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DEVELOPMENT OF BREEDING OBJECTIVES FOR PRODUCTION SYSTEMS UTILISING THE BORAN CATTLE BREED IN KENYA

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DECLARATION AND APPROVAL

1. DECLARATION

This thesis is my own original work and has not been presented for a degree or diploma in any other university.

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2. APPROVAL

This thesis has been approved for final submission with our approval as University supervisors.

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Date: 11-11-2004

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ABSTRACT

Boran cattle are important in the Arid and Semi-Arid Lands (ASALs) of Kenya for beef production and as a source of livelihood to pastoralists as dual purpose animals providing both milk and meat. Despite their importance, no formal breeding objectives exist. The aim of this study was to develop breeding objectives for production systems utilising the Boran. Six systems were described by sale age of animals, levels of input and final goal as; short fed medium input beef (SFMB); long fed medium input beef (LFMB); short fed high input beef (SFHB); long fed high input beef (LFHB); long fed low input dual purpose (LFLD) and long fed medium input dual purpose (LFMD). Bio-economic profit functions were constructed and subsequently used to derive economic values of breeding objective traits under fixed herd-size and fixed pasture input situation. The traits were classified into production (sale weight of steers – SWs and heifers - SWh; dressing percentage – DP; consumable meat percentage – CMP, and milk yield – MY) and functional traits (cow weight – CoWT; cow survival rate – CoSR; post-weaning survival rate – PSR; feed intake of cows - FIc, heifers - FIh and steers - FIs). The influence of the estimated economic values on genetic improvement was also assessed using different selection indices. The outputs from the profit functions included revenue, costs and feed intake of cows, heifers and steers in the different production systems. In the fixed herd-size situation, the economic values for production (except MY in pure beef systems) and functional traits (except feed intake in all systems) were positive meaning a unit increase in genetic merit of these traits had greater influence on revenues than costs. The economic value of MY was negative in the pure beef systems (SFMB, LFMB, SFHB and LFHB) and positive in the dual purpose systems (LFLD and LFMD). Economic values estimated in the fixed pasture input situation were lower than those under fixed herd size for feed intake in the three classes of livestock and other traits related to feed intake namely, CoSR, CoWR, PSR, CoWT, SWh and MY in all systems. The economic values of CoWT in the LFLD and LFMD systems were negative (KSh -11.14 and -15.33, respectively). The magnitude of the economic values for production and functional traits estimated in this study suggest that genetic improvement would have a positive effect on profitability of Boran cows kept in dual-purpose systems and when herd-size is restricted. In pure-beef systems, genetic improvement of MY would have a negative effect on profitability, especially when restrictions on herd-size and feed exist.

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ABBREVIATIONS

ASALs	Arid and Semi – Arid Lands
ASK	Agricultural Society of Kenya
BLUP	Best Linear Unbiased Prediction
CAIS	Central Artificial Insemination Station
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GOK	Government of Kenya
KARI	Kenya Agricultural Research Institute
KBF	Kenya Beef Records
KMC	Kenya Meat Commission
LRC	Livestock Recording Centre
MAFF	Ministry of Agriculture, Fisheries and Food, United Kingdom
MoARD	Ministry of Agriculture and Rural Development
NBRC	National Beef Research Centre
NDP	National Development Plan
ONBS	Open Nucleus Breeding Scheme

CHAPTER ONE:
GENERAL INTRODUCTION

1.1 Background information

The agricultural sector contribution to the Gross Domestic Product (GDP) of Kenya is between 20% and 30% with the livestock sub-sector contributing over 10% to the GDP (MoARD, 1997). Beef production is a vital component of the livestock sub sector and contributes significantly towards food security. Beef is acceptable by a majority of consumers and can be produced in Arid and Semi-Arid Lands (ASALs), which cover 80% of the country. Moderate to low rainfall characterizes the ASALs and they are of low potential for crop production but can be classified as high potential for beef cattle production (Okeyo et al., 1998). The predominant cattle raised in these areas are the *Bos indicus* whose population is currently estimated at over 10 million as reported by the Ministry of Agriculture and Rural Development (MoARD, 1998). It has been estimated that 70% of beef consumed in Kenya is from *B. indicus* breeds, while the remainder comes from the dairy industry (dairy culls, bull calves) and a few exotic beef cattle breeds (MoARD, 1998; Indetie et al., 2001). However, a decline in productivity in the livestock sub-sector over the last decade has been noted and needs to be arrested since the sector employs over 50% of the agricultural labour force (Kilungo and Mghenyi, 2001).

The market for beef is large both locally and internationally, and as consumer tastes and preferences change, the quality and quantity of beef produced is expected to change accordingly. In Kenya, there have been attempts at improving beef production. In 1968, a beef industry development programme was proposed which led to the establishment of the National Beef Research Centre (NBRC) (Creek, 1976). However, the programme targeted the marketing segment of the industry using different *B. indicus* cattle breeds for feedlot fattening, and neglected various breeding and production systems. In 1973, a beef cattle recording scheme, the Kenya Beef Records (KBR) was established under the management of the Livestock Recording Centre (LRC) to support improvement of beef cattle. A number of large scale ranches, most of which are located in the ASALs, were involved in the scheme whose main objective was to provide management decisions on selection based on the records (Indetie et al., 2001). However, this scheme has not been very successful probably due to constraints related to uncommitted involvement of

stakeholders, sub-optimal prevailing policies on livestock development, unclear breeding objectives and structure of the beef industry, diverse management, production and marketing systems for beef and beef cattle (Rege et al., 2001).

Among the *B. indicus* breeds found in the ASALs, Boran constitute a large proportion of cattle kept for commercial beef production in Kenya, however, other cattle genotypes kept for beef production include *B. taurus* breeds such as the Hereford, Simmental, Charolais, Angus and their crosses. Through natural and artificial selection, the Kenya Boran breed has developed characteristics that facilitate its higher performance in constrained ASALs environments than temperate beef breeds. As a result, the Boran has greater ability to survive, grow and reproduce in conditions of high ambient temperature, poor feed quality and high pathogen incidences (that typify Kenya's ASALs) than *B. taurus* breeds (Davis, 1993; Herlocker, 1999). Studies have shown the superiority of Boran cattle and its crosses for growth, carcass traits and cow productivity index in the tropics over other *B. indicus* and *B. taurus* breeds (Gregory et al., 1984; Mwandoto et al., 1988). Due to these potentials, this breed is recommended for use in performance improvement of other indigenous and exotic cattle for beef production in the tropics (Trail et al., 1984).

Despite the importance of the Boran cattle in Kenya, no formal breeding objectives exist. Breeding objectives comprise of the economic values and breeding values of traits a producer would like to improve because of their influence on profitability in the production system. A number of factors contribute to the lack of formal breeding objectives such as lack of consistency in recording and sub optimal animal evaluation. Beef cattle farmers have therefore been left to define their own breeding objectives which are mostly biological in nature without due regard to the economic implications of such decisions. In addition, in most cattle production systems, farmers have relied on visual appraisal or the use of foreign germplasm for breeding purposes. Ojango and Pollot (2002) noted that the use of imported germplasm without considering genetic x environment (G x E) interaction could lead to depressed performance in the population of interest. It is therefore of great interest to suggest the possibility of implementing a genetic improvement programme in Kenya within a specialised breed of cattle that can satisfy pure beef or dual-purpose production for regions where such cattle thrive.

The process of genetic improvement of animals needs to be systematic and follows several important steps; definition of breeding objectives, development of selection criteria, genetic evaluations, selection of animals and finally design of appropriate mating systems. The definition of breeding objectives constitutes the most important step in the design of sustainable breeding programmes for various livestock species. Economic values are an indication of the relative importance of traits in a given production system.

1.2 Objectives

The overall objective of this study was to develop breeding objectives for production systems utilising the Boran cattle breed in Kenya. The specific objectives were:

- To develop bio-economic profit functions appropriate for the determination of profitability in production systems utilising the Boran cattle breed.
- To identify breeding objective traits and estimate their economic values under different defined production scenarios.
- To assess the influence of the estimated economic values on genetic improvement in Boran cattle.

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CHAPTER TWO:
LITERATURE REVIEW

2.1 The Kenyan beef industry

2.1.1 Historical background

Commercial beef ranching has been practiced in Kenya since the 1920's. Over the years, the predominant beef cattle breed has been the Kenya Boran, which originated from southern Ethiopia (Kimenye, 1983). By the beginning of the 1930's, crossbreeding regimes had already been established between indigenous breeds and the British beef breeds such as Shorthorn and Hereford. Therefore, the initial populations of beef cattle had some exotic blood (Trail et al., 1984; Gregory et al., 1984). Through backcrossing and selection the Kenya Boran (improved Boran was developed. Chirchir (2001) presented a comprehensive review on the development of the Kenya Boran. These cattle supplied most of the beef that was previously sold to a central marketing body, the Kenya Meat Commission (KMC), before liberalisation of the beef industry in 1987.

Beef production was initially practiced on large scale ranches of 1000 acres and above as well as by pastoralists in the ASALs. However, the subdivision of land in the late 1960's contributed to a depression in beef output since a producer requires at least 100 breeding cows in an optimum stocking area of 1000 acres for sustainable production (Berry, 1993; Prettejohn and Retief, 2001). In an attempt to stratify the industry, a development project was put in place in 1968 at the request of the Government of Kenya (GOK) with the main objective of inducing stratification of the beef industry through the development of an economically viable feedlot finishing sector (Squire and Creek, 1973). The price for feedlot beef was high for local consumers due to the high cost of inputs and thus the programme was not sustainable.

2.1.2 Beef production trends

Beef output in the country has been fluctuating since 1997. Table 1 presents the number of animals raised for beef, estimated off-take in metric tonnes per head and projections of output and demand for the years 1997 to 2008. The average annual increase in beef output has been about 10 tonnes. However, the figures presented should be used with caution given that they were calculated from hides and skins data. The figures ignore

animals that were slaughtered and not inspected by the Department of Veterinary Services, thus beef outputs in the country are expected to be much higher than the reported figures given that the outputs were calculated from hides and skins data (MoARD, 1998).

Table 1. Total number of animals raised for beef and estimated output and demand in metric tonnes per breed from 1997-2008[1]

	1997	1998	1999	2001	2004	2008
Cattle population	9,824,500	9,956,200		11,000,000	12,000,000	13,600,000
Output from Zebu cattle	182,560	189,000	195,615			
Output from Exotic cattle	78,240	81,000	83,835			
Total output	260,000	270,000	279,450	295,610	323,021	363,563
Total Demand				329,600	360,200	405,300

[1]Source: Ministry of Agriculture and Rural Development (MoARD)- Animal Production Division Annual Reports 1997 – 1998 and National Development Plan for the period 2002 - 2008 (NDP, 2002).

The demand for beef between the years 2004 – 2008 has been projected to be higher than the supply as stipulated in Table 1. The output is projected at 363,563 metric tonnes by the year 2008 against a potential demand of 405,300 metric tonnes. This means that demand for beef in Kenya is growing at a faster rate than its production (MoARD, 1998). Therefore, production must improve to avoid future scarcity of beef. Increased output could also allow for supply of surplus produce for export. Currently, the domestic beef supply is being augmented by imports of cattle from neighbouring countries particularly Ethiopia, Tanzania and Somali (Indetie et al., 2001).

2.1.3 National beef cattle development policy

The agricultural sector in which the livestock sub sector falls is currently undergoing reforms most of which are geared towards liberalisation (NDP, 2002). Throughout the 1980's and early 1990's, GOK expenditure on agriculture declined following policy changes that included the transfer of holding grounds to county councils, decontrol of meat and feed prices, and liberalisation of veterinary and artificial insemination services (NDP, 1997). The overall goal of GOK has been to facilitate the attainment of a sustainable balance in investments and provision of services between the

public and private sectors and the beneficiaries (NDP, 2002). The recommendation by GOK through the Ministry of Agriculture and Rural Development in the late 1980's to decentralise and liberalise the slaughter houses, a role earlier carried out centrally by KMC stimulated growth in the industry especially in the marketing segment. This was to allow beef cattle producers to access outlets without incurring additional marketing expenses that would impact negatively on consumers through inflated meat prices (Kilungo and Mghenyi, 2001). Direct policies on the issues of breeding and genetic improvement on livestock however are unclear despite the declaration of important policy statements in key government documents (Indetie et al., 2001).

2.1.4 Structure of the beef industry

The structure of the livestock industry is composed of individuals or institutions responsible for the production, marketing and consumption of products (Rege et al., 2001). The beef industry in Kenya is composed of producers (includes both large scale farmers and pastoralists), marketers (livestock traders and slaughter houses), retailers (Butcheries), policy makers (Government and research institutions) and consumers (Kilungo and Mghenyi, 2001). Production of quality beef is the primary goal for producers, although a well coordinated national breeding programme is absent (Indetie et al., 2001).

Organised livestock industries are useful in setting market prices and producer goals which encourages the development of sustainable breeding programmes important for the overall improvement of animal breeds and use of breeding and reproductive technologies (Davis et al., 1994). In the industry, producers can be structured to include beef cattle breeders and commercial producers to increase specialisation in form of a tier system such as the nucleus breeding scheme (Bondoc and Smith, 1993). However, such a strategy would require a complimentary organisation of the marketing systems that could augment the increased efficiency in production (Hirooka et al., 1998).

2.1.5 Beef cattle production systems

In the country, beef production systems can be classified into various categories; commercial beef production, dairy ranching, agro-pastoralists and pastoralists (Kilungo and Mghenyi, 2001). In all these categories, beef production is pasture-based under extensive grazing. This is in line with the increasing international demand for beef

produced from cattle reared on natural pastures (Rege et al., 2001). In commercial ranches, breeding systems practiced include pure-breeding based on *B. indic*us breeds (especially the Boran) and crossbreeding of *B. indicus* and *B. taurus*. In most cases, the agro-pastoralists and pastoralists utilise pure breeding based on *B. indicus* breeds (Okeyo et al., 1998). The interaction between pastoralists and commercial ranches is active since there is regular exchange of breeding material between them, and when necessary semen is sourced from the Central Artificial Insemination Station (CAIS) (Mukisira, 1998).

2.1.6 Marketing of beef cattle

Until 1987, KMC was the main marketer of beef and beef products in Kenya, hence determined prices of both live animals and beef (MoARD, 1998). The restructuring of the beef industry during this time coupled with the collapse of KMC resulted in livestock producers seeking alternative markets (Kilungo and Mghenyi, 2001). An illustration of various beef marketing channels before and after the exit of KMC is presented in Figure 1.

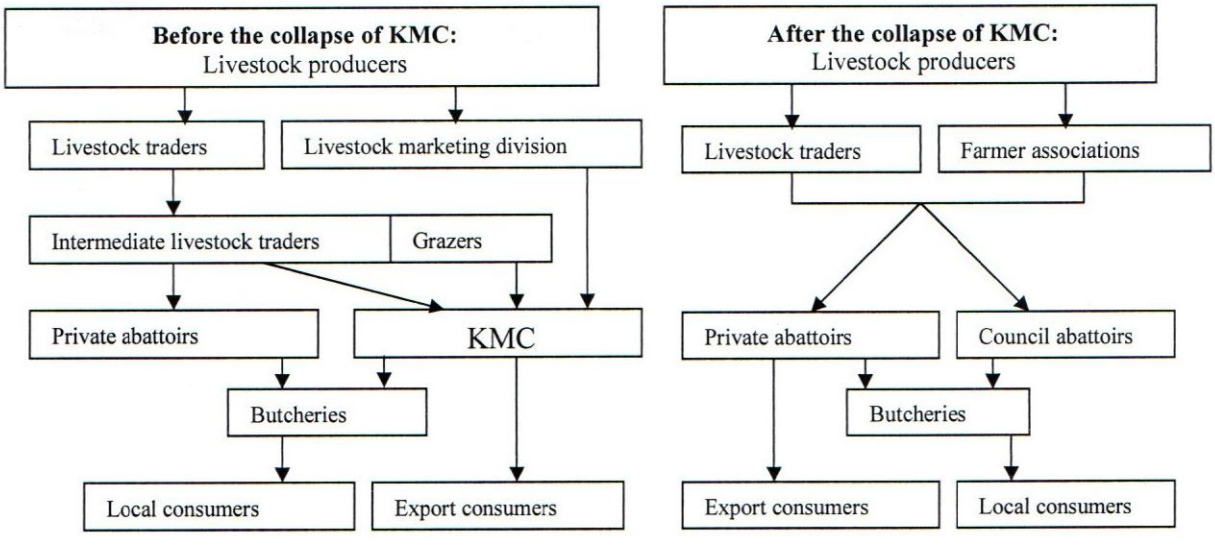


Figure 1. Beef marketing channels before and after the collapse of KMC. Source: Kilungo and Mghenyi (2001).

When KMC was operational, an extra step in the marketing of beef was required. After its collapse, some of its functions were taken over by council abattoirs. The market however lacks stratification (MoARD, 1998). Kilungo and Mghenyi (2001) defined three

main beef marketing categories in operation as primary, secondary and terminal markets. Primary markets comprise of local herders as the main sellers with local butcheries and itinerant traders as the main buyers. Secondary markets comprise local herders as the main sellers and larger and more established traders and butcheries as the main buyers. In both primary and secondary markets animals are traded for both resale to middlemen and slaughter. The terminal markets comprise of mainly large-scale traders and major butcheries. The challenge for local producers is the increased competition from traders from neighbouring countries currently marketing over 400,000 heads of cattle annually across major urban centres in Kenya (NDP, 2002).

2.2 Performance of *Bos indicus* cattle and their crosses

In the process of developing breeding objectives, information on the average performance in different traits is required to identify the age structure, numerical distribution, replacement rate and the number of each class of animal in a particular herd (Ponzoni and Newman, 1989; Urioste et al., 1998). In the tropics, growth and survival traits are important since they result in higher off-takes (Baker and Rege, 1994). Fertility traits such as calving rate (CR), calving interval (CI) and age at first calving (AFC) are also essential as they determine the calf crop, cow weaning rate (CoWR) and the number of animals to be finished for sale (Annor, 1996).

The genetic potential for milk and meat production characters is generally low in most *B. indicus* cattle breeds. Many breeds of *B. taurus* cattle have greater genetic potential for milk and meat production, but in many African situations it is not economically feasible to provide the environment necessary for them to realise this potential (Rege et al., 2001). However, some *B. indicus* cattle such as the Boran outperform most exotics in beef production in the ASALs (Gregory et al., 1984).

The most logical approach to increasing milk and meat production appears to be some modification of the environment to ensure productivity is technically and economically practical. This could be combined with the use of organised breeding programmes or the formation of composite breeds based on *B. indicus* and *B. taurus* parental stock (Trail and Gregory, 1981). To achieve this, consideration must be given to the comparative advantage of various breeds for specific traits related to growth, survival, reproduction and longevity especially in sub-Saharan Africa.

2.2.1 Growth

In commercial cut-based beef cattle, production parameters related to growth are important since they determine the size of an animal at slaughter. Growth in beef cattle is dependent on age, nutrition and genotype (McDonald et al., 1995). The most commonly recorded growth characters include birth weight (BW), weaning weight (WW), yearling weight (YW), 18-month weight (18WT), 24-month weight (24WT), pre-weaning average daily weight gain (ADG), post-weaning average daily weight gain (PADG) and sale weight (SW) (Payne, 1970; Trail et al., 1984; Gregory et al., 1984; Mwandoto et al., 1988; Davis, 1993; Indetie et al., 1996; Burrow, 2001). However, BW in most cases is measured only when there is need to select against calving difficulty, since under extensive range systems, it is difficult to obtain accurate measures (Davis, 1993).

