, livestock producers as those that supply additional inputs to improve animal production, while livestock breeders are those having integrated herd management focussing on disease control, feeding and reproduction. Application of genetic improvement practices without consideration of these differences generally leads to failure. The group that is more likely to respond to systematic breeding practices are the livestock breeders. As observed by Sölkner *et al.* (1998), the step from livestock user to livestock breeder is large and must first be preceded by the step from livestock user to livestock keeper. The difficulty to convert from user to keeper relates to productivity with respect to capital. Livestock users achieve high work productivity due to their extremely low inputs (almost zero capital) even though product output is low compared to livestock keepers (Neidhardt *et al.,* 1996). However, external pressures such as increase in human population, increase in demands for products and reducing land sizes favour the change from user to keeper or producer. The market-oriented group (Table 2.2), which comprises of breeders and producers, have been regarded as primary targets for consideration when establishing genetic improvement programmes (Kahi *et al.,* 2005). A reason for this view is the inclination of the market oriented groups to technology adoption and transfer of genetic material. Less organised groups like nomadic pastoralists could also benefit from genetic improvement without necessarily increasing their input levels, if genetic improvement is directed towards their needs. In some cases, interactions between the pastoralists and breeder/producer groups exists (Rewe, 2004). This could allow for improved genetics to flow across different production systems (Kahi *et al.,* 2005).

The lack of success of the few attempted nucleus breeding programmes in sub-Saharan Africa requires the development of alternatives. Less bureaucratic nucleus breeding programmes based at the community level have been suggested (Sölkner *et al.,* 1998; Galal *et al.,* 2000; Kahi *et al.,* 2005). Nakimbugwe *et al* (2005) presented a case for Friesian cattle nucleus breeding programme in Uganda where a selected large-scale farm was targeted as the potential nucleus. In such situations, the administration of dissemination of superior genetics is done by small groups that are connected by similarity in production objectives. For instance, Kahi *et al.* (2005) presented a collaborative breeding programme depicting an organisational structure led by the community of interest working with strategic partners. In such a programme, the management of dissemination of genetic material through appropriate reproductive techniques would be the prerogative of strategic partners which would include National Agricultural Research Systems (NARS) and breed societies. The role of breed societies is vital especially in maintaining breed standards and marketing the breed. Moreover, breed societies could participate in running a breeding plan within a community-based livestock genetic improvement scheme. National scale breeding programmes suffer the disadvantage of being too complicated with respect to scale of operations and further complicated by political discontinuity, political rather than technical priorities and infrastructural bottlenecks. This problem could be approached through minimising complexity of the breeding programme as is the case in regional or community-based livestock breeding programmes (Trivedi, 1998).

Figure 2.3 shows a classical nucleus breeding pyramid modified into a less complex organisational entity. In this case, a regional breeding programme with strategically “dispersed” nucleus herds operates under a centralised data management system where breeding objectives are developed and selection decisions made. Regional breeding programmes could play a major role in maintaining genetic diversity and serve as a less complex community-based organisation for genetic improvement of livestock (CBOGIL).



Key: NH = Nucleus herds; NM = Natural mating; EV = Economic values for breeding objective traits; EBV = Estimated breeding values; ET = Embryo transfer; BLUP = Best linier unbiased prediction for genetic evaluation

Figure 2.3 Operations of a breeder group and a commercial group within a regional closed-nucleus breeding schemes

Such organisations have the potential to serve as decentralised genetic improvement systems for specific beef cattle genetic resources based on certain breeding objectives to maintain a desired level of genetic diversity. But they need to be well coordinated by national livestock improvement bodies especially on exchange of genetic material between various CBOGILs. The collective effects of various CBOGILs could serve as an avenue for development of nationally co-ordinated breeding programmes with broader objectives in sub-Saharan Africa (Kahi *et al.,* 2006).

2.5 Examples of some breeding programmes in sub-Saharan Africa

2.5.1 N'Dama cattle of Western Africa

The N'Dama cattle are widely distributed in western Africa and are reared in low input systems characterised by periodic extreme scarcity of feed and the presence of Trypanosomiasis and tick-borne diseases (Dempfle and Jaitner, 2000). It is against this background that the International Trypanotolerance Centre (ITC) initiated the N'Dama pure-breeding programme in 1995 to propagate the genetics of the adapted N'Dama cattle in western Africa. The breeding programme operates under the ITC and was designed as a three-tier (nucleus, multiplier and commercial herds) open-nucleus system under a multiple breeding objective (meat, milk and disease resistance) (ITC, 1999). To maintain low operation costs and shorten generation intervals, a simple young-sire system was preferred over a progeny testing scheme. Two major factors noted as important for the success and sustainability of this programme were building of capacity of local staff and income generating ability of the programme through selling of breeding stock (Dempfle and Jaitner, 2000). These factors show the importance of local ownership as well as the need to consider the refinancing potential of breeding programmes and their connection to marketing. A close working relationship was emphasised and resulted in effective linkages between researchers operating the nucleus and participants in the second and third tiers of the scheme leading to the formation of the Indigenous Livestock Breeders Associations in 2002 (Bosso, 2006). In Gambia for example, the Gambian Indigenous Livestock Multiplier Association in the Salum and Fuladu areas (GILMA-Salum and GILMA-Fuladu) were established and their sensitisation supported through appropriate public awareness campaigns. The breeder associations are responsible for ensuring public awareness of the availability of breeding males in multiplier villages, purchase of male offspring from multipliers and dissemination to needy farmers, organising farmers to participate effectively in the breeding schemes as well as supplying veterinary inputs. These organisations experience constraints related to communication problems, shortage of publicity and lack of organisational and managerial skills and funds for self-maintenance. These challenges are being addressed by ITC and their partners comprising of departments of livestock services in the region (Bosso, 2006).

2.5.2 Boran cattle of Eastern Africa

Kenyan Boran cattle constitute the largest proportion of the population of *Bos indicus* breeds kept primarily for beef production in the semi-arid areas of Kenya. There, commercial beef production is performed under large-scale ranching. The challenge is how to manage the breeding activities in these ranches for purposes of advancing an organised genetic improvement programme. In 1968, a beef industry development programme was proposed and a National Beef Research Centre (NBRC) established which operated a nucleus herd. However, lack of well-defined breeding objectives, over-reliance on donor funding, as well as diversified and decentralised breeding, production and marketing systems led to stagnation of the programme (Rewe, 2004). In the 1970s, a recording scheme was initiated. Producers sent animal performance records routinely to the Livestock Recording Centre (LRC) for genetic evaluation. However, because of inconsistency and delays in the release of evaluation results, and the expenses associated with recording, most producers opted out of the scheme (Kahi *et al.,* 2006). From 1998 to 2000, a beef bull evaluation programme was introduced by the NBRC to spark off a genetic evaluation process within the various beef cattle farms in the country, but was short lived due to the absence of a long-term strategy both in terms of personnel and financing.

An operational genetic improvement programme comprising of all the vital components has therefore been elusive for the Boran breeders in Kenya. Nonetheless, individual efforts of the Boran cattle farmers under the Boran Cattle Breeders Society (BCBS) have led to the intuitive breeding of the improved Boran. The experiences of the Kenyan Boran cattle farmers under the Boran Cattle Breeders Society coupled with the unique herd characteristics of Boran cattle has attracted strong interests from countries such as South Africa and Australia. In 2003, the Boran Cattle Breeders Society of South Africa was founded with the overall goal of improving Boran production through breeding for both production and fertility traits under the South African National Beef Cattle Improvement Scheme (http://studbook.co.za/Society/boran/). At present, the activities of the society mainly involve administration, maintaining breed standards, and searching for new markets for both genetic material and beef. Boran cattle keepers are still independent with respect to selection and genetic improvement. To maintain the future competitiveness of this breed locally and internationally, a well-organised improvement programme with clear functional components of the genetic improvement process is necessary.

2.5.3 Nguni cattle of Southern Africa

The Nguni cattle, like most of their counterparts in Africa were previously crossbred with European breeds in an attempt to increase productivity. This dilution of indigenous cattle genetic resources continued as crossbreeding was assumed by most colonial settlers as the best means of genetic improvement. In 1950, the Bonsma report was published which brought to light the appreciable deterioration in performance of European breeds in the semi-tropical regions of South Africa (Nguni Cattle Breeders Society, 2006). The report further indicated that the performance of exotic cattle had dropped to a level even below the nondescript stock found in these areas resulting in the appreciation of indigenous cattle genetic resources (Bester *et al.*, 2001). In light of this realisation, the indigenous Nguni cattle were introduced into the commercial beef-growing sector where organised breeding was practiced. In 1985, the Nguni Cattle Breeders' Society was incorporated as a member of the South African Stud Book and Livestock Improvement Association with an approximate current population of 1.8 million heads. The Nguni is thus being selected for functional efficiency while maintaining its inherent unique traits (Nguni Cattle Breeders Society, 2006). The presence of the South African studbook and livestock breeders association who supports performance recording and organised breeding of not only the Nguni cattle but also other livestock species plays a major role in the sustainability and advancement of livestock breeding programmes in South Africa.

2.5.4 Ankole cattle of Eastern Africa

The on-going indiscriminate massive crossbreeding of the indigenous long-horned Ankole cattle with more productive exotic breeds has increased the threat to indigenous cattle breeds reputed for their adaptability to the local environment and having a great cultural significance to their local keepers. Conservation of the Ankole cattle through selective breeding to improve on production traits has been proposed through a nucleus breeding scheme with the nucleus at Nshaara stock farm, located in the traditional Ankole cattle keeping area in South-western Uganda. Uganda has responded to the challenge of making animal breeding an important component of its Poverty Eradication Action Plan (PEAP), by empowering the National Animal Genetic Resources Centre and Databank (NAGRC&DB), a corporate body under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) with the mandate to oversee animal breeding activities in the country. In response to the agro-ecological diversity, suitable for different types and breeds of cattle, NAGRC&DB has intentions to operate several large cattle breeding stock farms with different types of breeds including the indigenous Ankole cattle (Nakimbugwe *et al.,* 2005)

2.6 Breeding structures and choice of technology

In the breeding programmes illustrated above, as is the case in others elsewhere, governments and international development agencies took central roles in establishing breeding herds. Gradually, some strong local breed societies have taken up the initiative to oversee the breeding of their respective cattle types. The few existing breeding activities for some beef cattle breeds are mostly characterised by strong breeders' organisation as well as political goodwill. With strategic cooperation, breeding programmes could be established under the collective control of main stakeholders comprising of breed societies, government, and national agricultural research systems (NARS). Collective agreement by the stakeholders on the structures of the breeding programme enables the choice of appropriate breeding technologies.

The effect of breeding structures on the choice of technology is clear especially in extensive beef cattle production systems. Structural issues refer to the herd dynamics and the organisation of the production system. In developed livestock industries, stratification into breeders and commercial producers has emerged in some places. In sub-Saharan Africa, there is no clear demarcation of breeders and commercial producers and therefore beef cattle farmers play dual roles of breeding and trading in beef (Rewe, 2004). The movement towards differentiation within the beef industry in sub-Saharan Africa is hindered mainly by the lack of both technical and organisational incentives. For instance, technical incentives such as clear breeding objectives and selection criteria well coordinated within a selection tool are largely unavailable, a situation that could be attributed to the lack of well designed breeding plans. An organised breeding plan allows for the application of various technologies, may imply describing the functions of genotypes within the production system and defines the process of mate selection towards maximising genetic gain in traits of economic importance. Simulation offers a preparatory solution of testing several alternatives of breeding schemes useful for particular breeds of livestock within their environments. The analysis of alternative breeding schemes through simulation defines the direction of investment since breeding programmes are long term and expensive. This can avoid the chronic problem of dumping of development funds in unplanned breeding programmes that has resulted in the failure of some well-intended programmes (Sölkner *et al.,* 1998).

Establishment of breeding programmes requires special attention given the unique attributes of sub-Saharan Africa's low-input beef production systems. One important attribute is the existence of a wide variety of farmers with respect to organisational capacity and production objectives. In this regard, cattle keepers could be classified as breeder groups representing farmers who have some understanding of selection principles, combined with the ability to identify and record animals on-farm, and commercial groups representing producers of beef (Kahi *et al.,* 2005). Such community-based set-ups present a possibility of having a stratified system whereby breeder groups perform the roles of a nucleus serving as sources of breeding stock to the commercial groups. Figure 2.3 shows proposed operations of a simple community-based breeding programme based on a dispersed nucleus comprising of breeder groups. The organisational capacity of the breeder communities is presumed while considering the strategic involvement of government and NARS participating only as development partners. In the first process, breeding objectives that include economic and genetic values of animal traits could be developed by the community-based breeding organisation in conjunction with strategic partners that have capacity to implement various breeding technologies. Such technologies include bio-economic modelling for economic value estimation and BLUP for breeding value estimation. The initial important decision is the collective agreement on a recording system, which should outline the animal traits to be recorded, the methods of recording and the computerisation process of animal records. The convergence of data to a central work station for genetic evaluation based on the predefined community-specific breeding objectives requires the technological input of a strategic partner, for instance, the NARS. Having diverse regional breeding objectives even within the same breed of cattle is useful in maintaining the level of genetic diversity which presents an advantage for future breeders towards changes in consumer preferences. In this scenario, the breeder groups are expected to trade both on breeding stock and beef to optimise the profitability of their enterprise. They are also expected to disseminate breeding material to the commercial groups that do not record their herds but exist within the same region. The dissemination of genetic material depends on the conditions of infrastructure and the technology available for use. As illustrated in Figure 2.3, Artificial Insemination (AI), Embryo Transfer (ET) and Natural Mating (NM) are the major possibilities for dissemination of genetic material. However, in sub-Saharan Africa NM would be most common considering that beef cattle are reared extensively and that AI and ET may require substantial investment in related equipment and infrastructure. This is evidenced in ongoing programmes like the N'Dama pure breeding programme where NM is applied. The limitation of NM is related to the number of bulls required to service the entire herds of both breeder and commercial groups. Fewer bulls are required when applying AI or ET, which has also been shown to reduce the generation interval resulting in faster genetic progress (Kosgey *et al.,* 2005). A possible mechanism to further reduce the generation interval when applying NM is to use young bulls as opposed to old bulls. Disseminating young bulls born out of matings with high performance sires, selected based on individual records and records of ancestors, ensures faster availability of breeding material, avoiding situations of lost opportunities encountered when long periods of progeny testing are considered (Kahi *et al.,* 2004; Bosso, 2006). To avail enough males for mating in the commercial groups, a multiplier group might be required. In the N'Dama example for instance, the Gambian Indigenous Livestock Multiplier Association (GILMA) was established to provide the link between breeders and commercial farmers. Community based livestock improvement organisation is still rare in sub-Saharan Africa. However, as has been demonstrated, such kind of organisation is possible especially when farmers are ready to join forces, each one contributing where he can best function.

