DEVELOPING BREEDING GOALS FOR THE KENYA DUAL PURPOSE GOAT

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A thesis submitted to the Graduate School in partial fulfilment of the requirement for the Master of Science Degree in Animal Production (Animal Breeding option) of Egerton University.

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DECLARATION AND APPROVAL

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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: 31/10/2005

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Date: 31/10/05

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DEDICATION

This work is dedicated to

my parents Mr. William Bii and Mrs. Bornice Bii for there never ending support and

my siblings Collins, Hillary, Vicky, Beatrice and Caren for their prayers and encouragement.

ABSTRACT

The Kenya Dual Purpose goat (KDPG) was developed to increase both meat and milk productivity in smallholder production systems. However, an issue that received little attention was the development of sustainable breeding goals for genetic improvement of the breed. The aim of this study was to develop breeding goals for smallholder production systems utilising the KDPG. A deterministic model was developed and applied to evaluate biological and economic variables that characterise different smallholder production systems. Three systems were defined based on agro-ecological zones and management regimes as: smallholder low-potential (SLP), smallholder medium-potential (SMP) and smallholder high-potential (SHP). The models were subsequently used to derive economic values for breeding goal traits under fixed flock-size and fixed feed resource bases of evaluation. The breeding goals traits were classified into production (milk yield, MY, kg; 12-month sale weight, LW, kg; consumable meat percentage, CMP) and functional (doe live weight, DoWT, kg; number of kids weaned, NKW; kidding frequency, KF, %; kidding rate, KR, %; doe weaning rate, DoWR, %; doe survival rate, %, DoSR; post weaning survival rate, PoSR, %; pre weaning survival rate, PrSR, % and residual feed intake of yearlings, RFIy, kg and does RFId, kg) traits. In addition, the influence of these economic values on genetic improvement in breeding goal traits was assessed. The model was able to predict feed intake for all categories of animals and revenues and costs to the systems. The total profit per doe per year was KSh 315.48 in SMP, KSh –1352.75 in SLP and KSh –80.22 in SHP. Under both bases of evaluation, economic values were highest in SMP apart from the economic values for feed intake related traits (RFIy and RFId). The economic values for production traits (LW, MY and CMP) were positive in all the production systems apart from MY in SLP. Apart from the economic values of RFIy and RFId (in all the systems), DoWT (in SLP and SHP) and KF and KR (in SHP), economic values for most functional traits were positive. Among the functional traits, DoSR and PoSR had the highest positive economic values in all the production systems. Economic values for most traits were higher under fixed feed resource than under fixed flock-size scenario. The indices derived using different economic values maintained the direction of genetic change in several traits but the level of genetic gain for each trait was dependent on the index applied. Results suggest that utilisation of the KDPG goat in Kenya is more profitable in the SMP and achieving genetic improvement in both production and functional traits would have a positive effect on the profitability of the systems.

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ABBREVIATIONS

BLUP	Best Linear Unbiased Prediction
DFID	Danish Fund for International Development
GDP	Gross Domestic Product
GOK	Government of Kenya
KDPG	Kenya Dual Purpose goat
KMC	Kenya Meat Commission
MARD	Ministry of Agriculture and Rural Development
MLFD	Ministry of Livestock and Fisheries Development
SEAG	Small East African goat
SR-CRSP	Small Ruminant Collaborative Research-Support Program

CHAPTER ONE
GENERAL INTRODUCTION

1.1 Background information

In Kenya, small ruminants are an important component of the livestock sub-sector. They contribute approximately 30% and 4% of the annual red meat and milk sold in the formal markets, respectively (MARD, 1997). Goats are extremely important in ensuring food security in the country since they are used for both meat and milk production. Most of the meat goats are indigenous apart from the Boer goat breed while the dairy goats are mainly exotic breeds (Erasmus, 2000; Malan, 2000). Indigenous goats have countrywide distribution and the two common breeds include the Small East African goat (SEAG) and the Galla (Skea, 1989; Peacock, 1996). These breeds are more adapted to the local stresses of high ambient temperatures, poor nutrition and high disease challenges than their exotic counterparts (Baker and Rege, 1994; Peacock, 1996). The dairy goat breeds include the Toggenburg, Anglo-Nubian, Saneen and the Alpine (Gichohi, 1998; Muchina, 1998; Theuri, 1998). Dairy goats were first introduced in Kenya in 1950's by the white settlers and were confined to the high potential agricultural areas (Gichohi, 1998). From the settler farms, they gradually spread to the neighbouring areas through the sale of dairy bucks to farmers rearing the indigenous goat breeds.

Generally, goats express important economic aspects such as low capital investment and high reproduction rates that offers quick returns on investment and suitability for emergency sales. They therefore offer opportunity for smallholder farmers to benefit from an activity returning substantial financial income (Peacock, 1998). The declining farm sizes in the low to high potential agricultural areas due to the increasing human population density is encouraging a need for rearing of goats with multifunctionality, flexibility and adaptability to varied environmental conditions (Scarpa et al., 2003). As a consequence, in the 1980's, the Small Ruminant Collaborative Research-Support Program (SR-CRSP) embarked on the formation of a dual-purpose synthetic breed of goat for the smallholder goat farmers. The foundation breeds were the Toggenburg, Anglo-Nubian, Galla and the SEAG. Selection was then applied to the four-way crosses to produce a stable breed with 25% gene proportion from each of the foundation breeds (Ruvuna et al., 1985). This breed is known as the Kenya Dual Purpose goat (KDPG). Utilisation of the KDPG was recommended for smallholder systems, which are practised in areas with varying production potentials (low, medium or high) determined by the agro-ecological zones and management regimes (Mwandotto, 2000).