A comparison of growth traits for some *B. indicus* cattle and derived breeds is presented in Table 2. The South African cattle, Bonsmara (which is a stabilised synthetic breed from the crossing of Africander, Shorthorn and Hereford) and Africander (indigenous Sanga, *B. taurus africanus*) are heavier at maturity than the other cattle. In the East African region, the Kenya Boran outperforms other Large East African Zebu breeds but is matched by the Sahiwal. Weaning tends to be carried out at different ages, generally between the 7th and 9th month of age, hence reported weights are variable. The WW of 56kg for the Sahiwal was due to the fact that weaning was done at 12 weeks of age (Muhuyi et al., 1999).

The Mpwapwa, a synthetic composite breed of 35% Red Sindhi, 20% Sahiwal, 20% Tanganyika Zebu, 10% Boran, 5% Ankole and 10% *B. taurus* (mainly Ayrshire), like the Sahiwal, has favourable growth attributes and is used for dual purpose production in the dry areas of central Tanzania (Bwire and Wiktorsson, 1996; Rege, 1999). Boran crosses with Red Poll, Charolais and Santa Getrudis tend to be heavier at weaning than the purebred Boran (Trail et al., 1984). The superiority of the crosses is attributed to heterosis due to the wide genetic distance between the parents contributing to faster growth in the crossbred calves. The Boran has become a standard for comparison in beef production systems in East Africa (Gregory et al., 1984). It is used in various crossbreeding programmes to improve adaptability in exotic breeds in the tropics and to improve the overall beef characteristics of other indigenous breeds (Indetie et al., 2000).

Table 2. Growth performance of *B. indicus* and their crosses or derivatives reared in African tropics

Breed	Traits[1]								Author
	BW (kg)	ADG (kg/d)	Weanage (months)	WW[2] (kg)	PADG (kg/d)	YW (kg)	18WT (kg)	SW[3] (kg)	
Kenya Boran			8	141			190		Mwandoto et al. (1988)
	23.6			169		192			Haile-Mariam and Kassa- Mersha (1995)
	27.7	0.53	7	151					Indetie et al. (1996)
	25.2			158		179		338	Banjaw and Haile-Marriam (1994)
Boran x Friesian			8	152			223		Mwandoto et al. (1988)
Boran x Red Poll				177					Trail et al. (1984)
Boran x Charolais				211					Gregory et al. (1984)
Sahiwal				146			223		Mwandoto et al. (1988)
	21.4	0.30	3	56*	0.55			463	Muhuyi et al. (1999)*
Sahiwal x Friesian			8	155			234		Mwandoto et al. (1988)
Sahiwal x AyrshireX[4]	29.6	0.50							Kahi et al. (1995)
Bonsmara	37.0	1.27	9	229				430	Maiwashe et al. (2002)
	35.0			187					Dodi et al. (2002)
Mpwapwa				110			203		Bwire and Wiktorsson (1996)
Africander	37.7			163			255		Carvalheira et al. (1995a)
Nguni	32.6			150			237		Carvalheira et al. (1995a)
N'kedi	19.0							345	Rege et al. (2001)

[1] BW = birth weight; ADG = pre-weaning average daily gain; Weanage = Weaning age; WW = weaning weight; PADG = post-weaning average daily gain; YW = yearling weight; 18WT=weight at 18 months; SW= sale weight.

[2] The WW represent different ages ranging between 7 to 9 months * except for the Sahiwal.

[3] The SW was measured at 36 months of age.

[4] Sahiwal x AyrshireX = a two breed stabilised cross of 67% Sahiwal : 33% Ayrshire.

The preweaning calf growth rates of most *B. indicus* range between 0.3 kg to 0.5 kg per day depending on the level of management and mothering ability of dams, the latter being closely related to the amount of milk produced by the dam (Mwandoto et al., 1988). Animals with favourably high daily weight gains (ADG) have higher SW due to the positive correlation between ADG and mature weight (Maiwashe et al., 2002). In most of the tropics, growing cattle depend on availability and quality of feed that in turn varies seasonally. The differences in degree of weight loss during the dry season when feed quantity is limiting may be a useful indicator of the efficiency of an animal in maintaining its weight. The ability to grow or maintain weight in different environments during the wet or dry seasons determines how quickly an animal will reach market weight (Davis, 1993). Growth in beef cattle is important when designing breeding objectives and breeds that show superiority in these characters can be utilised in the improvement of other breeds.

2.2.2 Reproduction and longevity

Beef production enterprises are also driven by off-take, which describes the animal movement out of the system as sale or slaughter animals. In such circumstances, the desired outcome is a high proportion of animals available for slaughter from the herd. This depends on the reproductive ability of the herd in terms of conception rate, CR, AFC, CI and productive herdlife (PHL) (Baker and Rege, 1994; Burrow, 2001; Rege et al., 2001). These traits, besides survival, determine the overall calf crop from the herd and are a good indication as to how many animals will be availed for sale or slaughter. In tropical regions, indigenous breeds differ in their reproductive abilities. This could be an indication of differences in adaptability. Some measures of reproductive performance of *B. indicus* breeds in Africa are presented in Table 3.

There are differences in AFC between the breeds, with the smaller-sized breeds such as the Nguni and Nandi zebu calving first at an earlier age compared to the large breeds (Table 3). Smaller sized breeds tend to mature at a younger age than larger breeds. The CI also differs and ranges from 365 days for the small breeds to 577 days. However, the differences in CI can be attributed to parity status, as CI tends to reduce with increasing parity (Okeyo et al., 1998). Estimates of performance in fertility traits such as CR, sperm count and scrotal circumference (SC) are scarce in the literature for these

types of cattle. Nonetheless, these traits are also important determinants of reproductive performance in beef cattle breeds (Burrow, 2001; Maiwashe et al., 2002).

Table 3. Reproductive performance of some *B. indicus* breeds and their crosses in Africa

Breed	Traits[1]				Authors
	PHL (years)	AFC (months)	CR (%)	CI (days)	
Kenya Boran	10	46	75	577	Indetie et al. (1996)
Kenya Boran			82	426	Okeyo et al. (1998)
Boran x Friesian		47		552	Haile-Marriam et al. (1993)
Sahiwal		42		426	Rege and Wakhungu (1992)
Sahiwal	10	44		415	Muhuyi et al. (1999)
Friesian x Sahiwal				395	Kahi et al. (2000)
Nguni		41		425	Carvalheira et al. (1995b)
Africander		43		473	Carvalheira et al. (1995b)
Nandi Zebu		43		365	Rege et al. (2001)

[1] PHL = productive herd life; AFC = age at first calving; CR = calving rate; CI = calving interval.

The productive herdlife defines longevity or the ability of an animal to live and reproduce in a herd for a period of time. The average PHL for most *B. indicus* is 10 years, which allows for the animals to produce an average of 5 calves per lifetime depending on AFC and CI (Annor, 1996). Though information on longevity for the crosses is limited, their lower CI indicates their ability to reproduce at a higher rate per year than purebred indigenous cattle (Table 3). However, the low estimates for CI in the crosses could also be attributed to intensive management practiced in terms of feeding and disease management, which sustain production in the harsh tropical environments (Kahi et al., 2000).

2.2.3 Milk production

In most of the tropics, a majority of pastoralists keep *B. indicus* cattle not only for beef but also for milk production (MoARD, 1998). In addition, in beef production, good dams are those that produce considerable amounts of milk to better nurse their calves. Therefore, the milking attributes of beef cattle breeds are important as well. Table 4 shows the milk production performance for some *B. indicus* breeds and their crosses under the tropical conditions. These breeds are generally low milk producers, with the Kenana cattle of Northern Sudan and the Sahiwal from Kenya and India being the most

productive purebreds. The other indigenous African cattle produce between 3 - 6 litres of milk per day (Table 4). There are some variations in milk yield (MY) within Boran and Sahiwal breeds indicating the possibility of improving milk production in these breeds through strategic selection for milk attributes (Anindo and Topps, 1993).

Table 4. Milk production performance for some *B. indicus* breeds and their crosses in the tropics

Breed	Traits[1]				Authors
	LL (days)	DMY (kg)	Fat %	LY (kg)	
Kenya Boran	203	4.2	5.2	849	Ouda et al. (2001)
	200	4.5		889	Freetly and Cundiff (1998)
Tuli	200	4.6		911	Freetly and Cundiff (1998)
Sahiwal	293	5.4		1574	Muhuyi et al. (1999)
	288	3.5		1031	Hossain et al. (2002)
Friesian x Sahiwal	326	11.8		3852	Kahi et al. (2000)
Ayrshire x SahiwalX[2]	325	10.2		3321	Kahi et al. (2000)
Red Sindhi	287	3.5		1023	Hossain et al. (2002)
Kenana	385	8.6	5.5	3300	Rege and Tawah (1999)

[1] LL = lactation length; DMY = daily milk yield; Fat = butterfat content; LY = lactation yield.
[2] Ayrshire x SahiwalX = a two breed stabilised cross of 67% Ayrshire : 33% Sahiwal.

Ouda et al. (2001) noted the potential of partial milking as a means of utilising the Boran breed for both beef and milk production. In their work, partial milking of two quarters resulted in lower WW for calves but their SW was similar to those calves whose dams were not milked. This recovery in growth for calves fed on two teats was attributed mainly to postweaning compensatory growth. The main limitation of such a technique is the difficulty in maintaining the discipline of partial milking, especially when conditions are dry and milk is an important source of human food. The crosses of Indigenous and exotic dairy breeds show higher values for milk production (Table 4). However, to sustain production in these crosses some modification of the environment in terms of feeding and disease control is required (Kahi et al., 2000).

2.2.4 Carcass characteristics

The carcass merit of beef cattle is probably the most important attribute in beef marketing since it determines the amount and quality of salable meat harvested from slaughtered animals, and the revenue generated thereof. Carcass characters include kill

out percentage, marbling, fat depth, leanness, and odour (Caron and Kemp, 1998). Among the Zebu breeds, the Boran and its crosses have been reported to consistently produce meat of good tenderness, carcass marbling and rib eye area (ASK, 2001). The average dressing percentage for *B. indicus* ranges from 50 to 55% (Rege et al., 2001). However, in most developing countries, offal (such as intestines) from most livestock is consumed thus the percentage of consumable material from livestock may be higher (Rege et al., 2001).

The carcass characters for cattle have been studied mainly in regions where meat is valued in terms of quality (Wheeler et al., 2001). Comerford et al. (1988) evaluated carcass traits for several breeds in which, area of the longissimus at the 12th rib, fat thickness at the 12th rib, marbling score, dressing percentage and percentage of fat in kidney, pelvic and heart were studied. The study showed that there are significant differences in carcass characteristics between crosses of *B. taur*us and *B. indicus* indicating possibilities of improving on carcass merit through crossbreeding. The differences in market preferences has led to the redefinition of breeding objectives for beef cattle to allow for the supply of fatty beef, or lean meat to specialised markets (Hirooka et al., 1998; Kahi et al., 2003).

2.3 Principles of breed improvement

The main objective of breeding is the exploitation of inherited variability in important characteristics so that the performance of domestic animals can be changed (Pirchner, 1983). However, this change must be geared towards a profitable objective in commercial livestock production. The general direction of change is described as a breeding objective that answers the question "*where do we want to go*?" In the tool kit of an animal breeder, there exist mechanisms to achieve this goal namely genetic evaluation, selection and mating systems, which answer the question "*how do we get there*?" Developing breeding objectives for use in a selection programme involve several important steps, these include: development of breeding objectives, choice of selection criteria, genetic evaluation, selection and design of mating systems.

2.3.1 Development of breeding objectives

In any production system, a producer is normally faced with the task of identifying animal traits that directly influence production costs as well as revenues.

These traits of economic importance are usually aggregated to form the breeding objective (Ponzoni, 1986). The process of developing breeding objectives requires the knowledge of performance levels, the systems of production, available genetic resources among other production and economic information such as prices and their changes (Ponzoni and Newman, 1989; Urioste et al., 1998; Hirooka et al., 1998). This information is important for the establishment of factors that affect the economic worth of animal traits as well as outlining the traits of economic importance for different production systems.

Cattle production has been described as a complex system, which is affected by genetic, nutritional, management and economic factors and their interrelationships. Simulation using bio-economic models as a tool of system analysis can be employed to analyse the behaviour of such complex systems (Cartwright, 1979; Cheikh, 2003). Two points need to be considered when constructing the bio-economic models; description of the typical herd management for each production system and modelling the profit functions from a typical herd to obtain the difference between revenue and costs, as a function of the biological traits to be improved genetically (Smith, 1978). The procedures involved in this process are outlined below:

Specification of breeding production and marketing systems

A breeding system defines the way in which a breed or breeds of cattle are utilised. The function of the animals could be single or multiple, thus corresponding to the needs of the livestock producer. Within each of these functions, animals could be general purpose, or used as dam (maternal) line or sire (terminal) line. Among the beef breeds, the Hereford, Angus and other British breeds are normally used for general purposes in Australia (Ponzoni and Newman, 1989). Similar breeds are also in use in New Zealand (Newman et al., 1992) and Uruguay (Urioste et al., 1998).

The production system defines the type of product available for the market depending on the level of market segmentation, sophistication and specialisation (Hirooka et al., 1998). Some markets prefer marbled beef to plain beef valued in terms of quantity. Therefore, the prevailing breeding, production and marketing systems determine the level of inputs and value of outputs (Smith, 1978).

Identification of inputs and outputs in the system

Inputs are related to costs, which can either be variable or fixed. Variable costs are influenced by the level of production and include feed, husbandry and marketing costs. Fixed costs are independent of the herd production levels. Feed, veterinary and marketing costs comprise a large proportion of variable production costs in a beef production enterprise. Output in beef production enterprises include finished steers, heifer culls, cows culled for age and in some cases bulls culled for age (Ponzoni and Newman, 1989; Urioste et al., 1998).

Determination of biological traits influencing income and costs

In developing breeding objectives, traits that influence income and costs in the production system have to be identified. In cattle, growth-related traits, reproduction and survival are important in both dairy and beef production. An important trait normally ignored in some instances, probably due to the difficulty in measurement and quantifying its effects, is feed intake. Ignoring feed intake in the breeding objective has the effect of amplifying the effects of other traits in the breeding objective since feed costs comprises a big proportion of the overall production costs (Ponzoni and Newman, 1989). Traits considered important in different industry structures will differ, and therefore emphasis should be put on those traits that have substantial effects on farm profits. Some traits are determined more by market preferences. In highly specialised markets, where lean meat is considered valuable, fat-depth as an animal trait is considered of high economic importance (Hirooka et al., 1998).

Derivation of economic values

The definition of inputs and outputs can be either biological or economic. The biological definition of product efficiency is expressed in terms of energy and/or protein, however not all traits can be expressed in this way hence difficulties arise when comparing different traits (Groen and Ruyter, 1990). On the other hand, economic definition uses money as the unit of measure of efficiency. This makes comparison of performance of different products feasible and is therefore the method of choice in defining product efficiency. The unit contribution of genetic improvement of a trait to the improvement of production efficiency represents the economic value of that trait (Groen et al., 1997). In many circumstances profit maximisation is the goal, but in tropical

agriculture, for example, in smallholder dairy systems, minimisation of costs is important due to limitations in inputs (Kahi, 2000).

Simulation has been used to derive economic values of traits for use in genetic improvement programmes (Ponzoni and Newman, 1989; Newman et al., 1992; Annor, 1996; Urioste et al., 1998; Kahi, 2000). Economic values are derived from profit equations, which take the general form;

$$P = \sum_{i=1}^{m} \left[n_i (R_i - C_i) X_i \right] - F \qquad (1)$$

where P is the total profit, m represents the number of animal classes in the profit function, n represents the number of animals expressing the trait in the i^{th} class of animal, R is the revenue per unit and C is the cost per unit for trait X, and F are the fixed costs (Bekman and Van Arendonk, 1993).

From such profit equations, economic values can be estimated using two methods: partial budgeting and partial differentiation. In the partial budgeting method, the profitability of the herd is compared before and after genetic improvement. For example, if P is the profit of a cow in a herd and P' is the profit after increment by one unit in the trait in question, then the economic value of that particular trait is the difference between P' and P. The partial differentiation method is used to obtain economic values as the partial derivatives of P with respect to the trait of interest. In this method fixed costs can be ignored because terms not involving the trait of interest disappear when obtaining partial derivative of P (Smith,1978).

Biological traits are not all expressed at the same frequency or at the same time. Therefore, economic values must be discounted to account for this. The gene flow procedure is one method that can be used to discount economic values (McClintock and Cunningham, 1974). In this procedure, the number of discounted expressions of a trait is expressed as a function of the number of progeny or later descendants of an animal plus an annual discount factor (Newman et al., 1992). Another method also used for discounting is the diffusion coefficients method. In this method, only the non-generational delays are accounted for since it assumes that generational delays will be uniform for all traits (McArthur and Del Bosque Gonzalez, 1990). Discounting allows for the quantification of costs and benefits for the present that would be experienced in the future (Peter et al., 1980; McArthur and Del Bosque Gonzalez, 1990).

2.3.2 Genetic and phenotypic parameters

The traits to be included in the breeding objective depend on their heritability, which is the proportion of the phenotypic variance that is attributable to the additive genetic variance, and correlation between traits. These parameters are important as far as genetic progress for traits of economic importance are concerned (Falconer, 1981). Different traits may sometimes be under the control of the same genes or linked genes, such that the expression of one trait depends on the other. This relationship may not necessarily be positive in which case an improvement in one trait results in the decline of the other and vise-versa (Blair and Garrick, 1989). Such relationships are termed genetic correlations and only refer to that portion of phenotypic correlation between traits that is due to the effect of additive genes. Genetic correlations are threefold; - permanent genetic correlations caused by pleitropy, a situation where one gene codes for two or more traits, transient genetic correlation caused by linkage disequilibrium, and selection based correlation caused by selecting for different breeding goals within one population (Pirchner, 1983).

Growth traits (BW, WW, YW and SW), traits related to adaptation and disease resistance (tick count – TICK, faecal egg count – FEC, and rectal temperature - TEMP) and temperament (TMENT) have a higher heritability value when compared to reproduction (AFC and CI) and survival traits (pre-weaning survival rate - SR and post-weaning survival rate - PSR) (Table 5). Low heritability estimates for reproduction traits suggest that these traits are greatly influenced by environmental conditions hence attention should be focussed on pedigree selection and progeny testing of bulls coupled with good quality management (Jain and Tailor, 1994). Additionally, genetic improvement of fertility traits can only be gradually achieved by selection based on realised bull performance (Davis, 1993). Heritability estimates of carcass traits and their correlation with other traits for beef cattle in the tropics are scarce, however a trait such as dressing percentage is expected to be highly correlated to SW as final weight determines the amount of carcass to be harvested (Aass, 1996).