2.7 Conclusions

Breeding beef cattle in sub-Saharan Africa has one major advantage: the greater possibility of a totally pasture-based beef production system. Although there are several indigenous beef cattle genotypes with a potentially good beef production capability, this potential is unexploited as strategic breeding plans for genetic improvement are rare in this region. Therefore, there is a general lack of reliable sources of breeding stock whereas the stock available is of variable quality. The presence of varied production systems of beef cattle in this region requires systematic system-specific solutions, to maximise the benefit from available animal breeding technologies. The existing gap of undefined breeding objectives and schemes for beef cattle in sub-Saharan Africa should be a subject of current research.

CHAPTER 3

IMPROVED BORAN CATTLE BREEDING PROGRAMME

CHAPTER 3: IMPROVED BORAN CATTLE BREEDING PROGRAMME

Genetic and economic evaluation of a basic breeding programme for Kenya Boran cattle

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Abstract:

The objective of this study was to describe the present organisational structure of Boran cattle breeding and develop a model breeding programme using a deterministic approach. The current structure of the Boran Cattle Breeders Society was employed in designing the breeding programme. A breeding unit of 13,000 cows supplying bulls to a commercial population of 39,000 cows was assumed. Selection criteria used were growth and reproduction traits while breeding objective traits targeted were growth, carcass, reproduction, survival, milk yield and feed intake traits. Higher selection intensity was possible for breeding sires resulting in higher genetic gains compared to dams even though selection accuracies were generally low. Annual genetic gains were positive except for dressing percentage, cow survival rate, and age at first calving. However, a reduction of age at first calving by 9.5 days obtained a return of KSh 50.07. The overall monetary genetic gain obtained was KSh 85.49 with a profit per cow of KSh 360.62. The basic breeding programme could be expanded to accommodate a larger population of Boran cattle. The implications of the results are also discussed.

Key words: Breeding Programme, Genetic Improvement, Kenya Boran

3.1 Introduction

The Kenyan Boran is a *Bos indicus* breed primarily kept for commercial beef production in the semi-arid areas of Kenya. The breed originated from the Borana, Somali Boran and Orma Boran that were bought by European ranchers from central Kenya in the early 20th century (Rege *et al.,* 2001). Its potential for beef production brought together cattle breeders in 1951 to form the Boran Cattle Breeders Society (BCBS) (Rewe *et al.,* 2007). At present, co-ordinated breeding activities for purposes of advancing an organised genetic improvement programme are still a challenge that requires attention. In 1970, the

Livestock Recording Centre (LRC) of Kenya was established as a centre for genetic evaluation, however many producers pulled out of the scheme due to inconsistency and delays in the release of evaluation results, and the expenses associated with recording (Kahi *et al.,* 2006).

Individual efforts of the Boran cattle farmers under the umbrella of BCBS have intuitively developed the improved Kenyan Boran. The general independence of Boran cattle keepers with respect to selection and genetic improvement is a challenge for future competitiveness of this breed locally and internationally. These cattle keepers trade both in breeding stock and beef (Rewe *et al.,* 2006a) and therefore need special consideration as a result of the variation that exists in the organisational capacities and production objectives. A well-organised breeding programme with clear functional components of the genetic improvement process is necessary if breeding technologies are to be applied. Breeding technologies account for the functions of genotypes within the production system and the process of mate selection towards maximising genetic gain in traits of economic importance (Sölkner *et al.,* 1998). Most of the past breeding programmes for livestock improvement in Kenya overlooked the underlying conditions and type of target farmers resulting in a majority of these well-intended measures ending up in failure (Sölkner *et al.,* 1998). For the beef cattle in Kenya, the lack of quality breeding stock is aggravated by the eminent lack of sustainable breeding programmes. The objective of this study is therefore to describe the present organisational structure of Boran cattle breeding and develop an appropriate breeding programme using a deterministic approach.

3.2 Materials and Methods

3.2.1 Institutional framework in Kenya's beef cattle breeding sector

To identify the institutional support available for Boran cattle breeding in Kenya, a selective review of literature coupled with key-person interviews was employed. The studies reviewed included those that reported exclusively on organisational development of Boran cattle farmers as well as their interrelationship with government institutions, research institutions and animal production companies (Rege *et al.,* 2001; Heath, 2001; Aklilu, 2002; Kahi *et al.,* 2006; Rewe *et al.,* 2006a and b; Ojango *et al*., 2006; Gamba, 2006; BCBS, 2007). The breeding policy for Boran cattle in Kenya was assumed to reflect the recommendations of Meyn and Wilkins (1974) that suggested that commercial Boran cattle production be practiced in semi-arid rangelands, a situation that has been the trend in Boran cattle ranches.

Key persons were selected based on the importance of the supporting institutions they serve in. The institutions that were considered as key information sources were BCBS and the Boran cattle ranchers. The contact persons were consulted for unpublished information on cattle population, breeding herd management and breed standards using open questions. The institutions' websites were also consulted for information on roles and legal status. The interrelationship between the stakeholder institutions in relation to their contribution to Boran cattle breeding was sought in order to develop an industry picture depicting the organisational support available for sustainable breeding of Boran cattle.

3.2.2 Boran herd management data

The biological, technical and economic data for the Boran cattle breeding programme were obtained from the government Boran cattle stud reared at the Kenya Agricultural Research Institutes' (KARI) National Beef Research Centre (NBRC) based at

Lanet in Nakuru District. The ranch is located approximately 140 km North-West of Kenya's capital Nairobi at an altitude of 1840 metres above sea level within the Great Rift Valley (latitudes between 0° 10' and 0° 20' and longitudes between 36° and 36° 10' and average temperatures of about 28°C). This ranch has reliable data and information on Boran cattle keeping due to its consistency in animal performance measurement and record keeping. Supporting information on performance, herd size and composition were sourced from government reports, farm websites and published studies on other large scale ranches keeping the Kenya Boran cattle (Okeyo *et al.,* 1998; Heath, 2001; Aklilu, 2002; BCBS, 2007; DAGRIS, 2007).

In this study, natural mating was assumed and that bulls were used for up to three years after which they are disposed mainly through sale to other breeders when their daughters joined the breeding herd (Rewe, 2004). Breeding management was based on two breeding seasons running from January to March and from August to October under a single sire mating system to allow for calving during the wet seasons of October to December and May to July. Common traits recorded as routine management practice included birth, weaning and yearling weights, age at first calving and calving interval (Okeyo *et al.,* 1998; Rewe *et al.,* 2006b). Table 3.1 presents an overview of the variables used for the modelled closed-nucleus breeding programme.

3.2.3 Population structure and selection groups

A total cow population of 52,000 in 15 ranches that comprise the breeder group of the BCBS was used to simulate a basic Kenya Boran breeding programme utilizing a two-tier closed-nucleus programme. The size of the breeding unit with performance and pedigree recording was set at 25% (13,000 cows) of this population herded in groups of 200 cows. The breeding unit modelled was dispersed and it was assumed that the ranches were under the same environmental and management influence with a correlation in performance of unity between the different ranches.

Table 3.1 Overview of the assumed values of the variables used in the modelled Kenya Boran breeding programme.

Variables		Variable levels	
Management variables			
Population of cows in the breeding unit (25%)		13,000	
Population of cows in the commercial unit (75%)		39,000	
Calving rate		83%	
Pre-weaning survival rate		93%	
Bull survival rate (death and culling included)		90%	
Cow survival rate (death and culling included)		90%	
Productive lifetime sires in breeding unit		3 years	
Productive lifetime for dams in breeding unit		5 years	
Productive lifetime for sires in commercial unit		3 years	
Productive lifetime for dams in commercial unit		7 years	
Age at first calving for sires in breeding unit		3 years	
Age at first calving for dams in breeding unit		3.5 years	
Age at first calving for sires in commercial unit		3.5 years	
Age at first calving for dams in commercial unit		4 years	
Investment parameters			
Investment period (years)		25	
Interest rate for returns (%)		8	
Interest rate for costs (%)		6	
Variable costs[1] (KSh)		***Cost***	***Age of animal at cost occurrence(yr)***
Animal recording costs	(0.007% of salaries)	150	2
Recording birth weight	(0.001% of salaries)	20	0
Recording weaning weight	(0.002% of salaries)	40	0.58
Recording yearling weight	(0.003% of salaries)	70	1
Recording calving internal	(0.007% of salaries)	150	3
Recording age at first calving	(0.005% of salaries)	100	3
Fixed costs per year (KSh)			
Staff salaries (management and support staff)		2,059,505	

[1]Calculations basis: Staff salaries for management and other office staff totalling 2,059,505 KSh (standard Kenyan cattle ranch salaries for management and office labour per year from Heath (2001)) was used to derive percentage of variable costs per cow on the basis of time and labour units needed for recording purposes. One labour unit = 0.001% of fixed costs (KSh20) reflects the cost of measuring birth weight in Kenya (Kahi *et al.,* 2004) used in this study as the reference criteria trait for variable costs.

In the commercial unit, 70% of matings were by bulls from the breeding unit and 30% by bulls born in this unit but progeny of bulls born in the breeding unit with 100% natural mating in the breeding and commercial units. Table 3.2 shows the transmission matrix for the breeding programme with 9 selection groups. In the breeding unit, there were four selection groups, namely sires to breed sires (SS) and dams (SD) and dams to breed sires

(DS) and dams (DD). In the commercial sector, there were five selection groups, namely, sires (from the breeding unit) to breed sires (SS_C) and dams (SD_C) in the commercial sector and sires (from the commercial sector) to breed cows (S_CD_C) and dams to produce sires (D_CS_C) and dams (D_CD_C). The sons of sires born in the commercial unit were not used for breeding.

Table 3.2 Transmission matrix for Kenya Boran breeding programme within nine selection groups

		Tier 1 (breeding unit)		Tier 2 (commercial unit)	
		Sires	**Dams**	**Sires**	**Dams**
Tier 1	Sires	SS (1.0)	DS (1.0)	-	-
	Dams	SD (1.0)	DD (1.0)	-	-
Tier 2	Sires	SS_C (1.0)	-	-	D_CS_C (1.0)
	Dams	SD_C (0.7)	-	S_CD_C (0.3)	D_CD_C (1.0)

SS, SD = sires to produce sires and dams in the breeding unit; DS, DD = dams to produce sires and dams in the breeding unit; SS_C, SD_C = sires (from the breeding unit) to produce sires and dams in the commercial unit; S_CD_C = sires (from the commercial sector) to produce cows whose sons are not used for breeding and D_CS_C, D_CD_C = dams to produce sires and dams in the commercial unit. (Gene contribution of parent line in brackets)

3.2.4 Breeding objective, selection criteria and index information

The breeding objective was aimed at maximising beef production from 36-month old steers and heifers at optimal sale weights on pastures without supplementation. Traits considered in the breeding objective were: direct sale weight, dressing percentage, consumable meat percentage, cow weaning rate, cow survival rate, cow weight, age at first calving, milk yield, feed intake and post weaning survival rate. The economic values for the breeding objective traits were recalculated based on a re-integrated bio-economic model developed by Rewe *et al.* (2006a). However, in the present case a relationship between growth rate and sale weight was established as well as between feed intake and growth rate. Briefly, equation 1, 2 and 3 below show how the revenue ($R_{KSh}^{-cow-yr}$), costs ($C_{KSh}^{-cow-yr}$) and economic value ($EV_{KSh}^{-cow-yr}$) calculations were achieved;

$$R_{KSh}^{-cow-yr} = [(NsCy \times SWs) + (NhCycull \times SWh) + (RrCy \times CoWT \times CoSR)] \times DP \times CMP \times Pmeat \quad (1)$$

$$C_{KSh}^{-cow-yr} = FIXED + (NsCy + NhCycull) \times ma + (FIs + FIh + FIc) \times Pf + HS \quad (2)$$

$$EV_{KSh} = \frac{\Delta R - \Delta C}{\Delta t} \quad (3)$$

where NsCy is the number of steers attaining sale age, SWs is the sale weight of steers (kg), NhCycull is the number of heifers available for culling, SWh is the sale weight of heifers (kg), RrCy is the replacement rate (%), CoWT is the cow weight (kg), CoSR is the cow survival rate (%), DP is the dressing percentage, CMP is the consumable meat percentage, Pmeat is the price per kg of meat in KSh, FIXED are fixed cow costs per year (KSh), ma is the marketing cost per animal (KSh), FI is the feed intake in kg dry matter (DM) (s, h and c correspond to prefixes for steers, heifers and cows respectively), Pf is price of feed (KSh/kg DM), HS are the husbandry costs - which included labour and veterinary costs, ΔR is the change in revenue, ΔC is the change in costs and Δt is the marginal change in a trait after 1% increase. Feed intake was calculated based on the life cycles of all classes of animals (steers, heifers and cows) and type of feed consumed while employing the standard feed requirement equations of the Agricultural Research Council (ARC, 1980).