Estimates of genetic and phenotypic correlations are important in genetic improvement programmes since they indicate the extent to which one trait will genetically and phenotypically change if a correlated trait is improved. Table 5 presents

some of the heritability, genetic correlations and phenotypic correlations for production, reproduction and adaptation traits. These estimates vary from one population to another depending on gene frequencies, previous selection, environment and genetic history of the population. The estimates are usually unique to the specific population and environment from which the data were collected.

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Table 5. Heritabilities (along the diagonal), genetic correlation (above diagonal) and phenotypic correlation (below diagonal) of some production, reproduction and adaptation traits[1]

Traits[2]	BW	WW	ADG	PADG	YW	SW	AFC	CI	SC	SR	PSR	TICK	FEC	TEMP	TMENT
BW	**0.40**	0.52	0.30	0.13	0.38	0.55			0.25			0.14		-0.16	-0.03
WW	0.36	**0.34**	0.95	0.88	0.90	0.86			0.84			0.01		0.28	
ADG	0.19	0.95	**0.08**	0.09	0.83	0.78			0.28			-0.08	0.01	0.17	
PADG	0.13	0.88	-0.12	**0.23**	0.78		-0.09		0.12			-0.15	-0.22	-0.08	0.01
YW	0.35	0.73	0.71	0.70	**0.42**	0.95			0.91			-0.09	0.02	-0.10	0.01
SW	0.11	0.64	0.6		0.87	**0.31**						-0.10	0.15	-0.36	
AFC				-0.09			**0.33**	-0.12	-0.44						
CI							-0.12	**0.14**							
SC	0.25	0.84	0.31	0.12	0.90		-0.44		**0.37**			-0.04	0.11	-0.02	0.11
SR	0.05	0.04								**0.09**					
PSR											**0.01**				
TICK	0.03	0.02	-0.03	-0.13	-0.08	-0.09			-0.04			**0.41**	-0.01	0.22	-0.01
FEC		-0.02	-0.02	-0.02	0.01	-0.04			0.04			0.30	**0.36**	-0.03	
TEMP	-0.05	-0.09	-0.08	-0.08	-0.10	-0.11			-0.02			0.06	0.01	**0.18**	-0.06
TMENT	-0.03	-0.02	-0.02	-0.02	-0.05	-0.03			0.11			0.05	-0.02	-0.24	**0.44**

[1]Source; Mackinnon et al. (1991); Davis (1993); Lôbo et al. (2000); Burrow (2001); Maiwashe et al. (2002); Demeke et al. (2003).

[2]BW= birth weight; WW= weaning weight; ADG= pre-weaning average daily gain; PADG=post-weaning average daily gain; YW= yearling weight; SW= slaughter weight; AFC= age at first calving; CI= calving interval; SC= scrotal circumference at one year; SR= pre-weaning survival rate ; PSR= post-weaning survival rate; TICK= tick count; FEC=faecal egg count; TEMP= rectal temperature; TMENT= temperament.

Growth traits generally have a strong positive correlation with each other. Which means that selection decisions can be made based on traits that are recorded such as weaning weights and preweaning weight gains (Okeyo et al., 1998). Body measurement traits such as SC also show a positive strong correlation with almost all growth traits (Maiwashe et al., 2002). The strength of correlation between some body measurements and growth traits has been reported to be adequate to warrant the use of body measurements as an indicator of growth. This implies that SC may be used as selection criteria for some growth traits that are difficult to accurately measure (Newman et al., 1992; Maiwashe et al., 2002).

As indicated in Table 5, the phenotypic correlation between TEMP and growth traits is weak and mostly negative as opposed to the genetic correlations. The genetic correlation between TEMP with BW, YW and SW is strong and negative while that between TEMP with ADG and WW is strong and positive. This implies that TEMP can be measured and used as an indicator of growth rate at different stages. Another adaptation trait related to growth is FEC, which is a good measure of resistance to gastro-intestinal parasites (Kochapakdee et al., 1995). Its phenotypic correlation with most growth and reproduction traits is weak and negative (Table 5). However, genetic correlation of FEC and PADG is strong but negative.

2.3.3 Response to selection

Selection response is change in performance between the offspring of selected parents relative to that of the average population. Response to selection can be direct (i.e. change on a trait due to selection directed at the same trait), correlated (i.e. change in a trait due to selection directed at another trait), expected (estimated selection response based on genetic and phenotypic parameters) or realised (true changes in a trait from field evaluation) (Pirchner, 1983). It is important to note that the magnitude of selection response is also dependent on whether the generations are overlapping or not. In overlapping generations, improvement in performance in successive years resulting from a single year of selection is not constant (Hill, 1974). This is due to fact that genes from the selected group of animals may take many years to uniformly be possessed by the population. Selection responses can thus be estimated using gene flow procedures that

take into account generation differences (McClintock and Cunningham, 1974). This is particularly important when evaluating financial benefits arising from selection.

Selection criteria

To predict an animal's genetic value, use of observations or measurements is required, since the true genetic value based on a certain trait is unknown and sometimes not measurable (Falconer, 1981). The traits or measurements used to estimate an animal's genetic value are generally referred to as selection criteria. The traits targeted for improvement may not always be measurable therefore a series of measurable characters that are highly correlated to the target traits are chosen as criteria for selection for the former (Hazel, 1943). The basis for using a measurable character as a criteria lies upon the strength of genetic relationship between the character and the target trait. Selection accuracy is optimised when information sources are increased and more characters are included as criteria (Pirchner, 1983).

In beef cattle production, different criteria have been applied when selecting for growth, reproduction and carcass traits (Caron and Kemp, 1998; Charteris et al., 1998; Hirooka et al., 1998). SW for instance can be evaluated using BW, ADG and WW as criteria for selection while AFC, CI and CR can reflect reproductive performance (Annor, 1996). Survival traits are evaluated using mortality rates and tolerance to disease and parasite.

Selection index

Selection index is a combination of appropriately weighted information on a trait from the same or different individuals to be used as a selection criterion derived from a multiple regression equation in which the breeding value of the candidate is the dependent variable, while the information on performance of the individual and / or its relatives are the independent variables (Hazel, 1943). The selection index requires the knowledge of variances and means for the traits and it corresponds to the statistical estimate referred to as best linear prediction (Henderson, 1973). The structure of available information and variables to be predicted dictate the type of index to be calculated. Estimates can be of: breeding value of single traits from records of the animal and / or relatives on the same trait; breeding value of single traits from information on several

traits of the animal and / or its relatives; breeding value of multiple traits from the performance of the animal and; breeding value of multiple traits from the animal and its relatives.

A typical selection index equation takes the form below:

$$I = b_1X_1 + b_2X_2 + ... + b_nX_n \quad (2)$$

where I represent the index value (the estimation of the genetic value for the aggregate genotype), b_1 b_2 ...b_n are the weighting factors for the sources of information X_1 X_2 and X_n on an individual animal or its relatives (Falconer, 1981). The weighting factors (b) are calculated as coefficients that minimises the squared differences between the breeding objective and the predicted genetic merit (I). The associations between the breeding objective and the predicted genetic merit (selection index) are usually expressed in three main relationship matrices, a phenotypic variance-covariance matrix of traits in the selection criteria (P), a genetic variance-covariance matrix between traits in the selection objective and those in the selection criteria (G) and a genetic variance–covariance matrix of traits in the breeding objective (C) (Pirchner, 1983).

A formula incorporating P, G and economic values (a) of traits in the breeding objective gives the index coefficients as;

$$b = P^{-1}Ga \quad (3)$$

The selection index method is not optimal in estimating or predicting breeding values (genetic merit) of animals and has been reported to give biased estimates since it does not correct for possible systematic environmental effects on the phenotypes such as season, age, herd and year. The selection index therefore, requires that the systematic environmental effects be adjusted for before being fitted into equation (2) above. A more robust estimate (Best Linear Unbiased Prediction) was therefore developed to achieve increased accuracy in the prediction of unbiased breeding values (Henderson, 1973).

Best linear unbiased prediction (BLUP)

Best Linear Unbiased Prediction (BLUP) is a statistical estimate derived from a mixed model procedure that simultaneously accounts for possible systematic environmental effects on the phenotype (e.g. herd, year and season) as well as weighted information from relatives (Henderson, 1973). The capacity of BLUP is amplified by the fact that the mixed model procedure includes an animal relationship matrix enabling the

estimation of breeding values of all animals in the pedigree. BLUP also allows for sorting of animals in genetic groups to account for differences in expected value in the base population especially when it is not possible to go back to the unselected base population. It is also possible to analyse for additional random genetic and permanent environmental effects such as maternal genetic effects reflected in some traits such as survival of piglets or early growth in beef cattle. BLUP has therefore been adopted as the method of choice in animal evaluation. However selection index theory still remains a useful tool for approximating the accuracy of BLUP selection and predicting selection response.

2.3.4 Industry structures for dissemination of superior genetics

The aim of an animal breeder is to improve performance of the next generation of animals by use of parents that are genetically superior to their contemporaries or by crossbreeding. To optimise response to selection, selection needs to be systematically executed and the mating of genetically superior individuals be well planned (Schrooten et al., 1993). In most developed livestock industries, selection programmes are of a national scale and conform to specific structures that suit the application of existing recording systems and reproductive technologies (Bondoc and Smith, 1993). In most developing countries, the livestock industries are less structured and are constrained by infrastructural bottlenecks (Jasiorowsky, 1973). For this reason, use of nucleus breeding schemes are recommended because they concentrate investment within a central elite herd (Smith, 1988).

Unstructured industries

An unstructured breeding industry consists of a number of independent closed herds each of which has its own breeding objectives and develops targets for its own rate of genetic progress in the traits that each producer/breeder considers important (Cunningham, 1980). Most new livestock industries go through this phase where application of new technologies (AI and to some extent embryo transfer) have had unfavourable results due to inadequate infrastructure and limited means to organise, on a sufficient scale, reliable pedigree and performance recording. For this reason, substantial international assistance provided in the past to developing economies for building modern

selection programmes to improve their livestock, especially indigenous livestock breeds has generally been unsuccessful and unsustainable (Brumby, 1973; Jasiorowsky, 1973)

Structured industries

Structured breeding industries are more organised into components, each of which performs specific roles within the entire structure. The apex of such an industry is the nucleus. Other members of the structure include the multiplication tier and the commercial population. A nucleus refers to a central section of a system where selection decisions are made, meaning most technical genetic improvement emphasis and investments are made in this part of the structure. Smith (1988) recommended the use of nucleus breeding schemes in developing countries as a strategy to circumvent financial and infrastructural constraints. In such a scheme, a collection of the top most genetically superior stock are kept in the nucleus and constantly subjected to rigorous selection. The nucleus provides the genetic materials (breeding stock) to the rest of the tiers below it, with the very top animals being retained and used in the nucleus to produce replacements there. Depending on the state of the design, the nucleus can be closed off to the multiplier and commercial populations or opened up to receive additional superior genetics from the base as well as to limit inbreeding especially when the nucleus is small (Garrick, 1993).

Closed nucleus structure

A nucleus is said to be closed when replacement stock for the nucleus herds are selected only within the nucleus and no importation is allowed in from the rest of the population. Genetically superior animals from the nucleus are supplied to the rest of the population. Closed nucleus can either be geographically dispersed or centralised. Dispersed closed nucleus structures consist of groups of "elite" herds maintained by individual farmers/breeders among which selection decisions are made and from where improved germplasm is disseminated to the rest of the population. However, there are no movements of genetic material from the field population into these nuclei (Bondoc and Smith, 1993). This type of breeding structure is only possible when good infrastructure is in place as it requires high level of organisation, expertise and use of reproductive technologies such as artificial insemination and embryo transfer as is the case in

industrialised countries (Cunningham, 1980). However, after considerable gain has been made in the rest of the populations, above average animals can be imported into the nucleus to be used as dams of future sires (Nicholas, 1987).

Centralised closed nucleus structures are much similar to the dispersed closed structures only that the elite herds in this case are centralised in specific locations under the control of government or private breeders (Rege et al., 2001). This form of structure normally characterises the initial stages of development of livestock industry structures especially in developing countries where management of dispersed nucleus may be impossible due to the challenges of expert manpower and infrastructure. The structure allows for concentration of selection decisions on a centrally managed herd.

Open nucleus scheme

A nucleus is said to be open if the replacement stock for the nucleus population comes from both the nucleus and the rest of the population leading to a two-way flow of genes (Shepherd and Kinghorn, 1993). A dispersed-open nucleus scheme is that form of nucleus scheme in which animals are allowed to move in all directions between the different dispersed nuclei and the various lower tiers. Nicholas (1987) and Garrick (1993) observed that because of Mendelian sampling, offspring that may be genetically superior to their parents can be generated in the commercial tiers. It would therefore be worthwhile including such animals in the elite herds. The breeding scheme would then benefit from continual screening of the commercial females into the nucleus. Should selection objectives change to favour a trait that had not undergone selection or has been achieving little or no genetic change, then, it is possible that the commercial tier would have a greater proportion of the favourable animals with respect to this trait. The animals with such superior attributes would be selected and moved to the nucleus for the benefit of the entire scheme (Nicholas, 1987).

Centralised open nucleus herds are those in which the open nucleus is centralised in given locations under the control of government or private breeders. This form of structure has been commonly advocated for developing countries (Cunningham, 1980). Bondoc and Smith (1993) recommended the establishment of two-tier open nucleus breeding system to maximise genetic improvement, reduce inbreeding rate and reduce the total cost of recording in the field populations. The Food and Agriculture Organisation

(FAO) has been exploring the open nucleus breeding scheme as a possibility of improving the organisation of the nucleus flocks and herds in developing countries (Smith, 1988).

Sire reference scheme

For accuracy of calculation of breeding values to be improved in any breeding scheme, there is always need to provide a genetic link between herds especially in dispersed nucleus schemes (Garrick 1993). In such cases, sire referencing schemes become important. Sire referencing schemes involve the use of common sires by a group of farmers in two or more environments. The aim of a stud breeder is to select sires that produce progeny, which are superior to those currently being produced. A potential challenge with the use of a reference sire scheme is genotype by environment interactions because genotypes often differ in their expressions in different environments (Dickerson, 1962). Environments that minimise the expression of genetic differences will tend to prevent sires tested in these environments from being chosen. The most desirable selection approach is to select animals within the environment in which their progeny are expected to perform (Ojango and Pollot, 2002; Kahi and Nitter, 2004).

2.4 Conclusions

Beef cattle producers utilise animal breeding as a management strategy to maintain the integrity of a breed and improve performance. This is done by adopting well-defined breeding objectives and using appropriate mating systems to optimise genetic improvement. However, a breed should be viewed as a national resource so that trade in breeding material can be controlled and improvement of the breed can be approached from a broader perspective. The importance of such an approach is justified because genetic change is permanent. Also, the establishment of breeding programmes is expensive, requires various expertise as well as the authority of a strong governing body in order to be sustainable.

The most important consideration when planning to invest in a national breeding programme is appraisal of the planned investment (Hill, 1971). Since cattle production is a complex system the use of bio-economic profit functions to evaluate profitability of breeding objectives for different production systems is an essential step (Hill 1971; Smith, 1978; Peter et al., 1980; Cheikh, 2003).

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CHAPTER THREE:
DEVELOPMENT OF BIO-ECONOMIC PROFIT FUNCTIONS

3.1 Introduction

Beef production systems are complex because of the many inter-relationships that exist between various relevant genetic, nutritional, managemental and economic factors. Simulation using bio-economic profit functions can be used to analyse the profitability of such complex production systems. In this study, bio-economic profit functions for production systems utilising the Boran breed were derived by integrating biological and economic variables. The biological variables are partly determined by the genotype of the animals and also by the environment and are considered potential breeding objective traits. This chapter describes the relevant biological and economic elements and their inter-relationship within the bio-economic profit functions in a typical beef production system.

3.2 Materials and methods

3.2.1 Derivation of the bio-economic profit functions

Bio-economic profit functions were developed for Boran cattle production systems based on extensive grazing in the ASALs as well as systems where supplementation is practiced. Two points were considered while deriving these functions:

1. Description of the typical herd management for each production system. Six production systems were described according to the sale age, levels of input and overall goal. These included; short fed medium input beef, 24-month steers and heifers finished on pastures without supplementation (SFMB); long fed medium input beef, 36-month steers and heifers finished on pasture without supplementation (LFMB); short fed high input beef, 24-month steers and heifers which are later finished in the feedlot for 90 days (SFHB); long fed high input beef, 36-month steers and heifers which are finished on pasture but continuously supplemented in the fields (LFHB); long fed low input dual purpose, 36-months steers and heifers reared under traditional pastoral extensive management (LFLD); and long fed medium input dual purpose, 36-months steers and heifer finished on pasture without supplementation (LFMD). In the LFLD system, the calf is separated from its dam at night and milking of the cow is done in the morning. In the LFMD system, the calf is bucket fed and milking is done twice daily. In the other four systems

(SFMB, LFMB, SFHB and LFHB) the calf is allowed to run freely with the cow (cow-calf system). Weaning of calves in all systems was done at 7 months of age.

2. Modelling the profit from the typical herd i.e. the difference between revenue and costs, as a function of the biological traits to be improved genetically.

Economic evaluation of breeding objectives is difficult in situations where economic and biological information on the systems of production is scarce, a situation that is common in the African tropics (Rege et al., 2001). Nevertheless, use can be made of farms that keep good records to develop bio-economic profit functions that can be used to estimate baseline economic values (Kahi and Nitter, 2004). The values can then be used to design the initial selection programmes. The baseline economic values can later be updated as more data becomes available.

In this study, the baseline data for the SFMB, LFMB, SFHB, LFHB and LFMD systems were obtained from the Kenya Agricultural Research Institute (KARI) based at Lanet in Nakuru district. The economic data comprising of costs of inputs and prices of outputs was based on the prevailing production and marketing circumstances. Due to the peculiarities of pastoral production systems, obtaining exact figures on animal productivity was not possible. Hence for the LFLD system, certain assumptions were made based on information collected in the other systems. For example, in the LFLD system, the biological data was assumed to be 10% lower than that of the LFMB system. Veterinary, labour and reproduction costs were assumed to be 50% lower than those in the LFMB system. Caution was taken when assuming the costs in the LFLD and LFMD systems, since in these systems, cows are milked (only in the mornings for the LFLD system) and the milk sold. The morning and evening milk yields were assumed to be equal. Therefore, additional costs are incurred as a result of milking the cows and marketing of milk.

3.2.2 Description of the herd management

The Kenya Boran is a multi-purpose breed in the sense that it can either be used as a purebred and the sole breed in the production system or be used in crossbreeding as a dam line or part of a crossbred dam. In the present study, multi-purpose pure breeding scheme with the Kenya Boran cattle breed was assumed. The typical Kenya Boran herd was categorised into; calves, which are young animals below the age of 7 months;

weaned animals ranging from 7 months to 3 years of age; sale stock comprising of steers and culled heifers; replacement stock, which are heifers ready for bulling; the breeding cows, which are adult female animals over three years and have calved down.

Replacement and culling policy

Figure 2 shows the herd composition and flow of animals for all production systems defined earlier except for the LFLD system. In these systems all demographic parameters (survival, cow weaning and replacement rates) were assumed to be equal meaning that the bull to cow ratio and the number of animals born and sold from the systems are similar.