The selection criteria used included the basic characters recorded routinely in breeder group ranches and included growth (birth, weaning and yearling weights) and reproduction (age at first calving and calving interval) traits. Selection criteria for breeding unit sires (SS and SD) and dams (DS and DD) and for commercial unit sires (SS_C, SD_C) originating from the nucleus were birth weight, weaning weight, yearling weight from an individual and its relatives of both sexes and age at first calving and calving interval from its female relatives. For D_CS_C and S_CD_C, the selection criteria were weaning weight from own performance and calving interval from its dam, respectively. Generally, the information sources included the individual, its half sibs, its sire, its dam and the half sibs of sire and dam. Table 3.3 shows the information sources and selections criteria used in calculating the selection index. Table 3.4 shows the economic values as well as genetic and phenotypic parameters used in this study. The estimates of genetic and phenotypic parameters were from the literature and as much as possible confined mainly to tropical cattle (Haille-Marriam and Kassa-Mersh 1995; Lôbo *et al.,* 2000; Burrow 2001; Maiwashe *et al.,* 2002).

Table 3.3 Information sources and selection criteria for indices applied in the selection of sires and dams for the breeding unit and sires for the commercial unit.

Information sources	Selection criteria				
	Birth weight	**Weaning weight**	**Yearling weight**	**Age at first calving**	**Calving interval**
Animal	√	√	√		
Female Half-sibs (HS) of animal				√	√
HS of animal (both sexes)	√	√	√		
Sire	√	√	√		
HS of sire (both sexes)	√	√	√		
Female HS of sire				√	√
Dam	√	√	√	√	√
HS of dam (both sexes)	√	√	√		
Female HS of dam				√	√

3.2.5 Modelling the basic breeding programme

The computer programme ZPLAN (Willam *et al*., 2008) was used to model the basic breeding programme. The ZPLAN programme utilises biological, statistical, and economic parameters to calculate the annual genetic gain for the breeding objective, genetic gain for single traits, and returns on investment adjusted for costs using the gene-flow and selection index methodology. The programme ignores decreased genetic variance due to selection and inbreeding, but is able to calculate selection indices for breeding animals within one round of selection. ZPLAN applies order statistics to obtain adjusted selection intensities for populations with finite sizes while assuming that parameters and selection strategies remain unchanged during the investment period.

Table 3.4 Assumed heritabilities, phenotypic standard deviations, economic values, phenotypic correlations (above diagonal) and genetic correlations (below diagonal) among selection criteria (lower case letters) and breeding objective (upper case letters) applied in the evaluation of the breeding programme.

Trait[1]	CoWT	SWd	DP	CMP	CoSR	PSR	FI	CoWR	MY	afc	ci	bw	ww	yw
Units	kg	kg	%	%	%	%	kg DM	%	kg	days	days	kg	kg	kg
h^2	0.35	0.35	0.30	0.45	0.03	0.03	0.30	0.05	0.27	0.29	0.14	0.40	0.30	0.31
σ_p	40.00	50.00	1.80	2.00	9.95	9.95	47.00	43.30	165.66	499.80	199.10	4.20	25.00	22.00
EV[2](KSh)	8.87	18.36	210.36	158.53	108.81	79.79	-0.5	138.52	-0.003	-1.56	-	-	-	-
CoWT														
SWd	0.4													
DP	0.00	-0.06												
CMP	0.00	0.15	0.10											
CoSR	0.00	0.00	0.00	0.00										
PSR	0.00	0.00	0.00	0.00	0.00									
FI	0.0	0.0	-0.10	0.00	0.00	0.00								
CoWR	-0.53	-0.05	0.00	0.00	0.00	0.00	0.00							
MY	-0.22	0.0	0.00	0.00	0.00	0.00	0.00	0.00						
afc	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00		-0.21	-0.10	0.00	0.00
ci	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.10	-0.11	-0.21		-0.56	0.00	0.00
bw	0.40	0.40	0.00	0.00	-0.02	0.05	0.20	0.00	0.00	-0.10	0.00		0.40	0.55
ww	0.30	0.50	-0.05	0.05	0.00	0.04	0.40	0.00	0.10	0.00	0.00	0.40		0.90
yw	0.45	0.70	-0.05	0.09	0.00	0.00	0.50	0.05	0.10	0.00	0.00	0.35	0.60	

Source: Heritabilities, phenotypic standard deviations, economic values, phenotypic correlations and genetic correlations have been adapted from Haille-Marriam and Kassa-Mersh 1995; Lôbo *et al.,* 2000; Burrow 2001; Maiwashe *et al.,* 2002; Kahi *et al.,* 2004; Pitchford, 2007; DAGRIS, 2007.

[1]Breeding objective traits coded in upper case letters and selection criteria traits in lower case letters: CoWT=cow weight; SWd = direct sale weight for steers; DP = dressing percentage; CMP = consumable meat percentage; CoSR = cow survival rate; PSR = post-weaning survival rate; FI = feed intake; CoWR = cow weaning rate; MY = milk yield; afc = age at first calving; ci = calving interval; bw = birth weight; ww = weaning weight; yw = yearling weight.

[2]EV = economic value in Kenya shillings (1 US Dollar = KSh 62.89 (as at 27th March 2008)

The variable costs which include costs that were directly related to performance and pedigree recording are shown in Table 3.1. These costs occur exclusively in the nucleus. The fixed costs were those incurred in one round of selection and were the overhead costs of running the nucleus of 13,000 cows. The average time when fixed costs occur was assumed to be the mean generation interval. Variable and fixed costs only affect the profit but not the genetic response. The interest rates for returns (0.8%) and costs (0.6%) were based on the current marketing conditions in Kenya (Central Bank of Kenya, 2007).

3.3 Results and discussion

3.3.1 Institutional framework supporting Boran cattle breeding in Kenya

In Kenya, beef cattle breeding has undergone transitional changes reflecting emerging challenges at particular times in history. A notable challenge was faced by early white settlers attempting to practice commercial beef production with European beef cattle breeds. Homann *et al*. (2005) described this challenge as the platform that led to the development of the Kenya (improved) Boran breed. In that study, British ranchers were expected to buy pastoral Boran cattle (*B. indicus*) originating from southern Ethiopia, south-east Somalia and northern Kenya as an alternative to Hereford, Shorthorn and Simmental breeds (*B. taurus*) that could not cope with the harsh environment found in the semi-arid tropics.

The organizational structure supporting the breeding of Kenya Boran cattle is presented in Figure 3.1. The organizational players range from government institutions and national agricultural research systems to cattle keepers. The structure is not exclusive to Boran cattle (other cattle also benefit from these institutions), nonetheless, the Boran cattle breeders are considered one of the most active breeders' associations (Kahi, 2007).

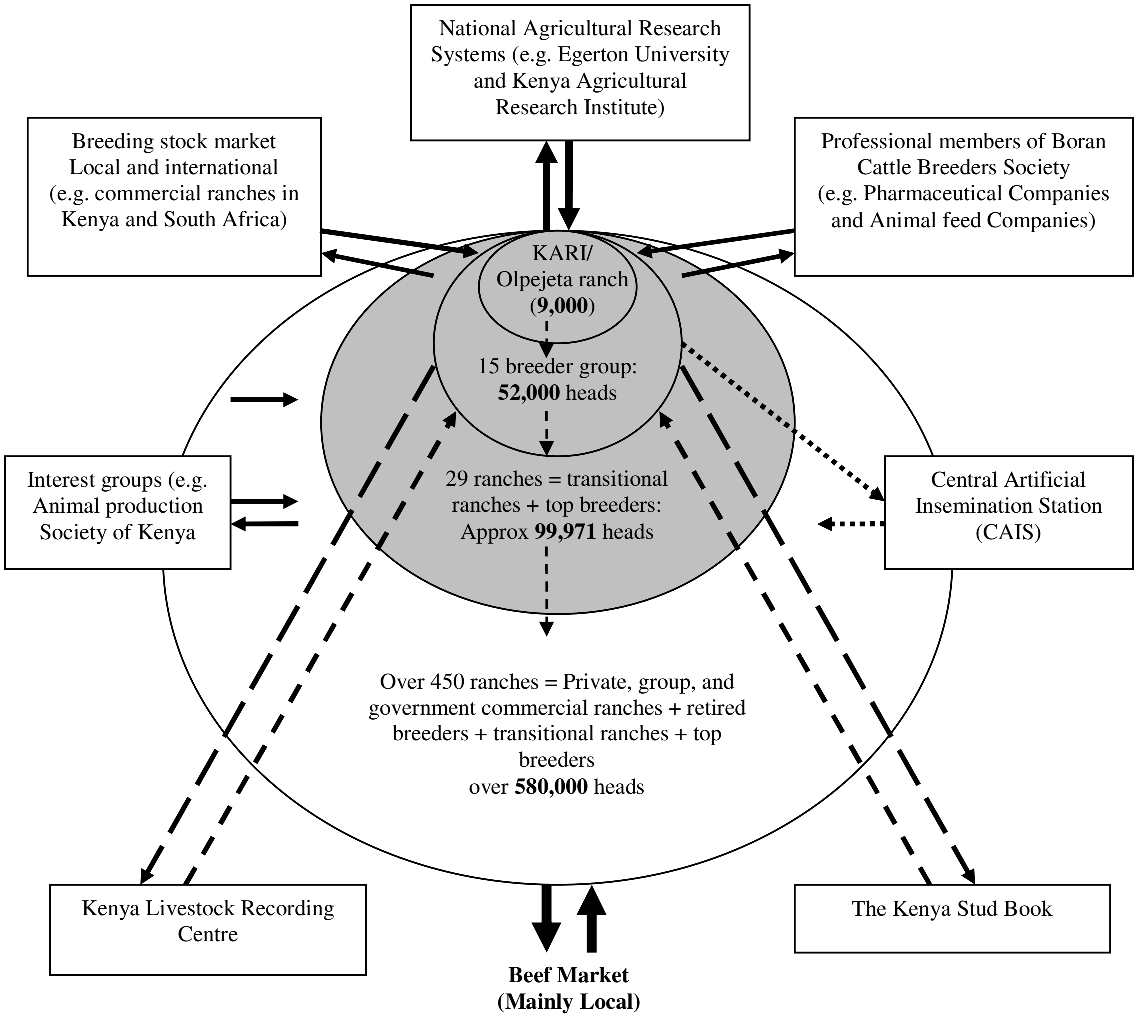

Figure constructed based on information from: Rege et a., 2001; Aklilu, 2002; Animal Genetics Training Resource, version 2, 2006; Kahi et al., 2006; BCBS, 2007;

Key: Joined lines indicate strong relationship while dotted lines indicate informal relationships (at varying intensities of relationships represented by longer and shorter dots) either through exchange of breeding material between the informally perceived tiers in the Boran Cattle Structure, data recording, or market information

Core membership of Boran farms in the Boran Cattle Breeders Society

Figure 3.1 Organisational structure depicting the Boran Cattle Breeders Society, Kenya Boran cattle keepers and institutional support in the Kenya Beef cattle breeding industry

The main institutional stakeholders include: 1) the Central Artificial Insemination Station (CAIS), the national AI service, 2) the Livestock Recording Centre (LRC) which doubles up as a database manager for animal recording and a genetic evaluation centre, 3) the National Agricultural Research Systems (NARS) that manage research activities, and

4) the different farm types keeping Boran cattle. The breeding programme was therefore assumed to operate on the basis of the following support structure; that farmers in the breeder group measure and keep animal records which are to be primarily collected from the various farms for analysis at the LRC; information on breeding values for the main selection groups, especially bull sires, is sent back to the farmers who make informed decisions on which bulls to use and which ones to transfer to the commercial herds; that the main decision making body is the BCBS secretariat supported by experts from the NARS. The cost of the breeding programme is therefore shared between the beef cattle farmers, BCBS and the LRC, with a bulk of the costs falling on the BCBS.

The BCBS has 44 members categorized into ranchers (29), retired farmers (10), research organisations/institutions (three) and pharmaceutical companies/animal feed companies (two). Out of the 29 ranches, 15 are producers of breeding stock registered at the Kenya Stud Book (KSB), forming the breeder group of the society (BCBS 2007; P. Valentine, personal communication, 2008). The KSB is a producer organisation supported by government grants that keeps pedigree records of purebreds for various animal breed societies in Kenya. Kenya Boran cattle totalling over 580,000 heads (Rege and Tawah, 1999) are found in different farm types many of which are not members of the BCBS. These types include group, company, private and government ranches, some of which have since closed down due to multiple factors including competition from illegal grazers and banditry. For example, one government ranch (Galana Ranch, Malindi District) that kept over 22,000 heads of cattle now accounts only for a paltry 3,500 cattle on farm (Aklilu, 2002; Heath, 2001). Table 3.5 presents approximate land area and Boran cattle population in selected breeder group ranches in Kenya. One of the largest private breeder ranches is the Ol Pejeta Ranch covering an area of approximately 80,000 acres of land with a population of 8,000 suckler cows and 10,000 sheep, with 2,000 cows reared in the breeding herd (Ol Pejeta, 2007). Approximately 52,000 heads of cattle in total are kept within the 15 breeder group ranches with an average of 3,447 per farm (Table 4.5). The Kenya Boran herds in breeder ranches are separated into stud herds and commercial units. Although there is no common policy among the breeders on the percentage of cows to be reared in the stud herd, trends from active breeders (e.g. KARI and Ol Pejeta Ranch) show that 25% - 30% of cows in the herd are reared in the breeding unit (Rege *et al.,* 2001; Ol Pejeta, 2007; P. Valentine, personal communication, 2008).

Table 3.5 Land sizes and cattle population in selected breeder group beef ranches keeping the Kenya Boran cattle

Beef Ranch	Approximate Farm size (acres)	Approximate Herd size
Kenya Agricultural Research Institute *National Beef Research Centre, Lanet (accessed on 10th November 2007 from http://www.tegemeo.org/documents/work/tegemeo_workingpaper_23.pdf)*	-	1,000
Ol Pejeta Conservancy *www.olpejetaconservancy.org (accessed on 10th November 2007)*	80,000	8,000
Lolomarik Farm, Marania Ltd *http://www.boran.co.za/ (accessed on 10th November 2007)*	10,300	900
Homa Lime Co. Ltd. *http://www.homalime.com/farming_livestock.htm, and http://www.homalime.com/Kwiesos_House_Brochure.pdf (accessed on 10th November 2007)*	3000	70
Mogwooni Ltd *http://www.boran.co.za/ (accessed on 10th November 2007)*	25,000	250
Mutara Estate (ADC) *http://www.boran.co.za/ (accessed on 10th November 2007)*	60,000	6,000
Kisima Farm Limited *http://www.boran.co.za/kisima.html*	43, 495	2,700
Lolldaiga Hills Ltd *http://journals.cambridge.org/download.php?file=%2FZOO%2FZOO244_02%2FS095283699800211Xa.pdf&code=4db6e119d49f7e71a22b52fd9ff5084a (accessed on 10th November 2007)*	49,000	4,500
Delamere Estates Ltd (Soysambu Ranch) *http://www.nationmedia.com/dailynation/nmgcontententry.asp?category_id=39&newsid=117823 (accessed on 10th November 2007)*	50,000	6,000
Segera Ranch Ltd *www.segeraranch.com and http://allafrica.com/stories/200710220638.html (accessed on 10th November 2007)*	50,000	4,500
Kakuzi Ltd *http://www.taa.org.uk/EastAfricanBranch/TAAEAGroupVisittoKakuziLtd%252520Mar1st'03.htm (accessed on 10th November 2007)*	-	4,000

Natural mating is practiced while using bulls in such a way that offspring-sire identification is possible by exposing bulls to cows for about ten weeks and allowing for a two-weeks break before introducing a new bull to the cow herds reared in groups of 150 –

200 heads (Okeyo *et al.,* 1998). In the KARI Boran herd where cattle are maintained for research and commercial purposes, all bulls for commercial herds are supplied from the stud herd as opposed to other large holdings where bulls needed are sourced from both the stud and commercial herds (Gamba, 2006). Over the years, active Boran cattle breeders have supplied their own cow replacements and breeding bulls with minimal introduction of animals from commercial herds into the stud herds (closed-nucleus).

The most important roles of BCBS are to maintain breed standards and explore markets for Boran genetics. The society introduced standards for registering typical Kenya Boran cattle which are executed by a panel of inspectors. The main standards for qualification include an animal's purebred status as an offspring of purebred parents at least one of which should be registered with the stud book. The animal must meet the weight, conformation and colour standards of the breed. An important consideration related to the breed standards is the management of the animals that must correspond to the minimum feeding, health and other routine management practices that support the maintenance of the breed on-farm. Some critical considerations for registration of breeding animals are presented in details elsewhere (BCBS, 2007). The 15 breeder group ranches that have animals registered with the KSB conform to these standards with their animals subjected to relatively similar conditions of husbandry (P. Valentine, personal communication, 2008). A transitional group of ranchers currently adjusting their management and breeding practices to conform to the breed standards for purposes of animal registration are represented by 14 out of the 29 active member ranches. The other members within the active group are considered retired breeders. The largest group of Boran cattle keepers most of which are low-input systems are currently non-members of BCBS (Figure 3.1).

3.3.2 Selection accuracy and genetic superiority for individual selection groups

Genetic response is generally expected from selection groups originating from the breeding unit where selection decisions are made and breeding costs are incurred (Nitter *et al.,* 1994). Therefore, only results for six selection groups with parents reared in the breeding unit are presented. The other selection groups are not relevant here since they do not contribute to the genetic response and do not incur breeding costs. Table 3.6 presents the total number of animals tested and selected including selection intensity, selection accuracy and genetic superiority for individual selection groups. Generally, selection accuracy for the different selection groups were similar since information sources used to generate the index for sire and dam were the same.

Table 3.6 Proportion of animals selected, selection intensities, accuracies and genetic superiority for individual selection groups in the breeding unit.

Selection parameters	**Selection groups**		
	Sires to breed breeding unit sires and dams	**Dams to breed breeding unit sires and dam**	**Sires to breed commercial unit sires and dam**
Animals tested	4014	70	4014
Animals selected	217	40	228
Percentage selected (%)	5.4	57.6	5.7
Selection intensity	2.03	0.67	1.39
Generation interval (yrs)	4.13	5.93	4.63
Selection accuracies	0.26	0.26	0.26
Genetic superiority/year (KSh)	646.25	214.11	-

The genetically superior selection group with over Ksh 646 monetary genetic gain was that of sires producing sires and dams for the breeding unit. The sire selection group also had the shortest generation interval (4.13 years) compared to the dam group. Putting more emphasis on sire selection for faster rates of genetic progress would be desirable (Kahi and Hirooka, 2005). In Kenya, breeding bulls are commonly transferred between beef cattle farms as opposed to breeding cows. This trend is expected to continue. Therefore, selection of bulls will account for most of the genetic progress expected in the improved Boran cattle.

3.3.3 Genetic response in individual breeding objective traits

Although Boran cattle farmers have no formal set of breeding objective traits, describing a formal breeding objective allows for the utilisation of the best selection criteria traits for purposes of genetic improvement. Table 3.7 presents annual genetic gains for individual traits included in the breeding objective. Generally, all traits had favourable mathematically positive genetic gains except dressing percentage, cow survival rate, age at first calving and milk yield. As expected, sire selection groups showed higher gains in individual traits than dam selection groups. The negative gains for dressing percentage and cow survival rate could be attributed to the negative genetic correlations between sale weight and dressing percentage and also between birth weight and cow survival rate. The negative gain (reduction) in age at first calving is desirable, since a reduced age at first calving implies that cows will calve earlier and will have higher chances of raising more calves per lifetime. Milk yield had modest reduction of -1.09 kg for the sire selection group (Table 7). Milk yield could impact mothering ability trait in Boran cows since this trait relies mainly on their milk production potential (Yilma *et al.,* 2006). Maintaining or slightly improving milk yield could be important for cow-calf systems, which is the case for Boran cattle. However, minimum manipulation of milk yield in cow-calf extensive systems that rely on rangeland pasture is advisable because higher milk production results also in higher feed intake of cows. The set of selection criteria and information sources applied yielded a correlation of around 0.26 to the breeding objective traits targeted. Investigation of genetic and phenotypic correlation between Boran cattle traits could allow for optimal identification of sound selection criteria to match the targeted breeding objectives and yield higher selection accuracies (Wasike *et al*., 2007).

Table 3.7 Genetic gain per year for breeding objective traits per selection group in the breeding unit

Traits	**Selection group**		
	Sires to breed breeding unit sires and dams	**Dams to breed breeding unit sires and dam**	**Sires to breed commercial unit sires and dam**
Sale weight (kg)	27.28	9.06	17.83
Dressing percentage (%)	- 0.05	- 0.02	- 0.03
Consumable meat (%)	0.15	0.05	0.07
Cow weaning rate (%)	- 0.23	0.08	0.02
Cow survival (%)	- 0.01	- 0.003	- 0.02
Cow weight (kg)	14.30	4.76	10.25
Age at first calving (days)	- 72.51	- 23.52	- 49.90
Milk yield (kg)	-1.09	-0.35	-0.75
Feed intake (kg DM)	14.75	4.89	10.15
Post weaning survival (%)	0.01	0.002	0.004

3.3.4 Annual monetary genetic gain, returns and profit per cow across selection groups

To choose an optimum breeding programme that will maximise productivity in selecting a set of objective traits and selection criteria while maintaining genetic progress requires more than just an analysis of individual genetic gains. A combination of genetic and economic evaluation is therefore essential. This requires evaluation of overall genetic gains for individual traits (an aggregate of all selection groups per breeding objective) and overall returns per trait aggregated in overall monetary genetic gain and profit. Table 3.8 shows the overall genetic and economic merits per cow for the basic Kenya Boran cattle breeding programme. As mentioned earlier, negative genetic gains were observed for dressing percentage and age at first calving, which resulted also in negative monetary returns for dressing percentage but positive returns for age at first calving. A decrease in age at first calving is expected to boost returns to the breeding programme. Sale weight obtained the highest returns of KSh 329.64 reflecting the positive economic value (KSh

18.36) for this production trait. Cow survival rate and post weaning survival rate had low levels of genetic gain, being slightly negative for cow survival rate (-0.001) (Table 3.8). Survival rate has low correlations with production and reproduction traits.

Table 3.8 Overall genetic and economic merits per cow for the basic Kenya Boran cattle breeding programme

Traits	Overall Genetic gain/year	Returns (KSh[1])/cow in the population
Sale weight	3.61 (kg)	329.64
Dressing percentage	- 0.01 (%)	- 10.43
Consumable meat	0.02 (%)	19.53
Cow weaning rate	- 0.03 (%)	21.62
Cow survival	- 0.001 (%)	- 0.46
Cow weight	1.89 (kg)	61.44
Age at first calving	- 9.54 (days)	50.07
Milk yield	-0.14 (kg)	0.00
Feed intake	1.95 (kg DM)	- 6.86
Post weaning survival	0.001 (%)	3.28
Monetary genetic gain (KSh)		85.49
Total returns (KSh)		467.85
Total cost (KSh)		107.23
Profit/cow (KSh)		**360.62**

[1] 1 US Dollar = KSh 62.89 (as at 27th March 2008)

The overall monetary genetic gain, returns and costs per cow were positive (KSh 85.49, KSh 467.85 and KSh 107.23, respectively) and were mostly determined by returns on sale weight. The basic breeding programme had a profit of KSh 360.23 per cow. Kahi *et al.* (2004) found a profit per cow of KSh 157 for a pure-beef objective in a smallholder dairy production system in Kenya, which was based on artificial insemination and recording for reproductive, productive and survival characters. Although that study included survival characters in the selection criteria, the unique technical, biological and economic parameters reflecting a typical dairy cattle production system in Kenya may be responsible for the lower profit compared to the present study. Notably, including survival characters in the selection criteria could be useful especially in safeguarding a potential increase in negative trends in production or loss of adaptability. Survival traits are complex in definition. However, use can be made of information on adaptability traits such as disease or heat tolerance to serve as indicators of survival, although these alternatives offer low selection accuracy and attract high costs of measurement and assessment. Alternatively, mortality data grouped by age could also be useful when comparing relatives of animals under selection on whether they survived past a certain age or not (Rege *et al*., 2001). Introduction of new measurements should be done with caution since it has an implication on the variable costs.

3.4 General discussion

Structured breeding programmes have three core platforms, namely performance recording, genetic evaluation and planned mating, which are either performed by government or non-governmental organisations. In developing countries, especially in Africa, most of the few livestock breeding activities are implemented on a national scale by government institutions working with foreign development agencies with no leader roles for participating livestock keepers (FAO, 2007). This phenomenon has hampered the success of many well-intended breeding programmes in these countries (Sölkner *et al.,* 1998). Breeding organisations and private companies have been described as effective non-governmental stakeholders that can implement successful breeding programmes (FAO, 2007). However, all key stakeholders, namely, government, animal breeders and research organisations, are important in the organizational structures that constitute functional breeding programmes. In developed livestock industries, two forms of organizational structures are common, i.e. farmer's cooperatives and shareholder controlled companies (Miller, 2002). The development of these organisations has in most cases been preceded by the formation of breed associations. As the breeding organisation in developing countries changes from government driven to farmer driven, the role of professional cattle breeders will change from just information users to decision makers, consequently leading to livestock breed associations playing a major role in making animal mating decisions matched with information from genetic evaluation (Miller, 2002).

In Kenya, the roles of the stakeholder institutions differ significantly in relation to their influence on Boran cattle breeding. Most of the institutions (Figure 1) are government institutions, including public universities. It follows that political goodwill plays a major role in the efficiency of their functions. Over the years, political interference that led to unbalanced distribution of qualified staff and underutilisation of resources contributed to low human resource output as well as non-performance of these institutions (Gamba, 2006; Kahi *et al.,* 2006; Heath, 2001). Transforming these organisations into independent parastatal bodies (autonomously run government institutions) could be helpful in enhancing their ability to deliver services to farmers. The success of the Boran cattle breeding programme depends on the strength of association between the BCBS and the stakeholder institutions that manage essential services in the breeding industry in Kenya. The breeder group that forms the active members of BCBS in Kenya represents a nucleus population of cows that can only serve a section of the population of Kenya Boran cattle. To advance a larger nucleus would require increasing the percentage of nucleus herds from 25% - which is already high - at the risk of further lowering the genetic merit of the breeding unit. Accommodating in the breeding programme a wider range of beef cattle keepers, some of whom are medium- to low-input producers, would imply a directional change of the breeding objective from increasing growth to optimising growth with adaptation traits and even putting some emphasis on milk production; an approach that is limited by the assumption that the various farm types of Boran cattle keepers will tend towards achieving uniform production conditions. Notably, current revenue collection for

BCBS could be restructured to bolster its ability to manage the breeding programme. For example, apart from receiving membership fees, BCBS could also receive a commission for every sale of breeding stock and charge a levy for the use of its brand name, which could be widely marketed to consumers to inform their choice for Boran meat.