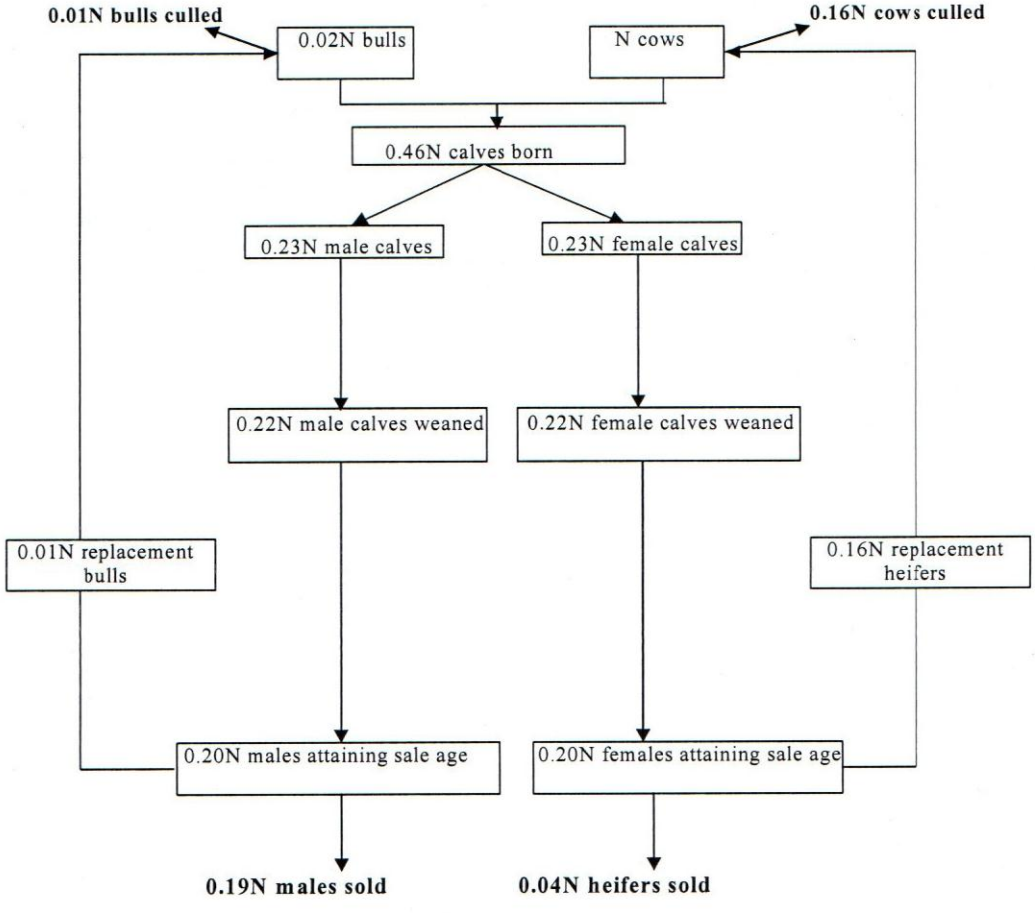


Figure 2. Demography of a typical Boran herd based on a constant number of N cows joined to the bulls

The size of the herd was kept constant over time since the number of replacement heifers was set to be equal to that of the cows culled for age. Breeding females were assumed to be kept in the herd for 10 years, but could still be culled based on other criteria e.g. fertility, mothering ability and temperament.

Health and reproduction

In the SFMB, LFMB, SFHB, LFHB and LFMD systems, veterinary intervention included dipping, vaccination, deworming and quarantine. It is assumed that dipping was done once a week through out the year while vaccination was done once a year for prevalent diseases such as Foot and Mouth Disease and Rift Valley Fever. Deworming is mainly done on the young stock at weaning when they are 7 months old. Treatment for microbial infections such as pneumonia, enteritis, eye infections and mastitis were also given.

In all systems, natural mating is practiced and the bulls are used for up to 3 years when their daughters join the breeding herd after which they are disposed off to avoid inbreeding. The bull to cow ratio was 1:50. 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 or May to July.

Feeding regime

In all the production systems the animals grazed on natural pastures, the predominant grass species being *Themeda triandra*. In the SFMB, LFMB, SFHB and LFHB systems, the calves were fed on their dam's milk up to weaning at 7 months. Thereafter, they were maintained on pastures until they attained their respective sale ages. For the SFHB system, animals were fed a feedlot mixture comprising of maize grain, urea, molasses, cotton seedcake and forage sorghum silage for an additional 3 months. In the LFHB system, the slaughter animals (steers and culled heifers) were provided with concentrate feeds while grazing in the field. It is assumed that such animals were fed fixed concentrate quantities of 1kg and 2kg per day during the pre-weaning and post-weaning periods, respectively.

3.2.3 Classification of traits

In this study, the traits were classified into production and functional traits. The production traits were beef and milk traits and included; sale weight for steers (SWs) and heifers (SWh) in all systems. In the LFLD and LFMD systems, milk yield (MY) was included as a breeding objective trait based on milk production data at the KARI station reported by Ouda et al. (2001). Dressing percentage (DP, carcass weight x 100/live weight) and consumable meat percentage (CMP, meat weight x 100/carcass weight) were the only carcass traits included in the bio-economic profit functions. Despite the importance of other carcass traits, the present pricing system in Kenya does not take into account variations in subcutaneous fat depth or any carcass traits.

The functional traits included cow weight (CoWT), reproduction and survival traits, which were; cow weaning rate defined as, calves weaned per 100 cows (CoWR); cow survival rate defined as, cows surviving per year, per 100 cows (CoSR); and post-weaning survival rate (PSR). Besides, feed intake of steers (FIs), heifers (FIh) and cows (FIc) were also included in the bio-economic profit functions. Since beef production in Kenya is based on extensive management, feed was assumed to be fully available and animals were assumed to consume feed *ad lib,* thus calculations for feed intake were based on nutritional requirement (McDonalds et al., 1995). Table 6 presents the biological traits that affect revenue and cost in the SFMB, LFMB, SFHB and LFHB systems for the different classes of cattle.

Table 6. Biological traits affecting revenue and costs in the SFMB, LFMB, SFHB, and LFHB[1] systems

Product or activity		Class of cattle	Traits[2]
Revenue			
		Steers	CoSR, CoWR, PSR, SWs, DP, CMP
		Heifer culls	CoSR, CoWR, PSR, SWh, DP, CMP
		Cows	CoSR, CoWT, DP, CMP
Costs			
	Husbandry	Steers	CoSR, CoWR, PSR
		Heifers	CoSR, CoWR, PSR
		Cows	CoSR
	Feeding	Steers	FIs
		Heifers	FIh
		Cows	FIc
	Marketing	Steers	CoSR, CoWR, PSR
		Heifer culls	CoSR, CoWR, PSR
		Culled cows	CoSR

[1]For LFLD and LFMD, milk yield was included as a biological trait influencing revenues from cows. See text for description of production systems.
[2]CoSR= cow survival rate; CoWR=cow weaning rate; PSR= post-weaning survival rate; SWs= sale weight of steers; SWh= sale weight of heifers; DP = dressing percentage; CMP= consumable meat percentage; CoWT=cow weight; FIs = feed intake of steers; FIh = feed intake of heifers; FIc = feed intake of cows.

3.2.4 Modelling the bio-economic profit functions

In general, profit per herd per year (in KSh) can be expressed as a function of traits in the breeding objective:

$$P = \sum_{i=1}^{m}\left[n_i(R_i - C_i)X_i\right] - F \qquad (4)$$

where P is the total profit, m represents the number of animal classes in the profit function, n represents the number of animals expressing a trait in the i^{th} class of animal, R is the revenue per unit and C is the cost per unit for trait X and F are the fixed costs. For the present study, total profitability was expressed per cow per year and based on the difference between revenue (R) and costs (C) for the three classes of livestock namely, steers, culled heifers and culled cows.

The revenues (R) per cow per year were calculated using the equation:

$$R = Rs + Rh + Rc \qquad (5)$$

where s, h and c correspond to prefixes for steers, heifers and cows, respectively while costs (C) were derived from the following equation:

$$C = (C_{Ms} + C_{Hs} + C_{Fs} + C_{Mh} + C_{Hh} + C_{Fh} + C_{Mc} + C_{Hc} + C_{Fc}) - \text{fixed costs} \qquad (6)$$

where M, H and F correspond to prefixes for marketing, husbandry and feeding activities, respectively. These costs (C) constituted the variable costs because they were influenced by the level of herd production while fixed costs included costs attributable to equipment, machines and farm structures.

Since marketing of animals was assumed to be done on farm, the marketing costs were charged per animal sold irrespective of the SW. For calculation of husbandry and feeding costs for each class of cattle, four different phases in the respective life cycles were identified; birth to weaning (calves); weaning to sale age (24 or 36 months); sale age to age at first calving (replacement heifers); and breeding cows (over 4 years old). Figure 3 shows the animal movements through the life cycle. The figure presents the inputs used at each stage of development of animals and the outputs obtained from the system. The various components of R and C were calculated as shown below. Table 7 gives an overview of the assumed values of the variables used in the parameterisation of the profit functions in all the systems. The abbreviations used in the equations below are also explained in Table 7.

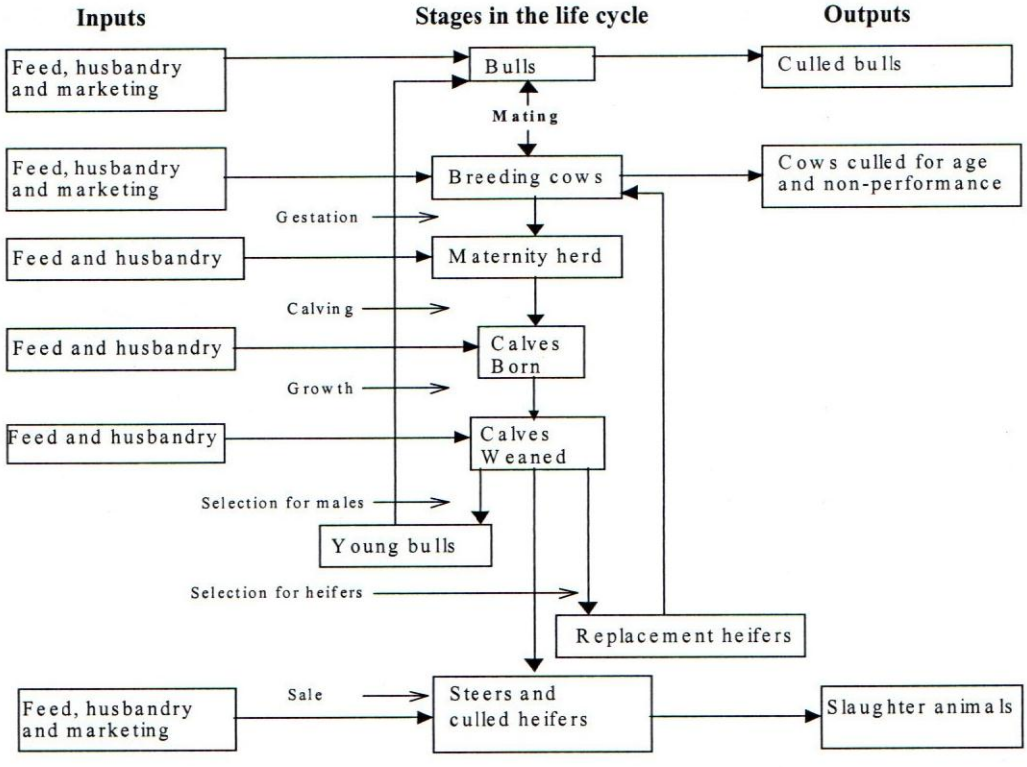


Figure 3. Animal movements in a herd through the life cycle

Table 7. Overview of the assumed values of the variables used in the parameterisation of the profit functions

Variables	Symbol	Production systems[1]					
Production variables		SFMB	LFMB	SFHB	LFHB	LFLD	LFMD
Consumable meat percentage (%)	CMP	69	69	70	70	69	69
Cow survival rate (%)	CoSR	97	97	97	97	87	97
Cow weight (kg)	CoWT	359	359	359	359	323	359
Dressing percentage (%)	DP	52	52	50	51	52	52
Annual milk yield (kg)	MY	1533	1533	1533	1533	1398	1533
Pre-weaning survival rate (%)	SR	93	93	93	93	84	93
Post-weaning survival rate (%)	PSR	93	93	93	93	84	93
Sale weight for heifers (kg)	SWh	276	356	350	444	330	356
Sale weight for steers (kg)	SWs	310	419	400	545	377	419
Average birth weight (kg)	BW	30	30	30	30	27	30
Average weaning weight (kg)[2]	WW	154	154	154	194	139	90
Milk fat (g/kg).	MF	52	52	52	52	52	52
Management variables							
Calving rate (%)	CR	75	75	75	75	68	75
Calving interval (days)	CI	577	577	577	577	577	577
Days from birth to weaning	WA	210	210	210	210	252	126
Replacement rate for cows (%)	RrCy	17	17	17	17	12	17
Sale age (days)	SA	720	1080	720	1080	1080	1080
Age at first calving (days)	AFC	1440	1440	1440	1440	1728	1440
Feed intake variables							
Energy content in pasture (MJ/DM)	ecp	4	4	4	4	4	5.5
Energy content in concentrate (MJ/DM)	ecc				7		
Management costs							
Cost of labour (KSh / day)	lab	3	3	5	4	1.50	3
Veterinary cost (KSh / day)	vet	2	2	2	2	1	2
Reproduction cost (KSh / day)	rep	1	1	1	1	0.50	1
Milking labour cost (KSh / kg)	lab_{milk}					0.50	1
Marketing costs							
Beef Marketing cost (KSh/animal/ year)	m_a	200	200	200	200	100	200
Milk marketing cost (KSh / kg)	m_{milk}					1.50	3
Prices							
Price of consumable meat (KSh / kg)	p_{meat}	174	174	210	210	120	174
Price of milk (KSh / kg of Milk)	p_{milk}					15	15
Price of concentrate (KSh / kg DM)	p_c				9		
Price of roughage (KSh / kg DM)	p_f	0.50	0.50	0.50	0.50	0.50	0.75
Price of feedlot mix (KSh / kg DM)	p_{mix}			1.50			

[1] SFMB=short fed medium input; LFMB=long fed medium input; SFHB=short fed high input; LFHB=long fed high input; LFLD=long fed low input dual purpose; LFMD=long fed medium input dual purpose.
[2] Weaning done at 7 months.

Calculation of revenues

In calculating revenues, numbers of animals at the various stages of the life cycle were important in deriving the number of animals sold at the end of the life cycle. Animal

numbers were affected by the CR, SR and PSR. For simplicity, two variables were introduced:

$$CoWR = \frac{365}{CI} \times CR \times SR \quad (7)$$

where CoWR = cow weaning rate per year and

$$NCW = CoWR \times CoSR \quad (8)$$

where NCW = number of calves weaned per cow per year.

1. Revenue from steers (Rs)

Assuming a sex ratio of 0.5, the number of steers per cow per year attaining the sale age was

$$NsCy = 0.5 \times NCW \times PSR \quad (9)$$

and therefore

$$Rs = NsCy \times SWs \times DP \times CMP \times p_{meat} \quad (10)$$

2. Revenue from heifers (Rh)

A distinction must be made between the proportion of heifers retained in the herd for replacement and the proportion of culled heifers sold for slaughter. The number of heifers per cow attaining sale age each year (NhCy) is equal to the number of steers attaining the same age (NsCy). If the replacement rate per year is RrCy, the number of heifers per cow and year available for culling was

$$NhCy_{cull} = NhCy - RrCy \quad (11)$$

and therefore

$$Rh = NhCy_{cull} \times SWh \times DP \times CMP \times p_{meat} \quad (12)$$

where $NhCy_{cull}$ = number of heifers per cow and year available for culling.

3. Revenue from cows (Rc)

This included revenue from culled-for-age cows and cows culled for other reasons and was therefore

$$Rc = RrCy \times CoWT \times CoSR \times DP \times CMP \times p_{meat} \quad (13)$$

For the LFLD system, additional revenue for cows was obtained from sale of milk and this was calculated as

$$R_{milk} = (\frac{1}{2} \times MY \times p_{milk}) \quad (14)$$

where the ratio $\frac{1}{2}$ represents the fact that the animals are milked once per day. For the LFMD system, the revenue from milk was calculated as above, however the ratio $\frac{1}{2}$ was not included since animals were milked twice per day.

Calculation of costs

Because of the numbers involved, costs attributable to replacement bulls and breeding bulls were assumed to be negligible but were reflected to some extent in the reproduction costs.

1. Marketing costs of steers (C_{Ms})

$$C_{Ms} = NsCy \times m_a \quad (15)$$

2. Marketing costs of heifers (C_{Mh})

$$C_{Mh} = NhCy_{cull} \times m_a \quad (16)$$

3. Marketing costs of cows (C_{Mc})

$$C_{Mc} = RrCy \times CoSR \times m_a \quad (17)$$

4. Milk marketing costs for LFLD and LFMD (CM_{milk})

Milk marketing costs for LFLD were calculated as

$$CM_{milk} = (\frac{1}{2} \times MY \times m_{milk}) \quad (18)$$

For the LFMD system, the milk marketing costs were calculated as above however the ratio $\frac{1}{2}$ was not included.

5. Husbandry costs for steers from birth to weaning ($C_{Hs}1$)

$$C_{Hs}1 = 0.5 \times NCW \times WA \times (lab + vet) \quad (19)$$

6. Husbandry costs for steers from weaning to sale age ($C_{Hs}2$)

$$C_{Hs}2 = NsCy \times (SA - WA) \times (lab + vet) \quad (20)$$

For the SFHB sytem, the husbandry costs for steers were calculated to slaughter age ($C_{Hs}2_{SFHB}$) as

$$C_{Hs}2_{SFHB} = NsCy \times (lab + vet) \times (SA - WA + 90) \quad (21)$$

7. Husbandry costs of steers from birth to sale age (C_{Hs})

$$C_{Hs} = C_{Hs}1 + C_{Hs}2 \quad (22)$$

For the SFHB system, the husbandry costs were calculated as

$$C_{Hs}^{SFHB} = C_{Hs}1 + C_{Hs}2_{SFHB} \quad (23)$$

8. Husbandry costs for replacement heifers from sale age to age at first calving ($C_{Hh}3$)

$$C_{Hh}3 = RrCy \times (AFC - SA)(lab + vet + rep) \quad (24)$$

9. Husbandry costs for heifers from birth to age at first calving (C_{Hh})

$$C_{Hh} = C_{Hs}1 + C_{Hs}2 + C_{Hh}3 \quad (25)$$

For the SFHB system, the husbandry costs for heifers from birth to age at first calving (C_{Hh}^{SFHB}) were calculated as

$$C_{Hh}^{SFHB} = C_{Hs}1 + C_{Hs}2 + (NhCy_{cull} \times 90 \times (lab + vet)) + C_{Hh}3 \quad (26)$$

10. Husbandry costs for breeding cows (C_{Hc})

$$C_{Hc} = 365 \times (lab + vet + rep) \quad (27)$$

11. Milking labour costs for LFLD and LFMD ($Clab_{milk}$)

$$Clab_{milk} = (\frac{1}{2} \times MY \times lab_{milk}) \quad (28)$$

For the LFMD sytem, milking labour costs were calculated as above however the ratio $\frac{1}{2}$ was not included since animals are milked twice per day.