The profitability of the evaluated breeding programme implies that it can be made to work under guided implementation based on strengthening the stakeholder institutions and strategic support from development partners. The main strength of the breeding programme discussed is the existence of support institutions. Even though these institutional structures are not working at their optimum, their existence and potential improvement are advantages that could be explored in the process of streamlining the breeding programme. The most important institution probably is the BCBS because of its direct influence on the cattle breed. The organisation exerts influence from the breeding to the marketing of breeding stock showing reasonable levels of organisation. The continued sound performance of Boran cattle in semi-arid rangelands presents an encouraging sign for success of the programme. Despite their susceptibility to some tropical diseases, Boran cattle have continued to produce good meat from dry grassland pastures with minimal or no feed supplementation at all (Rewe *et al*., 2006a; Animal Genetic Training Resource II, 2006). The programme faces steep huddles however, as it concerns the shared responsibilities of managing the breeding programme. For example, the three main stakeholders, Boran cattle farmers, BCBS and LRC, need to form a binding committee to oversee the day to day activities of the programme. The formation of such a committee is huddled by the fact that LRC is a government institution that is controlled by policies of government which presently have not put a high priority on animal breeding. Fund raising for breeding activities will require intensive lobbying and deployment of knowledgeable staff to the LRC. Computerisation and centralisation of animal data from the dispersed breeding herds poses another major challenge considering that the fiscal and technological infrastructure is still a work in progress in Kenya. Nonetheless, consensus has to be built on the need for the breeding programme if demand for high quality breeding stock for local and international customers is to be met. This may be the driving force allowing the stakeholder institutions to gradually but positively expand and benefit from the Boran cattle breeding programme in Kenya. Considering that the Boran cattle population is far larger than the 52,000 tested here, most of them kept under different production systems, it cannot be inferred that the economic and genetic merit of the proposed programme matches the case for the entire population. A systematic simulation of alternative breeding programmes for the entire population to evaluate the genetic and economic merit is therefore recommended. This is the subject of a subsequent study.

CHAPTER 4

ALTERNATIVE BREEDING PROGRAMMES

CHAPTER 4: ALTERNATIVE BREEDING PROGRAMMES

Trait improvement and monetary returns in alternative closed- and open-nucleus breeding programmes for Boran cattle reared in the semi-arid tropics

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Abstract

The aim of this paper was to evaluate genetic and economic merits of Boran cattle breeding programmes for large-scale commercial beef ranchers and low-input beef producers in Kenya. The study exploits the informal interactions that exist between these two systems that differ in both production goals and breeding objectives. Conventional breeding objectives for the commercial ranchers were derived from preceding studies while trait preferences for low-input farmers were sourced from appropriate literature. Three alternative closed and open nucleus breeding programmes were evaluated; a) a breeding programme closed to the members of the Boran Cattle Breeders Society aimed at improving growth (BCBS), b) an expanded breeding programme managed by the BCBS but incorporating the trait preferences of low-input production systems aimed at improving growth and adaptation (EXPO), and c) a breeding programme for the low-input production systems aimed at improving adaptation, growth and milk production (LOW). The effect of altering the nucleus size (5%, 10% and 25%), gene contribution to commercial herds (25%, 50% and 70%) and openness of the nucleus (10%, 20% and 30%) was tested. The closed-nucleus of the BCBS programme under growth breeding objective (option-one) realised an overall monetary genetic gain of KSh93 and profit amounting to KSh431, while application of a second breeding option (breeding for growth and adaptation) led to the rising of monetary genetic gain to KSh162 and profit to KSh893. Monetary genetic gain for BCBS open-nucleus (KSh117) was higher than the closed-nucleus for the first breeding option but obtained a lower profit (KSh404). This trend was similar for all alternative breeding programmes. Application of EXPO (growth and adaptation) breeding objective as opposed to BCBS (growth) breeding objective resulted in a 2 kg drop in sale weight gain but realised a gain of 20% in trypanotolerance. In the LOW programme a negative gain for milk yield of -1.1 kg was realised, however, restrictions on growth and adaptation on the breeding objective allowed for moderate positive gains in milk. The most profitable options for selection schemes were the nucleus size of 25%, genetic contribution to commercial herds of 70% and nucleus opening at 10%. Extra recording for trypanotolerance in the EXPO breeding programme commercial herds did not result in any additional benefits. The feasibility of the alternative breeding programmes has been discussed in detail in this paper.

Key words: Kenya, Boran cattle, genetic improvement, production systems

CHAPTER 5

GENERAL DISCUSSION

CHAPTER 5: GENERAL DISCUSSION

5.1 Introduction

The general discussion begins with an overview of aims and methodological approaches used to answer the scientific questions. Then follows the discussions on the major results from the three publications of this study on: breeding indigenous cattle genetic resources for beef production in sub-Saharan Africa (Chapter 2), genetic and economic evaluation of a basic breeding programme for Kenya Boran cattle (Chapter 3) and trait improvement and monetary returns in alternative closed- and open-nucleus breeding programmes for Boran cattle reared in semi-arid tropics (Chapter 4).

The overall aim of the study was to design and evaluate appropriate breeding programmes for Boran cattle populations in Kenya. This was done by describing the institutional and organisational capacity within the Boran cattle sector in Kenya, by defining the breeding objectives relevant for Boran cattle in different production systems and by evaluating the economic and genetic merits of alternative breeding programmes.

5.2 Methodological approaches

5.2.1 Institutional framework analysis

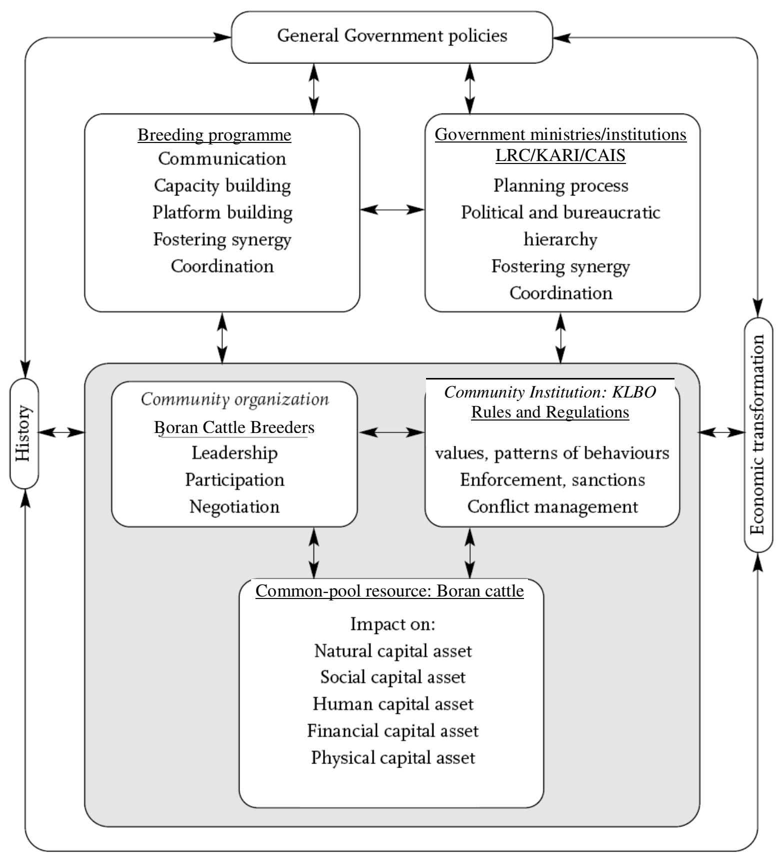
The approach used in this study to describe the institutional framework characterising the Boran cattle sector in Kenya was based on investigative research done through an on-line interview of key persons from the Boran cattle Breeders' Society. A review of scientific literature outlining the relationship of stakeholders in the beef industry in Kenya was also done. The method applied here is in agreement with a simple five point plan for institutional analysis presented by Grimble *et al*. (1995) which is: 1) clarification of the objectives of the analysis (why do we need to know the institutional framework?), 2) placement of issues in a systems context (e.g. livestock genetic improvement), 3) identification of decision-makers and stakeholders (e.g. Boran Cattle Breeders Society), 4) investigation of stakeholder interests and roles in the system and 5) investigation of patterns of interaction and dependence (e.g. the sharing of breeding stock between different groups of Boran farmers). The current study relied on previous review work undertaken on prospects for genetic improvement of Zebu cattle (Rege *et al*., 2001), on constraints and prospects for research and development in beef production in the arid and semi-arid lands of Kenya by Kahi *et al*. (2006), and on development of breeding objectives for production systems utilising the Boran breed in Kenya (Rewe *et al*., 2006a and b). The methodological approach used for Boran sector analysis was able to identify the institutions, their functions, legal status as well as some important interactions between them as presented in Table 5.1 below.

Table 5.1 Stakeholder institutions, their legal status and roles within the Boran cattle breeding sector

Institution	Year of establishment/Legal status	Main function	Status
Kenya Stud Book[1]	1920 – Farmer Organisation	Coordinate pedigree recording and registration	Operational
Boran Cattle Breeders Society	1951 – Breeders' Organisation	Breeding of Boran	Operational
Central Artificial Insemination Station	1966 – Government Parastatal	Artificial Insemination	Operational
National Beef Research Centre[2]	1968 – Government Research Centre	Research support	Operational
Kenya Beef Records[3]	1973 – Government Agency	Record keeping Genetic evaluation	Operational (sub-optimal)
Kenya Meat Commission[4]	2006 – Government Parastatal	Beef Marketing	Operational

[1]The Kenya Stud Book is operated by the Kenya Livestock Breeders' Organisation (KLBO).
[2]The National beef Research centre is one of the research centres operated by the Kenya Agricultural Research Institute (KARI) Livestock Recording Centre.
[3]The Kenya Beef Records is a department within the Livestock Recording Centre (LRC) operated by the Ministry of Livestock Development.
[4]Kenya Meat Commission was defunct since late 1980s but was re-established in the year 2006 to purchase livestock from traders for meat processing and export.
Source: Modified from Figure 3.1 in this thesis (Chapter 3, section 3.3.1)

The Boran Cattle farmers were identified as one of the important stakeholders in the breeding programme because of their ownership of the common-pool resource (Boran cattle). Specific interest of stakeholders was dependent on their legal status as enacted by the Kenyan parliament or by their association with the resource. The results from this approach can be represented in a systems-analytical framework describing the management of common resources as summarised in Figure 5.1 (modified after Sun, 2007). The framework shows overarching principles of the system, namely, government policy, history and economic development. The historical development contributes to community relationships and sustainable utilisation and management of common resources that could generate economic benefits.



Key: LRC = Livestock Recording Centre; KARI = Kenya Agricultural Research Institute; CAIS = Central Artificial Insemination Station; KLBO = Kenya Livestock Breeders' Organisation)

Figure 5.1 Key actors and interrelationships within the institutional framework for Boran cattle breeding in Kenya (modified from Sun, 2007);

To avoid duplication and conflicting operations between stakeholders, government policy regulating the system provides the roles of parastatal stakeholders. The breeding programme for the Boran cattle designed in this study is expected to benefit from this institutional framework.

The current study was limited in scope as only the institutions with direct involvements in livestock breeding processes were reviewed. Online interviews also limited the amount of information that could be retrieved from key persons. Limitations were also encountered as concerns government policy as documentation and reports on this subject were scarce and furthermore, Kenya currently has no active animal breeding policy (Wasike *et al.*, forthcoming). The limitations in information on the whole value chain was eminent in this study. Institutional framework analysis depends on the availability and accessibility of information (Grimble, 1998). Therefore, this study could not investigate the interrelationships among the stakeholders as well as the financial flows with respect to inputs and outputs within the system. A follow-up Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis based on an extensive field-survey would be able to retrieve more information to allow for the evaluation of other organizational aspects of the Boran cattle sector.

5.2.2 Design and evaluation of the breeding programmes

Breeding programmes were designed and optimised using procedures that determine population structures, selection processes, genetic gain and economic response based on the ZPLAN computer programme. Nucleus breeding programmes were chosen because of the possibility to concentrate breeding costs on smaller animal populations. These forms of breeding programmes have been recommended for developing countries due to limitations in infrastructure and financing (Bondoc and Smith, 1993).

The ZPLAN program is based on a deterministic model. Alternative nucleus breeding programmes for Boran cattle were designed in ZPLAN and genetic and economic responses to selection predicted. The effect of changes in biological and technical parameters over time on the economic and genetic sensitivity of Boran breeding programmes was tested through variation runs that simulate dynamic systems. The responses from selection groups were specific depending mainly on the gene transmission matrix, the discount (interest) rate and on the investment period defined. The programme also calculated total returns on investments per trait using the gene-flow procedures that utilise discounted expressions of traits to correct for differences in frequency and expression time by following the flow of genes through estimation of diffusion from age classes in any year to the next generation. The accumulated discount expression rate is obtained from the combination of the flow of each route, the discount rate and frequency of gene expression (Hirooka, 1999). Total returns therefore were obtained from the product of the genetic superiority and standard discounted expressions of each selection group multiplied by the undiscounted economic values of the traits. This was then summed up for all traits in all selection groups present in all levels of the breeding programme (e.g. nucleus and commercial units) (Nitter *et al*., 1994). Subtraction of total costs (fixed and variable costs) from the total returns obtained the profit per cow. Genetic responses were defined by modules based on selection index theory that utilises genetic and phenotypic parameters and economic values of traits to estimate genetic gain (Hazel, 1943). The genetic and economic merits of the breeding programmes evaluated in this study depended therefore on the system dependent input parameters for each alternative and the robustness of the ZPLAN computer programme.

One shortcoming of ZPLAN is the inability to account for the fact that genetic variance for traits which is expected to diminish with selection and inbreeding. This could lead to overestimation of genetic response and economic returns on investment. However, since the procedure was administered in all evaluated breeding programmes, it was possible to relatively compare breeding programmes sharing similar designs for biological and economic inputs. ZPLAN as a deterministic model requires that all processes including changes in the means for genetic and phenotypic parameters as well as selection criteria for all groups of animals (cost groups) be described in terms of algebraic functions, a requirement that is difficult in case of large complex functions (e.g. when information from several relatives are applied in a multiple step selection process). Another limitation was the inability of ZPLAN to monitor biases that occur due to correlations between estimated breeding values in cases where family information used in developing the selection index is predominant (Nitter *et al*., 1994). However, family selection can be accounted for by defining a value for reduced genetic variance within the ZPLAN. Stochastic approaches, consider variance due to selection and inbreeding but they do take up large amounts of storage space and involve a very large number of mathematical operations for every run and replications, and therefore take much longer to run than deterministic programmes (Kinghorn, 1993). The analysis of multiple parameters, such as genetic and economic, of a system simultaneously is, in most cases, difficult or impossible in stochastic modelling but deterministic models like ZPLAN are able to perform these evaluations simultaneously. This is because, it is possible in deterministic simulation to fix specific variable levels while setting all other factors constant, an exercise that is not possible in stochastic simulations.

In general, ZPLAN was flexible and fast, able to produce results from a simulated breeding programme for a half a million cattle in a matter of seconds. The knowledge of FORTRAN computer language is essential for users of ZPLAN (Willam *et al*., 2008).

5.3 Results

5.3.1 Evaluation of breeding objectives

The current study reviewed the situation of beef cattle production and breeding in the sub-Saharan region, depicting a detailed evaluation of the Boran cattle of Kenya. Beef production in this region was observed to occur under grassland-based production systems that impacted on the choice of breeding objectives (Rewe *et al*., 2007). This observation is consistent with those of Bayer and Bayer (1989) and Massey (1993) who described factors that control beef cattle production as: natural environment (forage resources and weather), costs, prices, market requirements, cattle type, breeding and management practices. Production factors are interactive and influence to a large extent the expression of genetic potential. The breeding objectives were also dependent on the relationship between farmers and their animals, which has been reported to complicate the pursuit of common production objectives (Neidhardt *et al.* 1996). The main production goal for the cattle in the current study was beef. The cattle are expected to contribute in the supply of meat for a growing demand projected at 65% of the total population for developing countries by the year 2020 (Delgado; 2003). A majority of developing countries are found in sub-Saharan Africa and are responsible for a total output of over 3,717,000 metric tonnes of beef. The east African region produces approximately 35% of this value (1,310,000 metric tonnes) (Tambi and Maina, 2003).

The presence of breeding activity in beef cattle raised in various regions of eastern, western and southern Africa did not necessarily reflect the existence of formal breeding objectives. In the early 20th century, crossbreeding was the most common breeding activity for beef cattle in Africa (Mpofu, 2002b; Madalena *et al*., 2002). The impact of crossbreeding activities has been both positive and negative. The crossing of the Zebu (*Bos indicus*), the near East-European *Bos taurus* and the native African *Bos taurus* in the 1920s led to the development of the improved Boran in Kenya (Hanotte *et al.,* 2000), while the performance of exotic cattle and their crosses in south Africa was reported to have dropped to levels even below the nondescript indigenous stock found in these areas (Bester *et al*., 2001). Pure-breeding strategies based on the indigenous Boran cattle of Kenya evaluated in this study showed potential for profitability and may contribute to conservation of these animals. Hodges (1984) outlined that breeding indigenous livestock was not only beneficial for sustaining productivity but also for conservation purposes. An ILRI (2007) report is in agreement with this objective by indicating that erosion of indigenous livestock genetic resources was due to the indiscriminate introduction of exotic breeds and germplasm from developed countries in local production systems in developing countries.

The combination of market and non-market values was employed in the definition of breeding objectives for breeding programmes incorporating improved and unimproved Boran cattle. Notably, the shift from market traits to a combination of market and non-market traits resulted in a loss in growth performance, however, the results showed an improvement in disease tolerance and post-weaning survival rate (20% PCV and 1% respectively) (Table 4.5, Chapter 4, section 4.3.2). This result is more beneficial especially for the open-nucleus option. The possibility of importing unimproved Boran into the nucleus is supported by Rolands (1995) who reported that unimproved types such as the Orma Boran were more trypanotolerant than the improved Boran. Selecting for disease tolerance will therefore be more possible with the inclusion of the unimproved Boran in the breeding programme. Dalton (2004) agrees with this objective by suggesting a refocus of national and international development cooperation towards evaluating a broader set of cattle traits beside beef and milk yield. This study employed the findings of extensive conjoint analysis studies among the pastoral and agro-pastoral communities in Kenya to identify trait preferences for the low-input production system. Ouma *et al*. (2007)

presented a range of production, fertility and adaptation traits preferred by cattle keepers in this system while Janssen-Tapken *et al*. (2006) and Pitchford (2007) presented estimates of economic values for both market and non-market traits within this production system. Adaptation traits related to disease tolerance (trypanotolerance and tick resistance) and docility (temperament) were found to be of high economic value alongside growth and lactation milk production. Milk production has been reported to be a useful cow trait amongst these farmers (Ouma *et al*., 2006). The trait preferences by Kenyan small-holder farmers were similar to those of small-holder (low-input) Nguni cattle farmers in Southern Africa (Mapiye *et al.,* 2009) and N'Dama cattle of West Africa (Fall *et al.,* 2003). The ranking of feed shortage, diseases and parasites as the most important constraints in small-holder systems (Mapiye *et al*., 2009) explains the choice of traits that tend towards fitness and survival. The results for genetic improvement showed that milk yield in this system would continue to be compromised when growth and adaptation are included in the breeding objective. In contrast, a study on N'Dama cattle (Dempfle, 1991) showed that it is possible to obtain genetic improvement in milk for a combined breeding objective with growth and trypanotolerance. That study differed from the current study in the application of relative economic values for market and non-market traits. The current study showed that restrictions on growth to allow for a positive trend in milk yield will be beneficial in meeting the multipurpose objectives of these farmers.

The Inclusion of functional traits in the breeding objective was in agreement with Burrow and Prayaga (2004) who indicated that production in tropical cattle depends on both genetic potential and the ability of cattle to withstand environmental stressors. Targeting growth as the main production trait for beef production alongside reproduction, carcass weight, milk production, feed intake, disease tolerance and adaptation traits allowed for moderate gains in growth. The findings of Frisch and Vorcei (1984) showed that improvement in growth is possible if animals increase in their ability to withstand prevailing environmental stressors. The breeding objective applied in the current study is in contrast with earlier informal breeding objectives for Boran cattle that mostly targeted growth resulting in negative impact on adaptation traits (Hanotte *et al.,* 2003). Introducing Trypanotolerance in the breeding objective for Boran cattle was able to reverse the loss in adaptation but with consequences on growth rate. However, improving adaptation to ticks may not necessarily have accounted for the responses in growth. Weak and non-consistent relationships between these two traits have been reported (Mackinnon *et al.,* 1991; Fordyce *et al.,* 1996). Improvement in temperament on the other hand, may have been influenced by the positive responses in growth. Burrow and Prayaga (2004) reported that larger animals tend to have lower flight speeds as a consequence of reduced activity levels. This allows for ease in handling and herding evidenced in the larger improved Boran cattle (BCBS, 2008).

Selecting for growth and cow weaning rate resulted in improvement in both traits. This result agrees with the findings of Burrow *et al.* (1991) who reported that heavier heifers conceived earlier than lighter ones and managed to rear more calves per lifetime. This finding is confirmed by the general reduction in age at first calving in the Boran cattle breeding objective even as growth improved. The consequences of increasing growth in tropical environments where feed is a limitation include the potential increase in animal feed requirement. The responses in feed intake could not be strictly attributed to changes in growth because of the obvious influence of the environment. However, increase in growth may indicate increase in feed intake (Morris *et al.,* 1992). Residual feed intake, which defines the difference between an animal's actual feed intake and its expected feed requirements for maintenance and growth, was not evaluated in the current study. Residual feed intake is mostly preferable in intensive beef cattle production as a means of lowering feed intake and controlling methane gas production (Hegarty *et al.,* 2007). Monitoring feed intake among other functional traits in the beef breeding objective was important in obtaining optimal genetic improvement with respect to long-term productivity.

Selection criteria traits used in this study were mainly growth and fertility characters. The combination of growth and reproduction in large-scale beef commercial system is practiced in other cattle in Africa such as the Simmentaler cattle of southern Africa (Kluyts *et al.,* 2007). In the current case, the inclusion of more functional traits in the breeding objective yielded a low correlation of selection criteria and breeding objective (selection accuracy) at 0.3, which improved to 0.5 as adaptation traits were introduced in the selection criteria. Dickerson *et al.* (1974) also reported improvement in selection accuracy (correlation between selection criteria and breeding objective) when the selection criteria were matched more closely to the breeding objective. The levels of accuracy achieved in the current study were from the selection young bulls without progeny testing. Pitchford (2007) also found selection accuracies of above 0.5 using a young bull selection strategy for Pastoralist cattle selected for production and adaptation. The current study relied on literature estimates for genetic and phenotypic parameters for the beef breed evaluated. Therefore, the level of correlated responses in traits was also dependent on these estimates. Nonetheless, literature estimates are important in situations where organised performance recording is still a work in progress as is the case with the Boran cattle in Kenya.

5.3.2 Optimisation of breeding schemes

Alternative breeding schemes were evaluated to test the effect of nucleus type (open or closed), and breeding objectives. Optimising the breeding programmes may require the application of an open-nucleus with a cost reduction strategy. This was observed when lower costs were found at lower percentages of gene importations into the nucleus. The costs may be further lowered by eliminating recording completely in commercial herds (Wilson *et al*., 1987; Rege *et al*., 2001).

The size of improved Boran cattle breeding population influenced genetic and economic performance of the breeding programmes. The elite BCBS group with 52,000 cows posted lower returns than those from the breeding programme incorporating the entire membership of the BCBS of up to 99.972 cows. These results denote the importance of minimum effective population size for breeding livestock. A Figure of 40 for dairy cattle has been recommended when considerations of net genetic response in economic merit are made (Goddard and Smith, 1990). Nomura *et al*. (2001) reported an effective population size of 17.2 for Japanese Black cattle and reported the major cause for the relatively small levels of effective size to be the intensive use of a few prominent sires. The Boran breeding programme simulated for the elite breeders is expected to be influenced by the negative effects of small effective population size.

Utilisation of indigenous genetic resources may facilitate conservation and sustainable production but was shown here to incur substantial costs to the system. Köhler-Rollefson (2003) highlighted the importance of protecting traditional systems with respect to use of the genetic traits of indigenous livestock breeds. Some of these traits of indigenous cattle pose logistical and breeding challenges and may play a part in the feasibility of breeding programme designed in this study. For example, Itty *et al*. (1998) showed that recording for disease traits is expensive and could cost up to 60% of the total variable costs. Emanuelson (1988) also showed that although disease traits show some considerable variation in the population, they posses low heritabilities and are in most cases antagonistic to production traits. That was evidenced in the current study by the slow rate of genetic improvement obtained for disease and adaptation traits even though they had high economic values. However, since the potential of Boran cattle for beef production and livelihood in the semi-arid tropics is known (Rewe *et al*., 2006a), strategic stakeholder partnerships may be persuaded towards management of this trait even through marker assisted selection (ILRI, 1996). Furthermore, indirect selection for disease tolerance using survival rate as a correlated trait is an option that is less costly (Rege *et al*., 2001) and is applicable in these breeding programmes.

Breeding programmes in developing countries are preceded by a history of unsuccessful examples which were modelled from the extension of programmes that focussed solely on milk and beef objectives (Madalena *et al*., 2002; ILRI 2007). The first priority for farmers relate to obtaining short-term benefits from their animals and any expectations of change that involve any level of input injection from them may be resisted (Winter and Doyle, 2008). In the current study, the total investment cost for the relatively small (5%) closed-nucleus of 24,002 cows from the breeding programme LOW was found to be over KSh864,000 per year while the open-nucleus breeding programmes had a cost of over KSh2.5 million year (Table 4.7, Chapter 4, section 4.3.4). The investment into the breeding programme for this group would require the involvement of multiple external stakeholders in order to translate breeding technologies into a simple village breeding programme to meet production costs rather than profit maximisation. For example, Demple (1991) in proposing the N'Dama nucleus breeding programme, suggested that investment appraisal of about US$ 13 million for over 5 million purebred N'Dama and 1.2 million crosses would make neither profit nor loss in the operations of the scheme but would be sufficient to operate the N'Dama nucleus herds.

In this study, reproduction was assumed to be entirely by natural mating. Artificial Insemination (AI) and Embryo Transfer (ET) produce higher rates of genetic progress but have very slow rates of adoption in extensive beef production systems (Cunningham, 1999). This is attributable to cost of technology and practicability of its application. A review on the possibilities and potentials for various reproductive techniques in Africa reported that most technologies have been applied to a lesser extent in this region due to the slow rate of economic growth compounded by poor infrastructure, technical and educational capacities (Kahi and Rewe, 2008). Furthermore, Janssen-Tapken *et al*. (2006) discussed the difficulties of applying AI in pastoralists' herds in Kenya as caused not just by unavailability of the service but the impracticability of heat detection in these extensive grazing systems coupled with increased labour requirements. Natural mating will therefore continue to dominate beef production systems in this region even though it requires the availability of high numbers of bulls to service entire herds. This has resulted in longer generation intervals compared to AI and ET (Kosgey *et al.,* 2005). The potential of young bulls in enhancing genetic improvement of beef cattle raised in low-input beef production systems has been demonstrated by Pitchford (2007). The current study did not evaluate the impact of ET on the breeding programmes, however, international trade in improved Boran cattle genetics has been done through ET (BCBS, 2008).