12. Feeding costs for steers from birth to weaning ($C_{Fs}1$)

Calculation of feed intake and feed costs in pasture based production systems is difficult. However, the feed intake can be calculated from energy requirement equations assuming that no differences in efficiency of feed utilization exist between different animals. Such an assumption is better than ignoring feed intake and hence costs (Kahi et al., 1998). The pre-weaning pasture intake by calves is assumed to actively begin 61 days after birth, since very young calves consume insignificant quantities of forage, as they cannot digest roughage. In this category, the animal requires energy for maintenance (E_m, MJ) and growth (E_g, MJ), which were calculated according to MAFF (1990) as:

$$E_{m_i} = 0.53 \times \left(\frac{LW_i}{1.08}\right)^{0.67} \quad (29)$$

and

$$E_{g_i} = \frac{4.1 + 0.332LW_i - 0.000009LW_i^2}{1 - 0.1475DG} \quad (30)$$

where LW_i = is the live weight (kg) on i^{th} day and DG is the daily gain (kg/day). The LW_i was calculated as

$$LW_i = (LW61 + (i \times DG)) \quad (31)$$

where LW61 = is the live weight at day 61 and is given by BW + (61 x DG). The total amount of DM consumed from pastures for this category during the whole pre-weaning period was therefore calculated as

$$FI_s1 = \frac{1}{ecp} \sum_{i=1}^{WA-61} (E_{m_i} + E_{g_i}) \quad (32)$$

Therefore, the feeding costs for steers from birth to weaning ($C_{Fs}1$) was given by

$$C_{Fs}1 = 0.5 \times NCW \times FI_s1 \times p_f \quad (33)$$

In the LFHB system, where animals were supplemented with concentrates at a rate of 1kg per day (0.89kg DM), the feeding costs for steers from birth to weaning ($C_{Fs}1_{LFHB}$) were given by

$$C_{Fs}1_{LFHD} = [0.5 \times NCW]\left[\left(FI_s1 - \frac{1}{ecp}(ecc \times conc1)(WA-61)\right) \times p_f + \left(conc1 \times (WA-61) \times p_c\right)\right] \quad (34)$$

where conc1 = amount of daily consumed DM from concentrates consumed daily during the pre-weaning period (kg).

13. Feeding costs for steers from weaning to sale age ($C_{Fs}2$)

Feeding requirements for this animal category, included energy for maintenance (E_m, MJ) and growth (E_g, MJ). The LW_i in equation (31) was calculated as

$$LW_i = (WW + (i \times DG)) \quad (35)$$

The total amount of DM consumed from pastures (FI_s2) for this category during this period was therefore calculated using equation (32) but the summation was done to (SA – WA) days. Therefore, the feeding costs for steers from weaning to sale weight ($C_{Fs}2$) was given by

$$C_{Fs}2 = NsCy \times FI_s2 \times p_f \quad (36)$$

In the SFHB system, the total amount of DM consumed from pastures (FI_s2) was calculated using equation (36). In addition, the animals were fed feedlot mix for an extra 3 months. During this time, it was assumed that consumption of the feedlot mix was above the energy requirement. The energy requirement during this period was therefore

set at 125% of that for maintenance and growth. Therefore, the total amount of DM consumed during this period (FI_s2_{fat}) was calculated as

$$FI_s2_{fat} = \frac{1.25}{ecmix} \sum_{i=1}^{90} (E_{mi} + E_{gi}) \quad (37)$$

The feeding costs for steers from weaning to slaughter age ($C_{Fs}2_{SFHB}$) was given by

$$C_{Fs}2_{SFHB} = NsCy \times (FI_s2 \times p_f + FI_s2_{fat} \times p_{mix}) \quad (38)$$

In the LFHB system, animals were supplemented with concentrates at a rate of 2kg per day (1.78kg DM) during the post-weaning period. The feeding costs for steers from birth to weaning ($C_{Fs}2_{LFHB}$) was given by

$$C_{Fs}2_{LFHB} = NsCy \times \left[\left(FI_s2 - \frac{1}{ecp}(ecc \times conc2)(SA - WA) \right) \times p_f + (conc2 \times (SA - WA) \times p_c) \right] \quad (39)$$

where conc2 = amount of DM from concentrates consumed daily during the post-weaning period (kg).

14. Feeding costs of steers from birth to sale age (C_{Fs})

$$C_{Fs} = C_{Fs}1 + C_{Fs}2 \quad (40)$$

This implied that the total amount of DM consumed from pastures by steers (FIs, kg) was given by

$$FIs = (0.5 \times NCW \times FI_s1 + NsCy \times FI_s2) \quad (41)$$

In the SFHB system, the total feed costs of steers from birth to slaughter age (C_{Fs}^{SFHB}) was given by

$$C_{Fs}^{SFHB} = C_{Fs}1 + C_{Fs}2_{SFHB} \quad (42)$$

while the total amount of DM consumed by steers (FIs^{SFHB}) was given by

$$FIs^{SFHB} = \left[(0.5 \times NCW \times FI_s1) + NsCy \times \left(FI_s2 + \frac{FI_s2_{fat} \times ecmix}{ecp} \right) \right] \quad (43)$$

In the LFHB system, the total feed costs of steers from birth to sale age (C_{Fs}^{LFHB}) was given by

$$C_{Fs}^{LFHB} = C_{Fs}1_{LFHB} + C_{Fs}2_{LFHB} \quad (44)$$

Since feed intake is estimated based on requirements, the total amount of DM consumed from pastures and concentrates for the LFMB system, (FIs^{LFHB}) was calculated using equation (41).

15. Feeding costs for replacement heifers from sale age to age at first calving ($C_{Fh}3$)

In this category, the animal requires energy for maintenance (E_m, MJ), growth (E_g, MJ), and gestation (E_p, MJ). The lw_i in equation (31) was calculated as

$$LW_i = (SW_h + (i \times DG)) \quad (45)$$

The total amount of DM consumed from pastures for growth and maintenance (FI_h1) for this category during this period was therefore calculated using equation (32) but the summation is done to (AFC - SA) days. The energy requirement for gestation was set at 80% of the maintenance energy requirement (McDonald et al., 1995) and amount of DM consumed from pastures (FI_h2) for gestation calculated as

$$FI_h2 = \frac{0.80}{ecp} \sum_{i=1}^{AFC-SA} (E_{mi}) \quad (46)$$

Therefore the feeding costs for replacement heifers from sale age to age at first calving ($C_{Fh}3$) was given by:

$$C_{Fh}3 = RrCy \times (FI_h1 + FI_h2) \times p_f \quad (47)$$

16. Feeding costs of heifers from birth to age at first calving (C_{Fh})

$$C_{Fh} = C_{Fs}1 + C_{Fs}2 + C_{Fh}3 \quad (48)$$

This implied that the total amount of DM consumed from pastures by heifers (FIh, kg) was given by

$$FIh = (0.5 \times NCW \times FI_s1 + NsCy \times FI_s2 + RrCy \times (FI_h1 + FI_h2)) \quad (49)$$

In the SFHB system, the feeding costs for heifers from weaning to sale age ($C_{Fh}2_{SFHB}$) was given by

$$C_{Fh}2_{SFHB} = (NsCy \times FI_s2 \times p_f) + NhCy_{cull} \times [(FI_s2_{fat} \times p_{mix})] \quad (50)$$

Therefore, the total feed costs of heifers from birth to age at first calving (C_{Fh}^{SFHB}) were given by

$$C_{Fh}^{SFHB} = C_{Fs}1 + C_{Fh}2_{SFHB} + C_{Fh}3 \quad (51)$$

while the total amount of DM consumed by heifers (FIh^{SFHB}) was given by

$$FIh^{SFHB} = \left[(0.5 \times NCW \times FI_s1) + (NsCy \times FI_s2) + NhCy_{cull} \times \frac{FI_s2_{fat} \times ecmix}{ecp} + RrCy \times (FI_h1 + FI_h2)\right] \quad (52)$$

In LFHB, the total feed costs of heifer from birth to sale age (C_{Fh}^{LFHB}) were given by

$$C_{Fh}^{LFHB} = C_{Fs}1_{LFHB} + C_{Fs}2_{LFHB} + C_{Fh}3 \quad (53)$$

Since feed intake was estimated based on requirements, the total amount of DM consumed from pastures and concentrates for the LFHB system, (FIh^{LFHB}) was calculated using equation (49).

17. Feeding costs of cows (C_{Fc})

In this category, the animal requires energy for maintenance (E_m, MJ) and lactation (E_l, MJ). It was assumed that after age at first calving, cows maintained a constant weight (CoWT) until attainment of culling age. The energy requirement for maintenance was calculated using equation (29) and fitting CoWT instead of LW and the amount of DM consumed from pastures for maintenance (FI_c1) calculated as:

$$FI_c1 = \frac{1}{ecp} \times 0.53 \times \left(\frac{CoWT}{1.08}\right)^{0.67} \quad (54)$$

The energy requirement for lactation (E_l) was calculated according to MAFF (1990) as:

$$E_l = \frac{MY}{365} \times (1.509 + 0.00406MF) \quad (55)$$

Therefore, the amount of DM consumed from pastures for lactation (FI_c2) was calculated as:

$$FI_c2 = \frac{E_l}{ecp} \quad (56)$$

The feeding costs per cow per year was calculated as

$$C_{Fc} = 365 \times (FI_c1 + FI_c2) \times p_f \quad (57)$$

This implied that the total amount of DM consumed from pastures per cow per year (FIc, kg) was given by

$$FIc = 365 \times (FI_c1 + FI_c2) \quad (58)$$

3.3 Model outputs and evaluation

Evaluation of any model is a very important step since the model should be a representation of the real system. In this study, practical field information on economic efficiency of existing beef production ranches was not available, therefore, it was not possible to validate the profit functions by comparing estimated values with actual observations from experimental results. The derived profit functions were used to evaluate the profitability of the different beef production systems defined and to predict feed intake for all classes of cattle. The profit functions were evaluated under the base

situation using the values presented in Table 7 to test their ability to estimate performance of real production systems.

The influence of changes in production variables on revenues and costs for all classes of cattle was quantified. This was achieved by performing a sensitivity analysis for parameters within the profit functions. Sensitivity of economic values to changes in prices and parameters that influence the levels of genetic merit and of inputs and outputs is presented in the subsequent chapter. However, the influence of changes in weaning weight and energy content in pasture on feed intake was quantified in the present chapter.

Table 8 presents the revenues, costs and profits for all the production systems evaluated in this study. The steers contributed the highest to revenue due to the high numbers of steers that are sold for slaughter in all systems (Figure 2). There was a positive relationship between the costs, the slaughter age and feeding requirements. Production systems that kept animals for longer periods had higher feeding requirements which resulted in higher overall production costs. Feed costs were highest for LFHB where supplementation using concentrates was provided to calves over 61 days up to 36 months of age. Though animals in the SFHB system had lower slaughter ages than those in LFMB, feed costs in this system were higher because of feedlot fattening. The LFLD system, had the lowest costs. These low costs coupled with the revenue accrued from the sale of milk resulted in this system having the second highest profits. However, this should be cautiously interpreted, since there is need to carry out a comprehensive analysis of production variables and hence revenues and costs in this system to fully validate its superiority. The LFMD system had the highest profits being a medium input system with milk as an additional output like the LFLD system.

When the profits from the single purpose systems were compared under the prevailing production and marketing environment, they were highest in the LFMB system and lowest in the LFHB system (Table 8). The higher profits in the SFHB system than in the LFHB system stress the importance of strategic supplementation of animal especially when they are almost ready for the market. The feed costs are minimised in the SFHB system as opposed to the LFHB system where animals are supplemented over a longer period of time. However, supplementation through out the life cycle ensures the animal is able to express its full genetic potential for growth. This is accounted for in the profit functions by the use of higher sale live-weights in the LFHB system than in the SFHB

system. The two systems with supplemental feeding (SFHB and LFHB) produce animals of good carcass characteristics that would fetch higher prices in markets that value beef quality.

Table 8. Estimated revenues, costs and profits per cow per year in the production systems

	Production systems[1]					
Parameters	SFMB	LFMB	SFHB	LFHB	LFLD	LFMD
Revenues (KSh)						
Milk	-	-	-	-	10485.00	22995.00
Steers	3851.67	5205.97	5851.04	8131.49	2143.13	5317.93
Heifers	499.96	644.88	746.41	965.82	170.93	739.99
Cows	3695.87	3695.87	4351.13	4438.16	1451.90	3695.87
Total (a)	8047.50	9546.72	10948.58	13535.47	14250.96	32748.79
Costs (KSh)						
Feed	1766.21	1785.73	2131.98	6104.82	1578.59	1863.18
Husbandry	4388.77	4738.02	6218.35	5600.38	1965.97	4784.92
Beef marketing	78.59	78.59	78.59	78.59	24.85	80.29
Milk marketing	-	-	-	-	1048.50	4599.00
Milking labour	-	-	-	-	349.50	1533.00
Fixed costs	100	100	100	100	50	100
Total (b)	6333.57	6702.34	8528.92	11883.79	5015.40	12960.39
Profit (a – b) (KSh)	1713.93	2844.38	2419.66	1651.68	9235.56	19788.40

[1] SFMB=short fed medium input; LFMB=long fed medium input; SFHB=short fed high input; LFHB=long fed high input; LFLD=long fed low input dual purpose; LFMD=long fed medium input dual purpose.
1 US$ = 75 Kenya shilling.

Figure 4 presents the estimated feed intake for all classes of animals in the different production systems. The feed intake of cows was highest in all the production systems. The feed intake of heifers was always intermediate. The difference between feed intake in steers and heifers was lowest in the SFHB system. In this system, all steers and only culled heifers were fattened for an extra three months in the feedlot where feed was expensive and feed intake was high. A higher number of heifers were required for replacement. These replacement heifers are fed on pastures just like the breeding cows and their feed intake was lower than in the feedlot.

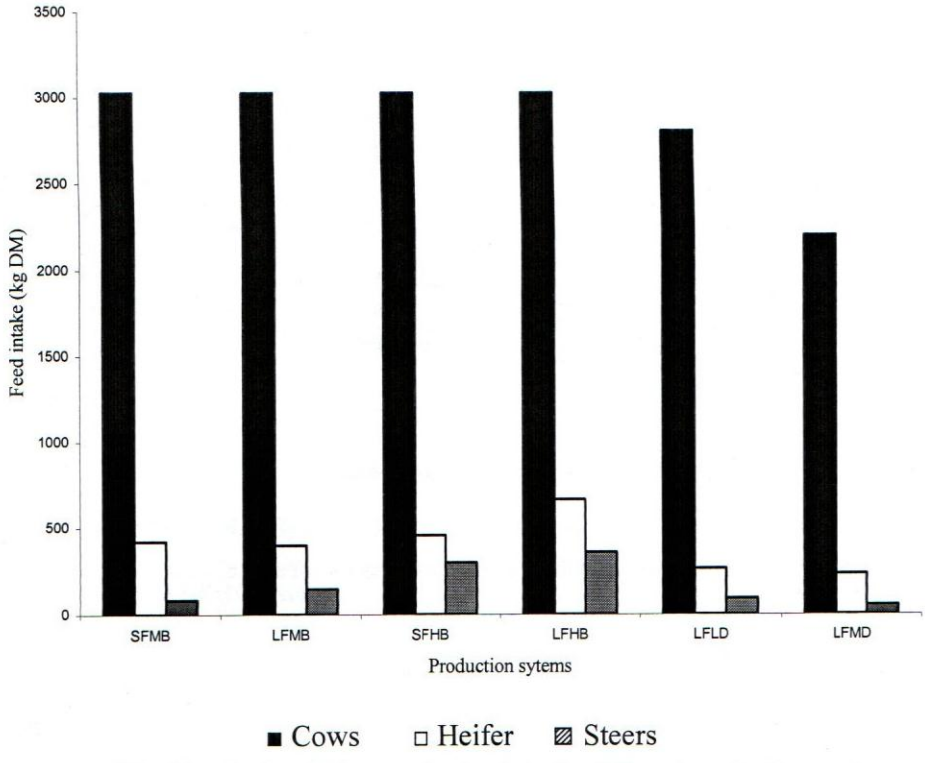
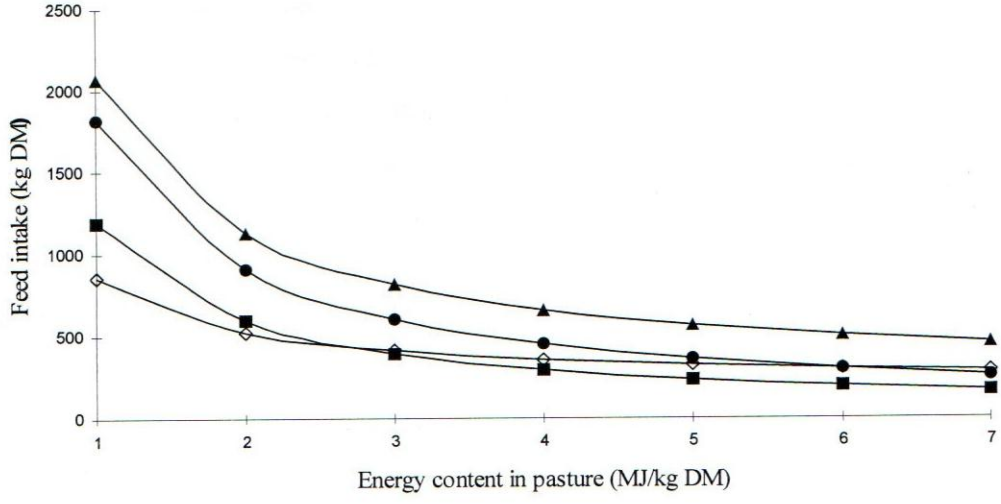


Figure 4. Estimated feed intake for all classes of animals in the different production systems

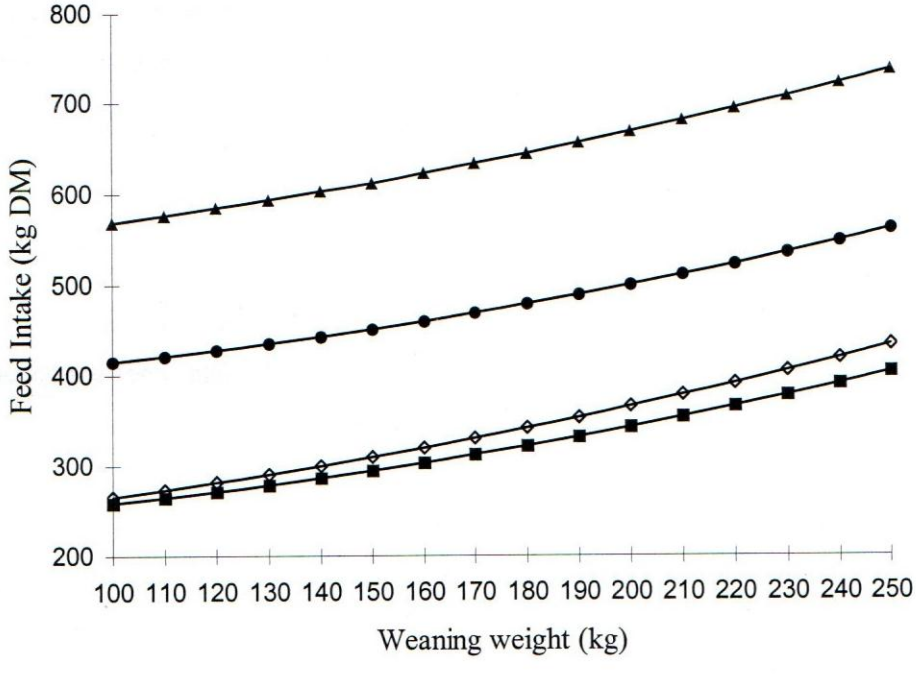
(SFMB=short fed medium input; LFMB=long fed medium input; SFHB=short fed high input; LFHB=long fed high input; LFLD=long fed low input dual purpose; LFMD=long fed medium input dual purpose.)