5.3.3 Organisational structures for breeding programme management

Harmonisation of breeding activities, centralising data management and genetic evaluation are necessary if the breeding programmes proposed in this study are to succeed. The current study introduced the institutional framework characterising the Boran breeding sector and revealed a set of stakeholders that perform specific roles working in partnership with the BCBS members. The commercial population of the BCBS members are active farmers who value good breeding stock. However, since there have been no common genetic evaluations before, it is unclear how they would respond to the ranking of bulls from different farms. In this study, dispersed nucleus breeding programmes were reviewed and recommended for beef production systems in Africa. The existence of BCBS is a strong characteristic for the improved Boran breeding programme. This is true for specialised indigenous cattle types in developing countries utilised in large-scale commercial systems, for example, the Tuli cattle breeders' societies in South Africa (Mpofu, 2002a). However, in contrast to the improved Boran situation, the breeding of Tuli cattle is organised by an umbrella institution, the South African Stud Book and Livestock Improvement Association, which caters also for other livestock in southern Africa. The nucleus herds for Boran cattle are dispersed among the farmers. Sustaining the status quo by avoiding centralising the breeding herds was recommended in this study (Rewe *et al.,* 2007). This is in concert with Rege *et al.* (2001) who reported that the success of a nucleus breeding programme for the improved Boran would be enhanced if the scheme was run without physically relocating animals. Centralisation of animal data may be more preferable than the centralisation of breeding herds.

Combining improved and unimproved Boran cattle within an organised breeding programme is expected to be complex. It is still unclear if Boran breeders will produce breeding stock for the low-input production system or whether the low-input producers will continue to demand larger Boran cattle from the breeders. The determinants of the success of this alternative breeding scheme include the levels of market orientation and organisation among the low-input farmers (Madalena *et al.,* 2002; Wurzinger *et al.,* 2008). The motivation for the Kenyan farmers would most likely be more economic than genetic assuming that the market-oriented low-input producers would be willing to buy the heavier Boran cattle from the commercial ranchers. The continued interaction between these two different production systems would probably be driven by the fact that some low-input producers, although resource-poor, raise substantial monetary income from trade of livestock (Mahmoud, 2001). These farmers may continue to buy bulls with the intention of improving their stock depending mainly on local knowledge. Indigenous knowledge is often applied by traditional farmers in low-input production systems to make strategic breeding decisions towards sustaining appreciable production in their stock (Wollny *et al.,* 2005).

The breeding programmes involving the low-input Boran cattle farmers' assumes a reasonable level of organisation among this group of farmers. Janssen-Tapken *et al.* (2006) cautioned that the willingness of these farmers to communally manage their animals is low. This differs with the situation in West Africa, where the Gambian Indigenous Livestock Multiplier Association (GILMA) is an organised farmer group that provides a link between breeders and commercial farmers and is responsible for the expansion of the N'Dama breeding scheme (Bosso, 2006). Mapiye *et al* (2009) suggests that Farmers' socioeconomic and pedo-climatic conditions should be considered when planning strategies for sustainable cattle development in the smallholder farming systems. Notably, lack of small-holder farmers' organisation in the Kenyan case may complicate the process of dissemination of genetic improvement. Community-based livestock improvement organisations are important for the management of animal genetic resources (FAO, 2003). The current study presented possibilities for regional as opposed to national breeding programmes for Boran cattle. Confining breeding programmes to regional operations minimises costs and logistical constraints through decentralisation of genetic improvement systems that maintains desirable levels of in-country genetic diversity (Kahi *et al*., 2005; ILRI, 2007).

The dependence of structured breeding programmes on institutional capacity, farmer organisation and government good-will was also implied in this study. These observations reflect the views on constraints to breeding programme establishment in Kenya by Kahi *et al*. (2006). That study outlined the major constraints to be infrastructural limitations (lack of good transport and communication networks), institutional shortcomings (underperforming government services and poor farmer organisation), logistical shortfalls (e.g. animal recording and evaluation techniques), input limitations (resource poor farmers), educational constraints (illiteracy and poor capacity building in local populations), cultural/socio-economic priorities (diverse breeding objective of farmers) and geo-political issues (land issues and government priority settings). These limiting factors are common in developing countries. For example, a major limitation in setting up a local guinea pig breeding programme in Bolivia was reported by Valle Zárate (1996) to be the lack of recognisable regional breeding structures characterised by poor institutional linkages. The small ruminants breeding programmes in Kenya (Kosgey *et al.,* 2006) and West Africa (Yapi-Gnaore *et al.,* 2003) also share these limitations on inputs, institutional shortcomings and diverse cultural and socio-economic priorities making it difficult to harmonise diverse breeding objectives of farmers. Strategic modifications to conventional breeding strategies within the process of introducing village breeding programmes may be done with the view of matching the breeding objective of Boran cattle farmers with the prevailing production and marketing circumstances characterising beef cattle systems in Kenya.

5.4 General conclusions for practical application of results

- Sub-Saharan cattle have potential for both production and adaptation traits and breeding activity amongst these cattle will be determined by the type of farmer *vis a vis* the role of the cattle within the production system. The potential for genetic improvement of indigenous cattle in sub-Saharan Africa exists not only because of the variation in performance but also the existence of breeders' organisations. A good example is the Boran cattle Breeders Society of Kenya that keeps the improved Boran breed.
- The institutional framework for the Boran cattle sector in Kenya described in this study could form a basis of further analysis of strengths and weaknesses of

the system using SWOT analytical procedures to reveal more information on the functional capacity of the Boran breeding industry.

- The improved Boran breeding programme has potential for profitability more so when the entire membership of the Breeders' Society are incorporated in a dispersed nucleus breeding plan. In situations where costs and adaptation are important factors, as is the case in this study, the approach should be cost minimisation from the application of optimal breeding programmes as opposed to profit maximisation.
- The Boran cattle kept by low-input producers are the majority and provide for more households than the improved Boran. This group could not be ignored in this study because of their interactions with the commercial beef ranches. The expanded breeding programme can be made to work if the farmers are organised within a breed society under committed partnership from stakeholders.
- The relative economic importance of traits projected the profitability of modelled breeding programmes but could not determine the feasibility of the same. Strong institutional framework, established infrastructural network, technology adoption and innovation as well as farmer organisation would collectively determine the feasibility of Boran cattle breeding programmes in Kenya.

CHAPTER 6

GENERAL SUMMARY

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6.1 Summary

Beef production with Boran cattle of Kenya presents an opportunity for utilising the potential of an indigenous breed. Improving the performance of these cattle through production of quality breeding stock may support the livelihoods of Boran cattle farmers. Organised breeding programmes for Boran cattle in Kenya are lacking. This thesis focussed on the design of optimal genetic improvement programmes for Boran cattle raised in the semi-arid tropics of Kenya. Specifically, the aims were: 1) to review the potential for beef cattle genetic improvement in sub-Saharan Africa, 2) to describe the state of institutional framework supporting Boran breeding in Kenya while considering the different categories of Boran cattle farmers, 3) to investigate the genetic and economic merit of alternative breeding programmes based on improved Boran, the unimproved Boran and the possibilities of expanding an inclusive breeding programme for these two strains of Boran cattle, 4) to discuss the feasibility of alternative breeding strategies within the context of a formal breeding programme in Kenya.

The methodological approach entailed a review of the literature on cattle production and genetic improvement strategies for sub-Saharan Africa. This was done by identifying previous and on-going breeding activities among indigenous cattle breeds based on their regional distribution in Africa. An institutional framework analysis to characterise the Boran breeding sector in Kenya was also performed. Open questions were presented to the Boran cattle Breeders' Society of Kenya through an online survey to ascertain the structure of the society in terms of membership, cattle populations and animal breeding activities. The production systems, cattle types and breeding objectives were also sought from previous studies on Boran cattle in the process of developing appropriate breeding programmes.

Design and evaluation of nucleus breeding programmes (genetically and economically) was done with the ZPLAN computer programme by defining the breeding objectives and selection criteria traits, describing breeding and commercial populations, describing selection groups as well as their reproduction performance parameters. The costs of the breeding programme included fixed costs and costs of animal recording. To account for genetic gain and the flow of animal genetics, a gene transmission matrix was defined utilising the selection groups alongside genetic and phenotypic parameter matrices. The information sources for the selection criteria were mainly parental selection groups and halfsibs of animal. The number of animals forming the selection groups and information sources was calculated in the NBILD and NUMBER subroutines of the ZPLAN. The interest rates for returns and costs were 8% and 6% respectively while the investment period was set at 25 years. The scope of the study was limited to two classes of farmers keeping Boran, the commercial beef ranchers and the market-oriented low-input beef producers that interact with commercial beef ranchers. Three breeding objectives were evaluated, 1) conventional breeding objectives with market (economic) values derived from bio-economic modelling, namely: direct sale weight, dressing percentage, consumable meat percentage, cow weaning rate, cow survival rate, cow weight, age at first calving, milk yield, feed intake and post weaning survival rate, 2) a combination of selected conventional target traits in addition to traits important to low-input farmers to exploit the ongoing informal interaction between the large scale ranchers and low-input systems, and 3) trait preferences for low-input farmers derived from conjoint analysis studies namely; sale weight, calving interval, temperament, tick resistance, trypanotolerance and lactation milk yield. To evaluate the benefit of perceived trypanotolerance in unimproved low-input herds, strategic recording for trypanotolerance for offspring of nucleus sires born in these herds was assumed. Closed and open-nucleus types were evaluated and variations on the nucleus size (5%, 10% and 25%).

proportion of gene transfer to commercial herds (25%, 50%, 70%) and the proportion of gene importation into the nucleus (10%, 20% and 30%) were tested.

The results from the institutional framework analysis showed that the Boran sector is structured with a section of the farmers being large scale commercial ranchers keeping approximately 17% of a total population of 580,000 heads of cattle. The rest were Boran farmers operating in low-input production systems keeping over 80% of the total population. The large scale commercial ranchers were found to be divided into two groups, about 52% of these farmers were elite breeders that record with the Kenya Stud Book and the rest were mainly commercial. The large scale commercial ranchers keep the improved Boran while the low-input farmers keep the unimproved Boran. The large scale commercial ranchers were organised into a breed society, namely, the Boran Cattle Breeders Society (BCBS), incorporating both the elite breeders and the commercial group. The BCBS was identified as a key stakeholder in the breeding of Boran cattle because of their informal role as suppliers of breeding stock.

The results from the evaluation of alternative open and closed-nucleus breeding programmes utilising the Boran cattle populations were obtained with the ZPLAN computer programme. For the elite breeders', where a total population of 52,000 cows with a breeding unit of 25% was assumed, the overall monetary genetic gain was KSh86 per cow while the profit per cow was KSh361 under the conventional breeding objective. The breeding programme with the entire BCBS group where a population of 99,972 cows was assumed obtained a higher monetary genetic gain and profit than the elite group per cow of KSh93 and KSh431 respectively under the same breeding objective. The results revealed the effect of a larger effective population size on performance of breeding programmes. The breeding programme based wholly on market oriented low-input producers was evaluated using farmer trait preferences as the breeding objective. This breeding programme posted a negative gain for milk yield of -1.1 kg, which improved when restrictions on growth and adaptation were applied. The introduction of the combined breeding objective that included adaptation and disease tolerance traits resulted in a drop in sale weight gain by almost 2 kg. However, post-weaning survival rate improved from 0.4% to 1% and trypanotolerance gained 20% packed cell volume within this breeding objective. There was reduction in feed intake under the combined breeding objective, which is desirable considering the prevailing limitations on land, feed and climatic conditions. This may induce a change in focus from the continuous improvement in sale weight. The gains in post weaning survival rate would support this objective. The results from the expanded breeding programme may be beneficial to both the low-input farmers and the commercial ranchers because of the advantages conferred from the improvement in adaptation traits. The benefits of extra recording for trypanotolerance in the commercial herds of the expanded programme were not realised. In general, the open-nucleus programmes were superior genetically while the closed-nucleus programmes were superior economically. The larger nucleus sizes (25%), higher gene contributions to commercial herd (70%) and limiting nucleus opening to 10% were most profitable.

The limitations of the study were observed from the online interviews with respect to the amount of information that could be retrieved from key persons. Similarly, information on the legal framework of the breeding sector was scarce since Kenya has no active livestock breeding policy. The design and evaluation of the breeding programmes was possible with ZPLAN, however, in this study, genetic variance for traits, which normally diminishes with selection and inbreeding, was not account for. This may have had implications related to overestimation of genetic response and economic returns. Nonetheless, the potential of the Boran for both beef production and fitness traits coupled with the presence of institutional support for animal recording in Kenya were evaluated as strengths of the system. This study has shown the possibilities of combining market and non-market traits useful in breeding programmes for cattle utilised in different production systems. This approach is useful in cases where interactions exist between different categories of farmers. To benefit from advantages offered by open-nucleus breeding, recording may be avoided in the commercial herds and selection be done under criteria that are acceptable by the farmers. Further investigations on farmer organisations and comprehensive livestock breeding policies may aid the process of establishing co-ordinated breeding programmes for Boran cattle in Kenya.

6.2 Zusammenfassung

Die Nutzung des Boran-Rindes in der Rindfleischproduktion bietet eine Möglichkeit, das Potential dieser Lokalrasse zu optimieren. Organisierte Zuchtprogramme zur Produktion von Hochleistungszuchttieren fehlen. Die vorliegende Arbeit konzentriert sich auf die Gestaltung optimaler Zuchtprogramme für das in semiariden Tropen beheimatete Boran-Rind. Ziele waren 1) das Potential für die genetische Verbesserung von Fleischrindern im subsaharischen Afrika zu evaluieren, 2) die Rahmenbedingungen der Institutionen zu beschreiben, die an der Züchtung des Boran-Rindes in Kenia beteiligt sind, 3) den genetischen und ökonomischen Erfolg verschiedener Zuchtprogramme zu ermitteln, und 4) die Umsetzbarkeit der verschiedenen Zuchtprogramme zu diskutieren.