The SFHB and LFHB systems were the two high input systems with feed costs contributing 34% and 51% to the total costs, respectively (Table 8). These two systems were used to quantify and illustrate the influence of changes in the energy content in pasture and WW of steers and heifers on the respective feed intake. Sensitivity of feed intake for steers and heifers in the SFHB and LFHB systems to changes in energy content in pasture is shown in Figure 5. There was a reduction in the feed intake as the energy content in pasture increased. Pasture quality is directly affected by seasonal rainfall patterns and thus the energy content of pasture may change seasonally. Figure 6 presents the sensitivity of feed intake for steers and heifers in the SFHB and LFHB systems to changes in WW. Feed intake was linearly related to WW. Weaning weight was used in formulating energy requirement and eventually in calculating feed intake.



■ = Steers in SFHB ● = Heifers in SFHB ◊ = Steers in LFHB ▲= Heifers in LFHB

Figure 5. Sensitivity of feed intake for steers and heifers to changes in energy content in pastures in the SFHB and LFHB systems.



■ = Steers in SFHB ● = Heifers in SFHB ◊ = Steers in LFHB ▲= Heifers in LFHB

Figure 6. Sensitivity of feed intake of steers and heifers to changes in weaning weight in the SFHB and LFHB systems.

3.4 Discussion and conclusions

In this chapter, bio-economic profit functions for use in the development of breeding objectives for beef production systems utilising the Boran breed were described. The profit functions were assumed to be linear and deterministic. The biological relationships and assumptions in the function were general and flexible and can therefore be applied to a wide range of beef cattle production circumstances by changing the input variables. In addition, by modifying the herd dynamics and management variables this function may be applied in Kenya or other countries to some production systems that utilise indigenous cattle genetic resources or their crosses with *B. taurus* breeds. However, some caution should be taken when the function is applied to production systems that utilise artificial insemination (AI) as additional costs resulting from administration of AI will have to be factored in. In this study, natural mating was assumed although this does not hold true for most dual-purpose production systems where both natural mating and AI are used (Kahi et al., 2004). When compared to natural mating, AI is more expensive and less efficient (due to challenges of heat detection). This will be reflected in overall higher reproduction costs in the production system.

The profit functions also assumed that feed was available throughout the year and that animals were fed to their full energy requirements. In most of the tropics, seasonal changes in available feed and pasture quality is common. Pasture quality is directly affected by seasonal rainfall patterns and thus the energy content of pasture changes seasonally, unless under irrigation. As shown in the present study, this is expected to influence the feed intake (Figure 5). Nonetheless, seasonal effects have been ignored in similar studies elsewhere (Davis et al., 1994).

The inclusion of some traits (e.g. SWs, SWh, FIs, FIh and FIc) in the profit functions is justified. SW determines the value of output from the system while feed intake reflects on the overall costs of inputs since feed comprises a large proportion of production costs. The inclusion of CoWR as a reproduction trait and CoSR as a survival trait determined the number of animals weaned from the system while PSR was an indicator of the off take. DP and CMP were included as the only important indicators of carcass characteristics. Other carcass traits especially those related to quality (e.g. lean percentage, marbling etc) could not be included in the profit functions since the market for beef based on carcass quality is not currently operational at a significant level in

Kenya. However, there are changes in the marketing strategy in that most beef cattle ranches in Kenya are now increasingly selling beef carcass as opposed to live animals. In addition, there are prospects of exporting Kenyan beef to markets that put more emphases on carcass quality. Therefore, there is need to record additional carcass traits if selection based on such traits is to result in overall profitability in the beef enterprise.

An important trait in the profit functions was feed intake. It's importance lies in the fact that feed costs form a large proportion (between 31% in LFLD to 52% in LFHB) of total production costs (Figure 4). The positive relationship between weaning weight and feed intake of steers and heifers (Figure 6) observed in this study suggests that weaning weight could be an indirect indicator of feed intake. However, more studies under different field conditions are required to quantify the strength of relationship between WW and FI.

There is evidence that blood serum Insulin-Like Growth Factor I (IGF-1) concentration is correlated to aspects of growth, body size, food conversion, milk production and carcass traits (Davis et al., 1995). Compared to carcass traits and feed intake measurement, IGF-1 concentration is simple and inexpensive to measure and, it can be measured early in life. This suggests potential for it's use as an indirect criterion for genetic improvement of both feed efficiency and carcass traits. Utilising feed intake records and IGF-1 concentrations in selection has been shown to improve the accuracy of breeding unit sire selection and to maximise profit in beef cattle breeding programmes (Wood et al., 2002; Kahi et al., 2003).

As is also the case in other tropical and subtropical areas, in Kenya resistance or tolerance to diseases is an important attribute desired by producers. However, it was not included in the bio-economic profit functions derived in this study. Resistance has multifold influences on inputs and outputs, which in turn affect profit. Resistance is further complicated by environmental factors, nonlinearity effects and interactions (Sivarajasingam, 1995). This makes it difficult to incorporate measures of disease resistance into a bio-economic profit function. Resistance reduces the risk of infection and consequently the costs associated with disease control and it allows full expression of genetic potential. Breeding for disease resistance has an advantage in that once achieved, adapted animals can sustain production without further maintenance costs (Rege et al., 2001).

The bio-economic model developed in this chapter presents important biological variables that affect revenues and costs. These biological variables form the potential breeding objective traits. The economic worth of these traits should be evaluated through the estimation of their economic values. Finally, the influence of the economic values on genetic improvement should be assessed. The subsequent chapter of this study presents the later phases in developing breeding objectives for the Kenya Boran.

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CHAPTER FOUR:
ESTIMATION OF ECONOMIC VALUES FOR PRODUCTION AND FUNCTIONAL TRAITS AND ASSESSMENT OF THEIR POTENTIAL INFLUENCE ON GENETIC IMPROVEMENT

4.1 Introduction

Economic values are an indication of the relative importance of traits in a given system and are derived in order for breeding objectives to be defined in economic terms. In a breeding objective, breeding values of traits are weighted by their respective economic values to come up with a total index, which is expressed in monetary terms. Economic values will therefore determine the rate and direction of genetic improvement. Economic values can be used to assess genetic gain in breeding objective traits within the structures of a breeding programme. In the literature, simulation models have been used to predict feed intake and cow performance on the basis of availability and quality of grass and other supplements; and to optimise insemination and culling policies (Hirooka et al., 1998; Koots and Gibson, 1998; Vargas et al., 2002). However, use of such models can become difficult when there is insufficient knowledge of the production system under analysis (Groen et al., 1997), as is the case in Kenya. A similar approach as used in the present study was used to estimate economic values for meat sheep (Kosgey et al., 2003) and dairy cattle (Kahi and Nitter, 2004) in Kenya. This chapter presents the estimates of economic values and their influence on genetic progress after one round of selection.

4.2 Materials and methods

In this chapter, biological and economic parameters reflecting the situation of Boran cattle were fitted into the bio-economic profit functions developed in chapter 3. These functions modelled revenues and costs for the traits of interest assuming that the current management practice is approximately optimal. Observed data were used to parameterise the profit functions (Ponzoni, 1992; Bekman and van Arendonk, 1993; Amer et al., 1998). The model used was only able to predict feed intake and evaluate profitability of the production systems.

4.2.1 Estimation of economic values

Economic values of traits can be estimated using two methods; partial differentiation of the profit function with respect to the trait of interest; and by partial budgeting i.e. accounting for unit changes in marginal returns and costs arising from the improvement in the trait of interest. In this study, the latter method was used. An additional section was added to estimate economic values based on the principles given by Kosgey et al. (2003) and Kahi and Nitter (2004). Economic values for production traits and functional traits (section 3.4) were estimated for six production systems described in section 3.2. Economic values were calculated for two evaluation bases; fixed herd-size and fixed pasture input in each of the six systems. Accurate calculation of economic values in relation to production circumstance is necessary. This may lead to a diversification of the breeding goal.

The issue of resource availability limits the ability of farmers to keep more animals even if they have enough land. This challenge produces a situation where production on farm is limited by herd-size a situation that is typical in most cattle production systems in Kenya (Rege et al., 2001). In such circumstances revenues and costs in the production system will correlate to the prevailing constraints. Under the fixed herd-size base of evaluation, economic values were estimated assuming that there is an optimal number of animals that can be supported by the production system. In this situation, the economic values were derived from the equation:

$$EV = \frac{\Delta R - \Delta C}{\Delta t} \qquad (59)$$

where EV is the economic value, ΔR is the change in revenue, ΔC is the change in costs and Δt is the marginal change in a trait after 1% increase.

Next, economic values were re-estimated assuming a fixed pasture input, which is a common characteristic of most production systems in Kenya. The general scarcity of feed resources as a consequence of both high market prices and limited land sizes is a major constraint in cattle production. Climatic factors contribute to variations in availability of feed resources while financial resources determine if producers can afford quality animal feed. Similarly limitation in land sizes also dictates the amount of grazing area available. For this case, the economic value of traits was obtained as:

$$EV = \frac{\Delta R - \Delta C}{\Delta t} - \left(\frac{\Delta FI}{\Delta t} x \frac{P_b}{FI} \right) \quad (60)$$

where EV, ΔR, ΔC and Δt are as defined in Eq. (59), P_b is the original profit per cow per year before genetic improvement, FI is the total feed intake per cow per year (kg DM) and ΔFI is the marginal change in FI after genetic improvement in the trait of interest.

4.2.2 Sensitivity of economic values to changes in production variables and prices

Additional analyses were carried out to assess the impact of changing production variables and prices on the economic values for the traits. These were considered under all evaluation bases (fixed herd-size and fixed pasture input) and production systems. Changes of ±20% with respect to the production variables (WW and CI) and prices of meat and feed were considered. The changes were performed one at a time, keeping all other parameters constant. The behaviour of economic values as a consequence of changes in production variables and prices gives information on the likely direction of future genetic progress and production systems, which have important applications in practical breeding programmes (Groen, 2000).

4.2.3 Assessment of the influence of economic value on genetic improvement

Discounting of economic values

All breeding objective traits cannot be expressed at the same time or with the same frequency, therefore, economic values were adjusted for this. The discounted gene flow method (McClintock and Cunningham, 1974) or diffusion coefficients (McArthur and Del Bosque Gonzalez, 1990) can be used. In the discounted gene flow method, the number of discounted expressions of a trait is expressed as a function of the number of progeny or later descendants of an animal plus the annual discount factor. The procedure accounts for both the generational (from selection to birth of offspring) and non-generational delays (birth to cash flow). The diffusion coefficients on the other hand account for the latter only. Adjustment for the generational delay were expected to be the same for all traits and hence, of no significance (McArthur and Del Bosque Gonzalez, 1990). Therefore, diffusion coefficients method was employed in the present study. This method is being used for calculating economic values in the B-OBJECT programme for beef cattle improvement in Australia (Brash et al., 1990). Diffusion coefficients were

calculated over 10 years and using a 5% and 10% discount rates. The correlation between sexes (steers and heifers) was assumed to be unity. In this case, the SW in steers and heifers were treated as the same trait i.e. direct sale weight (SWd). Similarly, the feed intake in steers and heifers were also treated as the same trait i.e. feed intake in the offspring (FIo). The economic value of SWs and FIs were used in the assessment of genetic gain in SWd and FIo, respectively. In most production systems studied, the economic values of SWh and FIh were close to zero since a very small percentage of heifers (4%) were sold off (Figure 2).

4.2.4 Phenotypic and genetic parameters

Selection as a basic tool in animal breeding requires that measurable characters be used to improve targeted traits. However, traits targeted for improvement must be heritable, variable and also phenotypically or genetically correlated with the chosen characters. In this study, an attempt was made to establish relationships between the objective and criteria traits, their heritabilities and phenotypic variances. Reliable estimates from literature were consulted confining our sources to tropical cattle as much as possible (Mackinnon et al. 1991; Rege and Wakhungu, 1992; Haile-Marriam and Kassa-Mersha, 1995; Lôbo et al., 2000; Burrow, 2001; Maiwashe et al., 2002). A thorough search of literature was necessary because current local estimates for variance components for cattle were lacking. Genetic and phenotypic variance/covariance matrices were checked to ensure they were positive definite. The phenotypic and genetic parameters assumed in this study are presented in Table 9.

Table 9. Assumed heritabilities, phenotypic standard deviation, phenotypic correlation[1] (above diagonal) and genetic correlation (below diagonal) among selection criteria and breeding objective traits.

Trait[2]	CoWT	SWd	SWm	DP	CMP	CoSR	PSR	FIo	FIc	CoWR	MY	AFC	CI	SC	BW	WW	YW
Units	kg	kg	kg	%	%	%	%	kg DM	kg DM	%	kg	days	days	cm	kg	kg	kg
h^2	0.35	0.35	0.06	0.30	0.45	0.03	0.03	0.30	0.30	0.05	0.27	0.29	0.14	0.40	0.40	0.30	0.31
σp	40.00	50.00	29.00	1.80	2.00	9.95	9.95	47.00	116.00	43.30	165.66	499.80	199.10	2.00	4.20	25.00	22.00
CoWT																	
SWd	0.75																
SWm	0.00	0.00															
DP	-0.05	-0.06	0.00														
CMP	0.00	0.15	0.00	0.10													
CoSR	0.00	0.00	-0.15	0.00	0.00												
PSR	0.00	0.00	0.00	0.00	0.00	0.00											
FIo	0.55	0.60	0.07	-0.10	0.00	0.00	0.00										
FIc	0.65	0.55	0.07	-0.10	0.00	0.00	0.00	0.80									
CoWR	-0.53	0.05	-0.05	0.00	0.00	0.00	0.00	0.10	0.10								
MY	0.23	0.34	-0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.10		0.21	0.11	0.00	-0.02	0.00	0.00
AFC	0.15	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.37		-0.02	0.00	-0.10	0.00	0.00
CI	-0.53	0.00	-0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.11	-0.03		0.00	-0.56	0.00	0.00
SC	0.28	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	-0.12	0.32		0.10	0.20	0.36
BW	0.40	0.40	0.00	0.00	0.00	-0.02	0.05	0.00	0.20	-0.03	0.00	0.34	0.00	0.10		0.40	0.55
WW	0.50	0.50	0.00	-0.05	0.05	0.00	0.04	0.45	0.40	0.00	0.10	0.00	0.00	0.15	0.65		0.90
YW	0.45	0.87	0.00	-0.05	0.09	0.00	0.00	0.50	0.45	0.05	0.10	0.00	0.00	0.36	0.35	0.73	

[1] Phenotypic correlations only required for selection criteria.

[2] CoWT=cow weight; SWd = direct sale weight for steers; SWm = sale weight steers maternal; DP = dressing percentage; CMP= consumable meat percentage; CoSR= cow survival rate; PSR= post-weaning survival rate; FIo= Feed intake of offspring; FIc = feed intake of cows; CoWR=cow weaning rate; MY=milk yield; AFC=age at first calving; CI=calving interval; SC=scrotal circumference; BW=birth weight; WW=weaning weight; YW = yearling weight.

4.2.5 Selection indices and criteria

Eight alternative selection indices were constructed for use in predicting genetic gain for the breeding objective traits. These indices were chosen because of their relevance to practical breeding programmes and were constructed with economic values derived in all production systems. The base selection index (I_0) was a multiple trait index resulting from the application of undiscounted economic values as weighting factors for the breeding objective traits. The second (I_5) and third (I_{10}) indices were similar to I_0 except they resulted from the application of economic values discounted at 5% and 10%, respectively. The fourth and fifth indices were constructed with economic values derived from the fixed herd-size scenario by setting feed costs to zero ($I_{FI=0}$) and increasing feed costs by 20% ($I_{FI \times 1.20}$), respectively. The sixth ($I_{M \times 0.80}$) and seventh ($I_{M \times 1.20}$) indices resulted from the application of economic values derived from the fixed herd-size scenario by reducing and increasing cattle meat prices by 20%, respectively. The eighth selection index (I_{SWd}) was a representation of an oversimplified breeding objective in which only SWd had an economic value different from zero.

The application of economic values is seen when selection is done for several traits where they are used as weighting factors (Hazel, 1943). The selection index coefficients were derived as follows;

$$b = P^{-1}Ga \qquad (61)$$

where b is a vector containing the coefficients of the index traits, P is a phenotypic variance – covariance matrix of the characters in the selection index, G is a genetic variances and covariance matrix between the characters in the index and traits in the breeding objective and a is a vector of economic values of the traits in the breeding objective. The efficiency of selection in the indices constructed were compared by checking the correlations among them according to the formula of James (1982) and also by estimating the genetic gain after one generation of selection assuming a selection intensity of one (i = 1) as shown,

$$g = \frac{b'G}{\sigma_I} \qquad (62)$$

where σ_I is the standard deviation of the selection index ($\sigma_I = \sqrt{b'Pb}$). b, P and G are as defined in equation (61).

The basis of defining breeding objective traits are normally economic in nature, however when considering evaluation of animals for selection, genetic considerations are strictly relevant (Ponzoni and Gifford, 1990). Not all traits in the breeding objective can be easily measured. However, there may be characters highly correlated to the objective traits but are not included in the objective. Selection criteria should correspond to the breeding objective.

The selection criteria included information on BW, WW, YW, SC, AFC, CI and MY. For BW, WW and YW, information sources included records on the candidate, the sire and the dam. For SC, information sources included records on the sire while on the dam for AFC, CI and MY. However, MY was included only in the dual purpose systems (LFLD and LFMD). The choice of selection criteria was based on traits that are normally recorded in most cattle ranches in Kenya (Rege and Wakhungu, 1992; Okeyo et al., 1998).

4.3 Results and discussion

4.3.1 Estimates of economic values

Fixed herd- size

Economic values per unit increase in genetic merit of traits under fixed herd-size for the different production systems are presented in Table 10. Economic values for production (except MY in beef systems) and functional traits (except feed intake in all systems) were positive meaning a unit increase in genetic merit of these traits had greater influence on revenues than costs. Among the productive traits, DP had the highest economic value. In the pure beef systems (SFMB, LFMB, SFHB and LFHB), the economic value of MY was negative since it was used in formulating feed requirement and consequently feed intake of cows. Under the pure beef systems, selection for increased MY would increase the cow feed costs as a result of higher pasture intake. Feed intake is a trait that is linearly related to costs. Due to the low cost of pastures, the economic value for feed intake in the three classes of livestock was also low. The economic value for SWs was higher than for SWh in all systems. This was expected because more steers than heifers contributed to revenue since a big percentage of heifers were retained as replacement (Figure 2).