Der methodische Ansatz bestand in einer ausführlichen Literaturübersicht zum Thema Fleischrinderproduktion und Zuchtstrategien für Fleischrinderrassen in Subsahara-Afrika. Außerdem wurde eine Analyse der institutionellen Rahmenbedingungen der Boranzüchtung in Kenia durchgeführt. Diese Analyse wurde durch eine Online-Befragung von Mitgliedern der Vereinigung der Boran-Rinderzüchter in Kenia ergänzt, um offene Fragen zur Struktur hinsichtlich der Mitgliedschaft, Rinder-Populationen und züchterische Aktivitäten zu klären. Produktionssysteme, Rindertypen und Zuchtziele wurden in früheren Untersuchungen beschrieben und identifiziert. Darauf stützend wurden Zuchtziele, Selektionsmerkmale, Tierpopulationen (Zucht- und Produktionsstufe), Selektionsgruppen und ihre Reproduktionsparameter definiert und Nukleus-Zuchtprogramme modelliert. Diese Modelle wurden mit dem Computerprogramm ZPLAN genetisch und ökonomisch bewertet. Die Zuchtprogramme wurden für zwei Gruppen von Boran-Tierhaltern modelliert: die Gruppe der kommerziellen Großbetriebe und die der Bauern mit Low Input Weidemanagement. Folgende Zuchtziele wurden definiert 1) konventionelle Zuchtziele mit durch bioökonomische Modellierung abgeleiteten wirtschaftlichen Gewichten, d.h.

Verkaufsgewicht, Bemuskelung, Schlachtkörpermasse, Aufzuchtrate, Überlebensrate und Lebendgewicht von Kühen, Erstkalberalter, Milchleistung, Futteraufnahme und Überlebensrate nach Absetzen, 2) Merkmalspräferenzen von extensiv wirtschaftenden Tierhaltern, die mit Hilfe einer Conjoint Analyse ermittelt wurden, d.h. Verkaufsgewicht, Zwischenkalbezeit, Temperament, Zeckenresistenz, Trypanotoleranz und Laktationsleistung, und 3) eine Kombination aus ausgewählten konventionellen Zuchtzielmerkmalen und Merkmalspräferenzen von extensiv wirtschaftenden Boran-Haltern, um informelle Interaktionen zwischen Großbetrieben und extensiv wirtschaftenden Boran-Haltern zu berücksichtigen. Andere Modellvarianten untersuchten die Effekte einer strategischen Datenerfassung für Trypanotoleranz in den Nachkommen von Vatertieren in der Produktionsstufe, geschlossene und offene Nukleussysteme wurden untersucht, die Nukleusgröße angepasst (5%, 10% und 25%) und schließlich der Anteil des Gentransfers in die Produktionsstufe (25%, 50% und 70%) bzw. der Anteil des Gentransfers von der Produktions- in die Elitestufe (10%, 20% und 30%) variiert.

Die Ergebnisse der Analyse der institutionellen Rahmenbedingen zeigten, dass der Boran-Sektor in zwei Bereiche unterteilt ist. Es gibt kommerzielle Großbetriebe, die etwa 17% der Gesamtpopulation von 580.000 Tieren halten. Mehr als 80% der Boran-Population wird von Tierhaltern in extensiver Weidehaltung gehalten. Etwas mehr als die Hälfte der Großbetriebe sind Elite-Zuchtbetriebe, die die Herdbuchpopulation halten. Die andere Hälfte der Großbetriebe sind hauptsächlich in der Produktionsstufe angesiedelt. Großbetriebe halten Improved Boran, während in der kleinbäuerlichen Rinderhaltung das Unimproved Boran vorherrscht. Alle Großbetriebe sind in der Vereinigung der Boran-Rinderzüchter (Boran Cattle Breeders Society, BCBS) organisiert. Die BCBS wurde auf Grund ihrer informellen Rolle als Anbieter von Zuchttieren als Schlüsselinstitution in der Boran-Rinderzucht identifiziert.

Durch Modellkalkulationen in ZPLAN wurden der genetische und ökonomische Erfolg der unterschiedlichen Nukleus-Zuchtprogramme für Boran-Rinder ermittelt. Für die Elitezüchter wurde eine Gesamtpopulation von 52.000 Kühen angenommen, davon 25% in der Zuchtstufe. Der ermittelte monetäre Zuchtfortschritt dieses Zuchtprogramms betrug KSh86 pro Kuh und der Züchtungsgewinn pro Kuh betrug KSh361. In einem Zuchtprogramm, das die gesamte BCBS-Gruppe berücksichtigte und für das eine Population von 99.972 Kühen angenommen wurde, konnte ein höherer monetärer Zuchtfortschritt und Züchtungsgewinn erreicht werden (KSh93 bzw. KSh431 pro Kuh). Dies belegt den positiven Effekt der effektiven Populationsgröße auf den genetischen und ökonomischen Erfolg eines Zuchtprogramms. Das untersuchte Zuchtprogramm für extensiv wirtschaftende Boran-Halter unter Berücksichtigung von Merkmalspräferenzen der Tierhalter führte zu einem negativen genetischen Trend in der Milchleistung (-1,1 kg). Dieser negative Trend konnte durch eine Begrenzung der Zunahmen und Adaptation verringert werden. Eine Kombination aus ausgewählten konventionellen Merkmalen und Adaptationsmerkmalen im Zuchtziel führte zu einer Verringerung des Verkaufsgewichts um fast 2 kg. Jedoch verbesserte sich die Überlebensrate nach dem Absetzen (von 0.4% auf 1%) und die Trypanotoleranz (+20% für das Zellvolumen). Außerdem konnte eine Verringerung in der Futteraufnahme erreicht werden, was aufgrund der knappen Land- und Futterressourcen und der schlechten Klimabedingungen als positiv bewertet werden kann. Eine Begrenzung in der Zunahme des Verkaufsgewichts sollte den genannten Beschränkungen ebenfalls Rechnung tragen. Der erwartete Nutzen der Messung von Trypanotoleranz in der Produktionsstufe konnte nicht bestätigt werden. Offene Nukleussysteme erzielten im Allgemeinen einen höheren genetischen Gewinn, wohingegen geschlossene Nukleussysteme ökonomisch überlegen waren. Ein größerer Nukleus (25%), ein höherer Gentransfer in die Produktionsstufe (70%) und eine begrenzte Öffnung des Nukleus (10%) erzielten den höchsten Züchtungsgewinn.

Beschränkend auf diese Studie wirkte sich die mangelnde Informationsbereitschaft von Schlüsselpersonen in Online-Interviews aus. Ähnlich gering waren die Informationen über die gesetzlichen Rahmenbedingungen in Kenia. Die Modellierung und die Evaluierung der Zuchtprogramme waren zwar mit ZPLAN möglich, jedoch konnte eine Verringerung der genetischen Variabilität in den Merkmalen durch Selektion und Inzucht nicht erfasst werden. Das könnte zu einer Überschätzung des genetischen und ökonomischen Erfolgs führen. Diese Studie verdeutlicht das Potential der Boran-Rinder in Kenia für die Fleischproduktion und Anpassungsmerkmale in Verbindung mit institutioneller Unterstützung für die Leistungserfassung. Es konnte gezeigt werden, dass eine Kombination aus marktfähigen und nicht marktfähigen Merkmalen im Zuchtziel und somit eine Berücksichtigung von Merkmalspräferenzen von Tierhaltern in unterschiedlichen Produktionssystemen möglich ist. Um von den Vorteilen offener Nukleussysteme profitieren zu können, sollten keine Datenerhebungen in der Produktionsstufe erfolgen, sondern Tiere auf Grundlage von Merkmalen selektiert werden, die für Tierhalter in extensiven Systemen wichtig sind. Weitere Untersuchungen zu bäuerlichen Organisationsformen und gesetzlichen Rahmenbedingungen sind notwendig, um die Entwicklung organisierter Zuchtprogramme für Boran-Rinder in Kenia zu gewährleisten.

6.3 Muhtasari

Ufugaji wa Ng'ombe wa Nyama wa Boran ni njia mwafaka ya kueneza mazao kutoka kwa Ng'ombe hawa wa Kiasili nchini Kenya. Uimarishaji wa mazao kupitia ufugaji bora kunaweza kuleta uhakikisho katika maisha ya wakulima wa Ng'ombe hawa. Kwa sasa hamna Mbinu mwafaka za ufugaji zinazo unganisha wakulima wa Boran nchini Kenya. Lengo kuu la Tasnifu hii ni kufafanua mipango ya kuboresha ufugaji wa Ngomba wa Boran hasa kupitia uzalishaji. Malengo mahsusi ni haya; 1) kufafanua ufugaji wa Ng'ombe wa nyama katika bara la Afrika kusini mwa Jangwa la Sahara, 2) kufafanua mikakati na Taasisi zinazo husika na uboreshaji wa mazao kutoka kwa Ng'ombe wa *Boran*, 3) kufanya uchunguzi wa mipango bora ya uzalishaji wa Ng'ombe hawa katika nyanja ya mazao na bisashara, 4) kutafiti fursa na vikwazo vilivyoko ambavyo vitatoa mwelekeo wa mafanikio.

Tasnifu hii ilitumia mbinu kadha wa kadha kutimiza malengo haya, kwa mfano, kupekua ripoti za utafiti zinazoeleza kinagaubaga ufugaji wa Ng'ombe Afrika, kuchambua Taasisi zilizoko Kenya na umuhimu wao katika ukuzaji wa Boran, na mwishowe mchanganuo wa mipango bora ya kukuza Boran iliyofanywa kupitia chombo cha *ZPLAN-computer-programme*, kilicho chombo cha kutafiti ubora wa mipangilio ya ufugaji katika nyanja ya mazao na biashara. Tarakibu tatu zilifanyiwa utafiti, 1) Tarakibu ya wakulima wa mashamba makubwa, 2) Tarakibu ya wakulima wa riziki, 3) Tarakibi iliyochanganyisha wakulima hawa kwa sababu ya biashara ya Ng'ombe inayoendelea kati yao.

Utafiti huu ulionyesha kuwa Sekta ya Ng'ombe wa Boran ina takriban asilimia 17 ya Ng'ombe 580,000 wanaokuzwa na wakulima wakibiashara wenye mashamba makubwa. Wakulima wa kutafuta riziki wakiwa na Ng'ombe zaidi ya asilimia 80 ya Ng'ombe hawa. Wakulima wakibiashara wenye mashamba makubwa wamegawanyika mara mbili, takriban asilimia 52 ni wafugaji na waliobaki ni hujihusicha na biashara pekee. Ngo'mbe wanao kuzwa na wakulima wa mashamba makubwa ni *improved-Boran* na Ng'ombe wa wanaokuzwa na wakulima wa riziki ni *unimproved-Boran*. Wakulima wenye mashamba makubwa wameungana katika shirika la wakulima la Boran (Boran Cattle Breeders Society (BCBS). Wakulima wa improved-Boran hufuga kwa lengo la kuboresha Nyama bali wali wa riziki hufuga unimproved-Boran kwa lengo tofauti kama maziwa na kinga kutokana na magonjwa.

Tarakibu iliyohusisha wanachama wafugaji wa BCBS pekee Ilikuwa na Ng’ombe 52,000 na ubora wa Viasili Uzazi ilifika takriban Shilingi 86 kwa Ng’ombe. Faida nayo kutoka kwa biashara ilifika takriban Shilingi 361 kwa Ng’ombe. Katika Tarakibu iliyokuwa na wanachama wote wa BCBS (Ng’ombe 99,972), Uboreshaji wa Viasili Uzazi ilikuwa takriban shilingi 93 na faida ya shilingi 431. Katika Tarakibu ya wale wakulima wa riziki, Utoaji wa maziwa ulishuka kwa kiwango cha -1.1 kg, hali ambayo sio nzuri kwa wakulima hawa wanaotegemea Maziwa kwa riziki yao. Lakini Visifa vya ukuaji wa mwili na kupambana na magonjwa vilipodhibitiwa, basi utoaji wa Maziwa uliongezeka. Tarakibu iliyochanganya wakulima wa mashamba makubwa na wale wa riziki iliweza kushusha ukuaji wa mwili (-2 kg) na maziwa (-0.9), lakini iliweza kuboresha uwezo wa Ndama kuishi kutoka 0.4% mpaka 1%. Ulaji wa chakula pia uliteremka, tukio ambalo ni muhimu wakati huu ambapo ardhi, chakula na hali ya anga vimekuwa vizuizi kwa Ufugaji.

Ukosefu wa habari za kutosha kuhusu wakulima wa Boran pamoja na sera zinazohusika katika ufugaji wa Ng’ombe Kenya ilikuwa kizuizi katika kazi hii. Chombo cha ZPLAN pia kilikuwa na kasoro ya kutoweza kufafanua kiwango cha uzalishaji unaohusisha Ng’ombe wa familia moja. Kasoro hii inaweza kufanya matokea ya faida au uboreshaji wa visifa kuwa juu ya kiwango cha kawaida. Hata hivyo, ZPLAN iliweza kutafiti Tarakibu hizi za Ng’ombe wa Boran na kuonesha Ubora wa Ng’ombe hawa katika visifa vya Nyama na vya kupingana na magonjwa. Tasnifu hii imeonesha jinsi ya kuunganisha malengo tofauti ya kufuga Ng’ombe panapokuwa na aina mbali mbali ya wakulima. Sera dhabiti za serikali zinazolenga kuimarisha Taasisi za ufugaji na mashirika ya wakulima zinaweza kusaidia uboreshaji wa nyanja ya Ufugaji wa Ng’ombe wa Boran nchini Kenya.

CHAPTER 7

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