Milk yield had a positive economic value in the LFLD system. Kahi and Nitter (2004) found positive economic values for MY of dairy cattle, which is in agreement with results in this study. Economic values for MY in specialised dairy production systems in temperate areas where milk prices include the value of fat and protein yield are normally negative (Gibson, 1989; Groen, 1989; Bekman and van Arendonk, 1993). In these studies, the base price for volume milk was negative as opposed to the present study where the base price of milk was positive.

Table 10. Economic values per unit increase in genetic merit for traits under fixed herd-size

Traits[1]	Production systems[2]					
	SFMB	LFMB	SFHB	LFHB	LFLD	LFMD
CMP	+ 116.63	+ 138.35	+ 156. 43	+ 193.37	+ 54.58	+ 141.36
CoSR	+ 96. 02	+ 112.19	+ 124.35	+ 168.53	+ 52.93	+ 114.57
CoWR	+ 128.08	+163.63	+ 175.51	+ 270.66	+ 87.54	+ 165.29
CoWT	+ 8.09	+ 8.09	+ 9.92	+ 10.16	+ 2.21	+ 10.55
DP	+ 154.76	+ 183.58	+ 218.99	+ 265.41	+ 72.42	+ 187.57
FIc	- 0.50	- 0.50	- 0.50	- 0.50	- 0.50	- 0.75
FIh	- 0.50	- 0.50	- 0.57	- 3.59	- 0.50	- 0.75
FIs	- 0.50	- 0.50	- 1.21	- 6.20	- 0.50	- 0.75
MY	- 0.22	- 0.22	- 0.22	- 0.22	+ 6.29	+ 10.77
PSR	+ 65.62	+ 82.49	+ 90.06	+ 134.23	+ 39.62	+ 84.99
SWh	+ 0.84	+ 1.22	+ 2.14	+ 1.61	+ 0.07	1.43
SWs	+ 12.42	+ 12.42	+ 14.63	+ 14.92	+ 5.69	+ 12.69

[1] CMP= consumable meat percentage; CoSR= cow survival rate; CoWR=cow weaning rate; CoWT=cow weight; DP = dressing percentage; FIc = feed intake of cows;. FIh = feed intake of heifers; FIs = feed intake of steers; MY = milk yield; PSR= post-weaning survival rate; SWh= sale weight of heifers; SWs= sale weight of steers.

[2] SFMB = short fed medium input; LFMB = long fed medium input; SFHB = short fed high input; LFHB = long fed high input; LFLD = long fed low input dual purpose; LFMD = long fed medium input dual purpose.

The high input systems (SFHB and LFHB) had the highest economic values mainly because they had the highest revenues. The lowest economic values for the breeding objective traits were observed in the LFLD system since this system was assumed to correspond to the low input extensive systems practiced by pastoralist communities in Kenya. However, due to lack of direct data from this system, a validation of these results by investigating the input-output relationships in this system is recommended.

The differences in economic values in the medium input systems (SFMB and LFMB) can be attributed to the differences in sale weights of slaughter animals. Animals in the LFMB system had heavier sale weights than those in the SFMB system. Positive economic values for most production and functional traits studied indicate that improvement in these traits will lead to increased profitability in the systems especially when availability of feed is optimal. The negative economic value for the feed intake in the three classes of cattle was expected. Lowering feed intake will change the product output levels of a herd and hence profitability.

Fixed pasture input

Table 11 shows the economic values per unit increase in genetic merit of traits for the different production systems under the fixed pasture input situation.

Table 11. Economic values per unit increase in genetic merit for traits under fixed pasture input

Traits[1]	Production systems[2]					
	SFMB	LFMB	SFHB	LFHB	LFLD	LFMD
CMP	+116.63	+138.35	+156.43	+193.37	+54.58	+141.36
CoSR	+95.17	+109.76	+120.42	+167.54	+46.85	+106.14
CoWR	+126.20	+158.28	+166.85	+268.47	+72.91	+147.15
CoWT	+5.95	+4.58	+7.10	+8.36	-11.14	-15.33
DP	+154.76	+183.58	+218.98	+265.41	+72.42	+187.57
FIc	-0.99	-1.29	-1.14	-0.91	-3.43	-8.72
FIh	-0.99	-1.29	-1.21	-3.99	-3.43	-8.72
FIs	-0.99	-1.29	-1.85	-6.61	-3.43	-8.72
MY	-0.42	-0.56	-0.49	-0.39	+5.03	+8.27
PSR	+64.75	+79.98	+85.98	+133.22	+33.35	+75.57
SWh	-0.11	+0.27	-0.09	+1.15	-2.57	-5.46
SWs	+12.42	+12.42	+14.63	+14.92	+5.69	+12.69

[1] CMP= consumable meat percentage; CoSR= cow survival rate; CoWR=cow weaning rate; CoWT=cow weight; DP = dressing percentage; FIc = feed intake of cows;. FIh = feed intake of heifers; FIs = feed intake of steers; MY = milk yield; PSR= post-weaning survival rate; SWh= sale weight of heifers; SWs= sale weight of steers.

[2] SFMB=short fed medium input; LFMB=long fed medium input; SFHB=short fed high input; LFHB=long fed high input; LFLD=long fed low input dual purpose; LFMD=long fed medium input dual purpose.

In this evaluation, increase of genetic merit of a trait changed the economic values of feed intake in the three classes of livestock and other traits related to it for all production systems. These traits were CoSR, CoWR, PSR, CoWT, SWh and MY. When compared to the fixed herd size situation, in this evaluation the change in economic values was downward as is the case when a production factor is restricted (Vargas et al., 2002; Kahi and Nitter, 2004). SWs was not used in formulating feeding requirements or

feed intake for steers thus the economic value did not change. Similarly, economic values for DP and CMP were not affected under fixed pasture input situation.

There was a negative economic value for CoWT in the LFLD and LFMD systems. This suggests that breeding for increased CoWT will result in a reduction in profitability in dual-purpose production systems especially where feed is limited. Larger cows eat more than small cows, and this is an important factor when the production of the cow is not fully expressed due to feed-related limitations. Normally, in the tropics, it is always important to consider input restriction since feed is scarce and availability is limited by land sizes and seasonal variation in rainfall (Dekkers, 1991; Kosgey et al., 2003; Kahi and Nitter, 2004). In these circumstances, fixing pasture input is appropriate since economic values will be independent of feed costs thus solving the problems of variations in the function thereof, hence removing the need to explicitly assign a value to feed which is normally difficult where feed valuation is undefined (Ponzoni, 1992)

4.3.2 Sensitivity of economic values to changes in production variables and prices

The sensitivity of economic values to changes in production variables and in meat and feed prices was done for all evaluation bases and production systems. The trends were similar in the two evaluation bases. Similarly, within each evaluation base, the trends were similar in all the production systems. Therefore, only results for one pure beef system (i.e. the LFMB system) under a fixed herd-size base of evaluation are presented. Table 12 presents the economic values for production and functional traits that responded to changes in level of production variables and prices of meat (p_m) and feed (p_f) in the LFMB system under fixed herd-size.

Reducing CI caused a significant rise in economic values for SWs, SWh, DP, CMP, CoSR and PSR (Table 12). A reduction in CI increases the number of calvings per year leading to an overall increase in feed and husbandry costs. Therefore, when there are restrictions on herd-size increasing number of animals weaned per year may not be necessarily profitable. Reducing WW resulted in an increase in the economic values of CoWR and PSR. This is because WW is related to feed intake and reducing it leads to a reduction in feed intake and thus feed costs. CoWR and PSR are related to the number of animals to be fed and managed after weaning. Therefore, in situations where feed costs are low, their economic values would increase.

Table 12. Sensitivity of economic values for production and functional traits to changes in level of production variables and prices of meat and feed in the LFMB system under fixed herd-size[1]

	%	CMP	CoSR	CoWR	CoWT	DP	FIc	FIh	FIs	MY	PSR	SWh	SWs
Base situation		+138.35	+112.19	+163.63	+8.09	+183.58	-0.50	-0.50	-0.50	-0.22	+82.49	+1.22	+12.42
Production variables[2]													
WW	-20			+164.60							+82.94		
	+20			+162.49							+81.96		
CI	-20	+173.25	+130.81	+163.64		+229.29					+103.12	+4.32	+15.53
	+20	+115.10	+99.79	+163.70		+152.73					+68.75	-0.85	+10.35
Prices													
p_m	-20	+110.69	+84.73	+120.00	+6.03	+146.88					+61.79	+0.86	+9.94
	+20	+166.03	+139.67	+207.29	+10.15	+220.31					+103.19	+1.58	+14.91
p_f	-20		+112.51	+164.32	+8.53		-0.40	-0.40	-0.40	-0.17	+82.81	+1.34	
	+20		+111.89	+162.97	+7.65		-0.60	-0.60	-0.60	-0.26	+82.18	+1.09	

[1]CMP = consumable meat percentage; CoSR = cow survival rate; CoWR =cow weaning rate; CoWT = cow weight; DP = dressing percentage; FIc = feed intake of cows; FIh = feed intake of heifers; FIs = feed intake of steers; MY = milk yield; PSR = post-weaning survival rate; SWh = sale weight of heifers; SWs = sale weight of steers.

[2]WW = weaning weight; CI = calving interval; p_m = price of meat; p_f = price of feed.

Generally, apart from the feed intake in the three classes of livestock, the other traits were sensitive to changes in the price of meat. Similarly, apart from CMP, DP and SWs, the economic values of the other traits were sensitive to changes in the prices of feed. The economic value of SWs was not affected by price of feed because SWs was not included in calculation of feed requirements or feed intake. When the effect of changes in prices of meat and feed on the economic values of various traits is compared, changes in meat prices had more effect than similar changes in the price of feed. This is explained by the relative low price of pasture applied in this study compared to meat prices.

4.3.3 Assessment of the influence of economic value on genetic improvement

Economic values were estimated and discounted for all systems studied and their influence on genetic improvement assessed. Since the pattern was similar among the systems, results of only two representative systems (LFMB and LFLD) are presented. Table 13 presents the discounted economic values of traits in the LFMB and LFLD systems. The influence of these on genetic improvement was assessed by comparing the genetic gains achieved in the breeding objective traits. The genetic gains achieved by one round of selection on the indices derived using different methods assuming a selection intensity (i) of one in the LFMB and LFLD systems are shown in Table 14. The three indices (I_0, I_5, and I_{10}) produced similar results for most systems and correlations among them were near unity (above 0.99) (not shown). Therefore, the I_5 was chosen as a basis for other comparisons. Table 15 shows the genetic gains in each trait resulting from the application of indices derived using different values for feed costs and meat prices and when an oversimplified breeding objective in which only SWd had an economic value different from zero was assumed.

Table 13. Discounted economic values of traits[1] in the LFMB and LFLD systems evaluated at discount rates of 5 and 10%

Production system[2]	Traits	Discount rates	
		5%	10%
LFMB			
	CMP	118.98	103.76
	CoSR	88.63	74.05
	CoWR	129.27	108.00
	CoWT	6.39	5.34
	DP	157.88	137.69
	FIc	-0.40	-0.33
	FIo	-0.43	-0.38
	MY	-0.17	-0.15
	PSR	70.94	61.87
	SWd	10.68	9.32
	SWm	9.32	7.20
LFLD			
	CMP	46.94	40.94
	CoSR	40.23	29.11
	CoWR	66.53	48.15
	CoWT	1.68	1.22
	DP	62.28	54.32
	FIc	-0.38	-0.28
	FIo	-0.43	-0.38
	MY	4.78	3.46
	PSR	34.07	29.72
	SWd	4.89	4.27
	SWm	4.04	2.67

[1]CMP = consumable meat percentage; CoSR = cow survival rate; CoWR =cow weaning rate; CoWT = cow weight; DP = dressing percentage; FIc = feed intake of cows; FIo = Feed intake offspring; MY = milk yield; PSR = post-weaning survival rate; SWd = direct sale weight for steers and SWm = sale weight steers maternal.

[2] LFMB=long fed medium input; LFLD=long fed low input dual purpose.

Table 14. Genetic gain in each trait with indices derived using economic values calculated by different methods[1]

		Traits in the breeding objective										
Production system[2]	Index[3]	CoWT	SWd	SWm	DP	CMP	CoSR	PSR	FIo	FIc	CoWR	MY
LFMB												
	I_0	1.373	3.780	0.401	-0.002	0.006	-0.000	0.001	1.000	2.211	1.908	1.441
	I_5	1.397	3.853	0.408	-0.002	0.007	-0.000	0.001	1.043	2.303	1.900	1.447
	I_{10}	1.332	3.820	0.387	-0.002	0.006	-0.000	0.001	1.022	2.257	1.907	1.444
LFLD												
	I_0	1.473	2.969	0.175	-0.001	0.004	0.000	0.000	0.605	2.036	1.718	20.694
	I_5	1.496	3.044	0.183	-0.001	0.004	0.000	0.000	0.645	2.120	1.718	20.618
	I_{10}	1.606	3.126	0.178	-0.002	0.005	-0.000	0.001	0.794	2.518	1.513	22.765

[1] CoWT = cow weight; SWd = direct sale weight for steers; SWm = sale weight steers maternal; DP = dressing percentage; CMP = consumable meat percentage; CoSR = cow survival rate; PSR = post-weaning survival rate; FIo = Feed intake offspring; FIc = feed intake of cows; CoWR =cow weaning rate; MY = milk yield.

[2]LFMB=long fed medium input; LFLD=long fed low input dual purpose.

[3] I_0 = index derived using undiscounted economic values; I_5 = similar to I_0 but with discount rate equal to 5%; I_{10} = similar to I_0 but with discount rate equal to 10%.

Table 15. Genetic gain in each trait resulting from the application of indices derived with different feed costs and cattle meat prices[1]

Production system[1]	Index[2]	Traits in the breeding objective[3]										
		CoWT	SWd	SWm	DP	CMP	CoSR	PSR	FIo	FIc	CoWR	MY
LFMB												
	I_5	1.397	3.853	0.408	-0.002	0.007	-0.000	0.001	1.043	2.303	1.900	1.447
	$I_{FI=0}$	1.460	3.878	0.421	-0.002	0.007	-0.000	0.001	1.066	2.353	1.894	1.476
	$I_{FI \times 1.20}$	1.356	3.759	0.397	-0.002	0.006	-0.000	0.001	0.987	2.181	1.910	1.434
	$I_{M \times 0.80}$	1.406	3.850	0.411	-0.002	0.007	-0.000	0.001	1.040	2.297	1.900	1.443
	$I_{M \times 1.20}$	1.354	3.737	0.395	-0.002	0.006	-0.000	0.001	0.976	2.158	1.912	1.440
	I_{SWd}	2.323	6.447	0.664	-0.006	0.017	-0.001	0.004	3.044	6.617	0.707	1.208
LFLD												
	I_5	1.496	3.044	0.183	-0.001	0.004	0.000	0.000	0.645	2.120	1.718	20.618
	$I_{FI=0}$	1.591	3.115	0.204	-0.002	0.005	-0.000	0.000	0.697	2.234	1.704	20.683
	$I_{FI \times 1.20}$	1.448	2.939	0.169	-0.001	0.004	0.000	0.000	0.586	1.995	1.721	20.686
	$I_{M \times 0.80}$	1.502	2.921	0.163	-0.001	0.004	-0.000	0.000	0.637	2.156	1.602	22.143
	$I_{M \times 1.20}$	1.489	3.108	0.199	-0.001	0.004	0.000	0.000	0.641	2.068	1.794	19.337
	I_{SWd}	2.410	6.497	0.648	-0.006	0.017	-0.001	0.004	3.020	6.682	0.772	4.456

[1]LFMB=long fed medium input; LFLD=long fed low input dual purpose.

[2]I_5 = index derived from economic values discounted at 5%; $IFI_{=0}$ and $I_{FI \times 1.20}$ = indices constructed with economic values derived from setting feed costs to zero and increasing feed costs by 20%, respectively; $I_{M \times 0.80}$ and $I_{M \times 1.20}$ = indices resulted from the application of economic values derived from reducing and increasing cattle meat prices by 20%, respectively; I_{SWd} = oversimplified breeding objective in which only SWd had an economic value different from zero.

[3] CoWT = cow weight; SWd = direct sale weight for steers; SWm = sale weight steers maternal; DP = dressing percentage; CMP = consumable meat percentage; CoSR = cow survival rate; PSR = post-weaning survival rate; FIo = Feed intake offspring; FIc = feed intake of cows; CoWR =cow weaning rate; MY = milk yield.

When feed costs were set to zero ($I_{FI=0}$), the gains were amplified for all traits in both systems except DP and CoSR while an increase in feed costs ($I_{FI \times 1.20}$) had a negative effect. Ignoring feed costs had the overall effect of shifting the emphasis in genetic gain from carcass traits and cow survival to growth, reproduction and milk yield. These results are in agreement with those reported by Ponzoni and Gifford (1990). The genetic gains in SWd, SWm, DP and CMP when meat prices increased ($I_{M \times 1.20}$) were similar to the gains achieved with the index I_5, reflecting the high correlation between the two indices (Table 16). This indicates that in the near future a change in meat prices will not adversely affect genetic improvement in sale weight and carcass traits. In the LFLD system, the gains in MY were more when meat prices were reduced ($I_{M \times 0.80}$) than when they were increased ($I_{M \times 1.20}$). This indicates that MY increases in importance when meat prices are low in systems that sell milk as an additional source of revenue.

Table 16. Correlations among indices derived with different feed costs and cattle meat prices

Production system[1]	Index[2]	$I_{FI=0}$	$I_{FI \times 1.20}$	$I_{M \times 0.80}$	$I_{M \times 1.20}$	I_{SWd}
LFMB						
	I_5	1.000	1.000	1.000	1.000	0.598
	$I_{FI=0}$		1.000	1.000	0.999	0.602
	$I_{FI \times 1.20}$			1.000	1.000	0.583
	$I_{M \times 0.80}$				1.000	0.597
	$I_{M \times 1.20}$					0.580
LFLD						
	I_5	1.000	1.000	0.995	0.997	0.469
	$I_{FI=0}$		0.999	0.996	0.997	0.479
	$I_{FI \times 1.20}$			0.995	0.997	0.452
	$I_{M \times 0.80}$				0.986	0.450
	$I_{M \times 1.20}$					0.478

[1]LFMB=long fed medium input; LFLD=long fed low input dual purpose.
[2]I_5 = index derived from economic values discounted at 5%; $IFI_{=0}$ and $I_{FI \times 1.20}$ = indices constructed with economic values derived from setting feed costs to zero and increasing feed costs by 20%, respectively; $I_{M \times 0.80}$ and $I_{M \times 1.20}$ = indices resulted from the application of economic values derived from reducing and increasing cattle meat prices by 20%, respectively; I_{SWd} = oversimplified breeding objective in which only SWd had an economic value different from zero.

In I_{SWd}, the genetic gain in MY was decreased by over 80% (from 20.6 kg to 4.5 kg) in the LFLD system. This index, depressed gains for CoSR and CoWR while increased gains for SW (both direct and maternal) indicating that the emphasis in genetic gain shifted away from functional to production traits (Urioste et al., 1998). However,

oversimplifying the breeding objective is unrealistic since it might lead to overestimation of genetic gain in both production and functional traits. Table 16 shows the correlations among indices derived using different values for feed costs and meat prices and when an oversimplified breeding objective in which only SWd had an economic value different from zero was assumed. The correlation between I_{SWd} and other indices were the only ones that were below 0.99.

4.4 Conclusions

The economic values estimated were fairly robust to changes in prices and production variables. There is a general scarcity of information on economic evaluation of cattle production in most of sub-Saharan Africa and therefore some interest and creativity is required to identify important traits and derive their economic values. The magnitude of the economic values for production and functional traits estimated in this study suggest that genetic improvement of these traits will have a positive effect on profitability of Boran cows kept in dual-purpose systems and when herd-size is restricted. In pure-beef systems, genetic improvement of MY will have a negative effect on profitability, especially when restrictions on herd-size and feed exists.

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CHAPTER FIVE:
GENERAL DISCUSSION

5.1 The aim of this study

As a purebred, the Boran breed is utilised in beef production systems and in systems where milk also forms an important output. When crossed with exotic dairy breeds, the resulting genotypes are used in lowland dairy production systems. Over time, the breed has gradually been developed through both natural and artificial selection to attain characteristics that facilitate its comparatively higher performance in the ASALs than any of the indigenous and exotic beef breeds (Gregory et al., 1984; Mwandoto et al., 1988; Herlocker, 1999). It's ability to survive and produce in these environments coupled with its general purpose functions makes the Boran a very important animal for rangeland livestock production not only in Kenya but also in other tropical countries. Presently, there is a growing interest in the Boran in Australia and South Africa and in several occasions, Boran embryos have been sourced from the local ranchers for export to these countries (Ouda et al., 2001).

To maintain the level of production required to meet the ever growing demand for livestock products amidst changing agricultural production systems, including diminishing agricultural land sizes, there is need for systematic improvement in the efficiency of production. Designing sustainable breeding programmes is one of the most practical means of improving efficiency in livestock production. To design breeding programmes, it is essential that appropriate breeding objectives must first be developed. Breeding objectives constitutes economic values and breeding values of traits a producer wishes to improve because of their influence on profitability in the production system. Economic values indicate the relative importance of traits in the system and can only be estimated if the breeding objectives are defined in economic terms. This process is what represents the definition of formal breeding objectives, which has been lacking for the Boran cattle in Kenya. It is with this background that the present study was conceptualised. The overall aim of this study was to develop breeding objectives for Boran cattle selection programmes in Kenya.

5.2 Study methodology

The methods applied in this study were based on the principles of bio-economic modelling, assessment of marginal returns and the selection index (Ponzoni, 1986; Ponzoni and Newman, 1989; Newman et al., 1992; Bekman and van Arendonk, 1993; Wilton and Goddard, 1996; Kosgey et al., 2003; Kahi and Nitter, 2004). The production systems described represented the ones present in Kenya and included short fed and long fed medium input pure beef systems, short fed and long fed high input pure beef systems and long fed low input and medium input dual purpose systems. In each system, a bio-economic profit function was developed. Partial budgeting was applied to obtain the effect on profits when a trait is improved by one percent and this represented the economic value. A set of selection indices were developed based on the economic values and their influence on genetic improvement of the traits of interest assessed. The response to selection of traits achieved after one round of selection was used as a means of testing the viability and efficiency of the developed breeding objectives (Cunningham, 1980; Franklin, 1986; Smith, 1988; Ponzoni and Gifford, 1990).

5.3 Profitability of breeding objectives

All objectives applied resulted in a general increase in profits after genetic improvement of cattle performance in all systems. This confirmed the role of genetic improvement in the improvement of efficiency of cattle production. The behaviour of the various production systems studied was similar and therefore for illustration purposes the LFMB system (to represent pure beef systems) and the LFLD system (to represent dual purpose systems) have been used. Table 17 presents estimated revenues, costs and profits before genetic improvement and after genetic improvement resulting from the application of different selection indices. The values for revenue costs and profits before genetic improvement were adopted from Table 8 while the values after genetic improvement for each index were derived from the recalculation of revenues, costs and profits using the new values for breeding objective traits produced from the application of the selection indices. In general, all indices (save for I_{SWd}) produced similar results in terms of profitability of the production systems mainly because the correlations among them were near unity (Table 16). However, applying the index $I_{FI=0}$ amplified the economic values of most production

and functional traits resulting in either overestimation or underestimation of genetic gain (Table 15).

Table 17. Estimated revenues, costs and profits per cow per year before and after genetic improvement in the production systems

Production system[1]	Selection indices[2]	Total Revenue (KSh)	Total Cost (KSh)	Profit (KSh)
LFMB	Before genetic improvement	9546.72	6702.34	2844.38
	After genetic improvement			
	I_0	10027.23	6811.57	3215.66
	I_5	10026.40	6811.16	3215.24
	$I_{FI=0}$	10025.21	6810.79	3214.42
	$I_{FI \times 1.20}$	10026.87	6811.53	3215.34
	$I_{M \times 0.80}$	10026.50	6811.18	3215.32
	$I_{M \times 1.20}$	10026.51	6811.49	3215.02
	I_{SWd}	10072.65	6816.88	3255.77
LFLD	Before genetic improvement	14250.96	5015.40	9235.56
	After genetic improvement			
	I_0	14621.91	5085.98	9535.93
	I_5	14621.94	5086.02	9535.92
	$I_{FI=0}$	14621.01	5085.01	9536.00
	$I_{FI \times 1.20}$	14621.65	5085.75	9535.90
	$I_{M \times 0.80}$	14619.21	5085.04	9534.17
	$I_{M \times 1.20}$	14620.60	5086.52	9534.38
	I_{SWd}	14419.27	5049.44	9369.83

[1]LFMB = long fed medium input beef production; LFLD = long fed low input dual purpose.
[2]I_0 = index derived using undiscounted economic values; I_5 = similar to I_0 but with discount rate equal to 5%; $IFI_{=0}$ and $I_{FI \times 1.20}$ = indices constructed with economic values derived from setting feed costs to zero and increasing feed costs by 20%, respectively; $I_{M \times 0.80}$ and $I_{M \times 1.20}$ = indices resulted from the application of economic values derived from reducing and increasing cattle meat prices by 20%, respectively; I_{SWd} = oversimplified breeding objective in which only SWd had an economic value different from zero.

When $I_{FI=0}$ was applied in the LFLD system, improvement was observed for growth, reproduction and MY. This resulted in an increase in profits for the system from KSh 9235.56 to KSh 9536.00 (Table 17). This is attributable to the increased revenues obtained from sale of beef and milk as well as the reduction in production costs resulting from equating feed costs to zero. In the LFMB system, the highest profits were observed when the oversimplified objective (I_{SWd}) was applied. This system values sale weight as the main source of revenue, therefore improving sale weight would improve profitability. It is important to note that the effects of economic values of other traits on genetic gain were not factored in this objective creating bias in the estimates of genetic gains. In the LFLD system, increasing the number and size of animals impacts negatively on production costs since the system is limited in terms of resources and thus the

oversimplified objective was the least profitable. The index that comprised of economic values calculated when meat prices were increased ($I_{M \times 1.20}$) was profitable in both systems. However, the differences between this index and the one where meat prices were reduced ($I_{M \times 0.80}$) were small indicating that changes in meat prices in the future would not adversely influence genetic improvement in the production systems (Table 15). All indices applied in the LFMB and LFLD systems were inferior to the base situation (I_0) in terms of profitability except I_{SWd} in the LFMB system and $I_{FI=0}$ in the LFLD system.

5.4 Implementing a breeding programme

Beef production in Kenya is becoming organised (Ouda et al., 2001). The demand for improved animal genetics is expected to increase to meet animal product demands. This means that a functional breeding programme needs to be established to strengthen the existing programmes so as to satisfy a majority of cattle farmers in arid and semi arid areas. In principle, a more possible design of a breeding programme will be that which concentrates costs within a given herd while effecting genetic gain in the whole herd. Such a programme requires full co-operation of farmers and other stakeholders including the government. Farmers should be assured of the potential benefits of participating in the breeding programme. The improved Kenyan Boran breed is a good starting point to establish a national breeding programme for Boran cattle. A number of stud herds originally established by European ranchers still exist. Based on these as nuclei, a nucleus breeding programme for Boran cattle in Kenya can be established. This would however require that the ranchers be encouraged to cooperate rather than compete with one another (Kahi et al., 2004).

5.4.1 Choice of breeding structures

Breeding structures provide systems for gathering information about assessment of animals in the production system and conditions that allow selection of parents of future progeny, and desirable mating systems of these animals (Rege et al., 2001). A breeding programme must consider and address how superior genes will be disseminated quickly throughout the whole population. Breeding programmes can only be implemented where accurate recording is possible. Accurate record keeping in field populations requires financial investment, expertise and a well-developed infrastructure. All these are

partially or completely lacking in most parts of Kenya where the Boran breed is predominant. Nucleus breeding schemes were developed to circumvent the high costs arising from performance recording and selection since they do not require expensive infrastructure because recording is done in the nucleus herd (Smith, 1988). Bondoc and Smith (1993) recommended the establishment of two-tier open nucleus breeding systems to maximise genetic improvement, reduce inbreeding rate and reduce the total cost of recording in the participating herds. Although recording is not essential in the participating herds, record keeping can gradually be introduced as part of the extension programme of the scheme. The nucleus can be opened to introductions from the participating herds or closed completely to importation from outside. Figure 7 shows a representation of an open nucleus breeding scheme where; (a) the nucleus is the tier that generates genetic gain and male selection is the main activity; (b) there is movement of bulls from the nucleus to sire progeny in the rest of the populations; (c) there is introduction of females born in the participating herds into the nucleus; and (d) there is strategic selection in the participating herds.

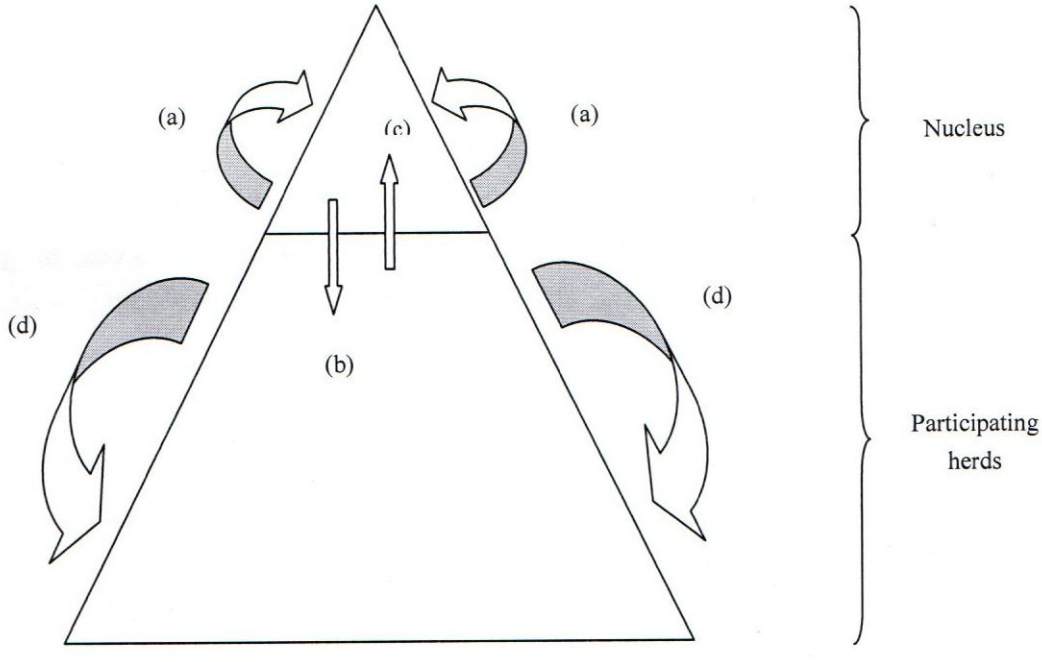


Figure 7. Two-tier open nucleus breeding structure with selection in nucleus and possibly in the participating herds, and downward and upward migration of superior genetics. Adapted from Kahi (2000).

Given the structure of the beef industry, an enhanced closed nucleus system might be a good starting point. Such a system is already being practiced in Kenya, although unconsciously. Large commercial ranches are the main sources of breeding stock to other farmers and pastoralists. These large scale commercial ranches maintain breeding herds separate from their commercial herds. This represents a tier system comprising of the breeding herds, commercial herds and other farmers/pastoralists. With proper incentives and organisation, this system of breeding can gradually be improved as an open nucleus system (Kahi et al., 2004). Open nucleus systems provide approximately 10% more genetic gain than closed systems because there are more animals which are potential candidates for selection. Such a system will integrate farmers' resources, reduce overhead costs and encourage more farmer participation (Bondoc and Smith, 1993).

5.4.2 Choice of selection criteria and scheme

To increase accuracy of selection, the number of traits considered in the selection criteria and the sources of information can be expanded. For example, in the pure beef cases, information on BW, WW and YW in half sibs, on SC in males and on AFC and CI in females, could be included. Additional characters such as slaughter weight and dressing percentage (in relatives) can be introduced to represent carcass traits since recording is based in the nucleus. Therefore, the nucleus carries the costs incurred due to recording of additional information sources for the benefit of the target farmers (Cunningham, 1980). The high costs associated with a selection criterion should not be ignored, as this can be a significant barrier to the adoption of any beneficial technology in practical breeding programmes (Kahi et al., 2004).

Production systems where milk forms an additional output are more challenging since recording for milk production traits must be done. This requires that the cows be milked and calves bucket fed as a means of monitoring milk production. Another alternative is for the calves to be separated from the cow at night to allow for milking in the morning, and allowed to run with the cow during the day. The aim is to allow for milk recording and selection of bull dams for the dual purpose objective. Traditionally, improvement in milk production is achieved through progeny testing, which takes long. This creates a situation of lost opportunities especially in undeveloped cattle industries. A

more practical means of improving dairy traits in the tropics namely, the young bull system, has been recommended (Kahi et al., 2004). In this system, young bulls from selected bull dams based on their own milk production records and sired by proven dual purpose bulls can be used directly without undergoing the rigorous process of progeny testing. Nonetheless, beef traits targeted for improvement are measurable in both sexes. This means that the proportion of the nucleus cows for use in the pure beef objective can be much lower (less than 5% of the total population of targeted population) (Rege et al., 2001). Over time, for traits such as AFC and CI, a progeny testing programme would evolve from the cumulated data, but the immediate costs and also the cost of waiting especially in undeveloped industries may reduce the rate of gain from such programmes. A relatively fast genetic gain is expected in a pure-breeding scheme as most of the beef traits are highly heritable and there will be large variation in the nuclei especially when they are made up of animals from different sources. When sufficient improvement has been realised in the nucleus, dissemination must be planned systematically to allow for bulls to move into the lower tiers where commercial activities are practiced.

5.4.3 Inclusion of adaptation traits

Cow survival influences the productive herd life, which determines the lifetime profitability of an animal since the costs of production are largely influenced by the ability of animals to cope with the prevailing environmental stresses (Baker and Rege, 1994). In the tropics, the ability of an animal to survive and produce up to a certain predetermined age reflects its ability to adapt to the prevailing conditions. While production can be measured in terms of quantity and quality of product, the greatest difficulty comes in identifying indirect measures of adaptation *per se*. Heat tolerance, resistance/tolerance to diseases and ability to produce and reproduce under these conditions are considered important. They can be measured in terms of the actual parasite levels (i.e. number of ticks on an animal, parasites in blood etc.) or its direct effects (i.e. packed cell volume, the faecal egg count etc.), cow and calf survival and the production levels under disease challenge or in periods of prolonged scarce availability of feed (Kahi and Graser, 2004).

The Boran breed is well adapted to the prevailing conditions in the ASALs of Kenya. However, given the negative genetic relationship between production and adaptation,

improving production will have a negative effect on adaptability. There are two options for improving both the production and the adaptation of animals. One is to concentrate on selection for production traits in the presence of environmental stress, thus allowing adaptation to respond as a correlated set of traits. The other is to attempt to understand the biology of adaptation and its relationship with production, and so develop criteria that are directed at improving both adaptation and production (Franklin, 1986). The second approach requires good estimates of genetic and phenotypic parameters for production and adaptive characteristics, some of which are available (Burrow, 2001). Reliable genetic parameter estimates would allow for development of optimal selection indices that are directly applicable to programmes selecting for improved performance in the Boran breed.

5.4.4 Genetic evaluation

Genetic evaluation has to be undertaken to ensure that the best animals are chosen as parents of the next generation by considering their estimated breeding values (EBVs). Proper evaluation methods must be used to accurately and reliably identify the superior animals. Selection can be based on BLUP EBVs since they are estimated based on inclusions of more information such as pedigree information, individual performance and genetic and phenotypic parameters. In addition, BLUP EBVs for older animals can be estimated while considering progeny information especially when progeny testing is a prerequisite for selection.

Genetic evaluations can also be done based on phenotype where animals are selected considering the deviation of their phenotypic value from their contemporaries in the same herd. The EBVs and the economic values can then be combined in a multi-trait index to result in an aggregate genotype expressed in monetary terms (KSh). This aggregate genotype would then be used to rank the animals. Selection using a multi-trait index will result in more genetic gain than selection by individual phenotype. However, selection based on BLUP might lead to higher levels of inbreeding since using information from family members could result in members of the same superior family being selected (Belonsky and Kennedy, 1988).

The application of BLUP in animal evaluation requires accurate collection and organisation of animal's pedigree and performance information in electronic form.

Computers are essential for storing electronic data for use in implementing BLUP-based evaluation procedures. The scope in establishment and use of computerised information lies in the depth and relevance of available information with respect to the target farmers. This requires availability of appropriate user-friendly computer software that meet the actual information requirement of farmers (Olivier et al., 2002).

5.5 Concluding remarks

This study provided vital information on the traits that should be included in breeding objectives targeting different production systems that utilise the Boran breed. The Boran breed is considered an adapted breed and by genetically improving its performance, it's conservation is enhanced and assured. This study has demonstrated that with a well planned and organised breeding programme, genetic improvement is achievable in traits of economic importance, which will improve the production efficiency cattle production systems in the long run.

Economic values were estimated using bio-economic profit functions (models) that were only able to predict feed intake, revenues and costs in different production systems. This model ignored some important interrelationships that exist between genetic, nutritional, management and economic factors. Therefore, further refinement of the model to include all the important relationships is recommended. An integrated function could have an important impact on estimates of economic values under different production and price situations.

Given the different roles cattle play in various production systems, especially under the traditional systems, there is the need to examine the impact of inclusions of intangible roles (i.e. insurance and finance) on the estimates of economic values and on the overall breeding programme. In establishing a breeding and recording scheme, the major emphasis is on it's return on investments needs to be considered. In this study, the effect of genetic improvement on overall profitability of the beef cattle production would be affected by including more interrelationships in the profit functions.

The objectives applied resulted in desirable genetic gains in traits of economic importance in the systems under study. However, as would be expected, breeding objectives differed in their effects on profits and genetic improvement in Boran cattle. These differences are also expected between the different breeding and recording

schemes. There is need therefore, to genetically and economically evaluate different breeding and recording schemes in relation to their implementation in different production systems. The present study did not include disease resistance and adaptation traits in the breeding objective. Further work on the estimation of economic values for such traits and their influence on genetic improvement is needed.

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