In order to obtain future breeding stock, multiplication of the genetically improved KDPG requires clearly defined breeding goals. Definition of the breeding goals forms the initial step in the development of genetic improvement programmes (Harris, 1970; Danell, 1980; Ponzoni, 1986 and 1992). Breeding goals comprise of traits a producer wants to improve because of the influence they have on either revenues or costs in the production system. Definition of breeding goals must be done after considering the needs of the target groups if we are to reduce the risk of it being neglected, being unproductive or not performing its intended function. In developing the KDPG, the varying production circumstances in the different smallholder systems were not accounted for. This might have impacted negatively on the overall utilisation of the breed and any further genetic improvement in traits of interest.

In developing breeding goals, both the genetic and economic worth of an individual animal must be combined (Harris et al., 1984; Harris and Newman, 1994). The worth of an individual is normally determined by combining economically important traits each weighted by its economic and breeding value. Economic values are defined as the effect of efficiency on production of a marginal unit increase in genetic merit of the trait, independent of changes in other traits included in the linear breeding goal (Hazel, 1943). Breeding goals also serve in defining traits of interest and important components of the breeding programme with an aim of supporting a production system to develop cost and resource saving production methods. By defining traits of interest economically, animal production will be more efficient. Therefore, development of breeding goals for the KDPG will enhance genetic improvement of traits of interest in the breed. This will result in general improvement in productivity and profitability of the smallholder production systems utilising the breed.

1.2 Objectives

The overall objective of this study was to develop breeding goals for smallholder production systems utilising the KDPG. The specific objectives were:

1. To construct bio-economic profit functions appropriate for the prediction of profitability in smallholder production systems utilising the KDPG.
2. To identify breeding goal traits and estimate their economic values under different production circumstances.
3. To assess the influence of economic values on genetic improvement in breeding goal traits.

1.3 Hypothesis

H_0: The utilisation of the KDPG is equally profitable in smallholder low-, medium and high potential production systems.

H_0: Economic values of breeding goal traits do not change with changes in the production circustances.

H_0: Economic values have no influences on genetic improvement in breeding goal traits.

CHAPTER TWO
LITERATURE REVIEW

2.1 Goat production in Kenya

Developing countries have approximately 95% of the world's goat population, 13% of which are found in Africa (Ademosun, 1994). In Kenya, there are approximately 11.3 million goats predominantly kept under pastoral production systems found in areas with marginal arable agricultural potential (DFID, 2001; MLFD, 2002). However, goats have gained importance in smallholder farming systems and in high potential areas due to increasing human population density and subsequent reduction in land sizes (Peters, 1989). Generally, they contribute greatly to the meat, milk, fibre, pelts and skins used locally (MARD, 2000). The relative importance of each of these products varies from one region to another due to ecological, economic and cultural factors. Table 1 presents the estimated goat populations, meat quantity and monetary value from 1998-2002. The number of animals raised for meat, their estimated off-take and monetary value has fluctuated over the years.

Table 1. Estimated goat populations, meat quantity and monetary value

	1998	1999	2000	2001	2002
Population ('000)	9,269	10,968	10,007	10,780	11,226
Hides and skins ('000)	2,012	2,008	2,107	2,008	2,684
Calculated off-take (%)	22	18	21	18	23
Total meat	29,165	29,102	30,552	43,007	38,918
Value (million KSh)	4,375	4,365	4,583	4,365	5,838

Source: MLFD (2002) Annual Report.

2.1.1 Production systems

The levels of production and cost of maintenance of breeding females determine to a large extent the economic viability of animal production systems (Dickerson, 1970). In Kenya, different feeding, breeding and functions of goats have evolved in response to climatic conditions, needs of the owner, economic and level of technology (Makokha, 2002). These have resulted in the keeping of goats under different production systems. Within each production system, goat keepers have developed their own husbandry methods according to their own particular circumstances (Devendra, 1992). Peeler and Omore (1997) classified these systems based on the level of production and products into small-scale dairy-meat and large-scale meat production systems.

Small-scale dairy-meat production system

The small-scale dairy-meat production systems are integrated crop-livestock farming systems in which small ruminants are a major component of the livestock sub-system. The crop-livestock (agro-pastoral) mixed farmers are found mainly in the medium to high potential agricultural areas and they own small land holdings (Rege, 1994; Peeler and Omore, 1997). Available land for livestock has become limited due to human population growth and therefore agro-pastoral farming systems are increasing at the expense of pastoral production systems (Perry et al., 2002). Agro-pastoralists not only produce meat and milk for their families but also for sale. However, production in these smallholder systems is based on survival and risk aversion strategies rather than increased productivity (Swift et al., 1996).

Large-scale meat production system

This system predominantly occurs in the marginal (medium to low potential) areas where goats are kept in large flocks. Goats are valued based on their ability to survive periods of drought. The breeds kept include the SEAG and the Galla. The system can be sub-divided into extensive nomadic and sedentary pastoral in which goats are raised on natural pastures (Devendra, 1992). The systems are characterised by a marked seasonality in feed supply occurring due to high variable rainfall and therefore availability of pastures affects production performance from year to year (Devendra, 1992). In the sedentary systems, goats are grazed where there is access to common grazing and /or marginal land. Large flocks of goats are often mixed with sheep belonging to several owners that are run and herded together (Devendra, 1992).

For pastoral production systems, small groups belonging to several owners migrate over large areas and disease control is minimal (Amer et al., 1998). In pastoral communities in medium potential areas there is a tendency towards sedentary agro-pastoral systems from purely keeping of livestock (Kosgey et al., 2005). In general, pastoral communities attach high value to the flock size and its survival. They therefore raise almost exclusively indigenous breeds that can cope with the harsh environmental stresses of seasonality in quality and quantity of available feeds, low managerial inputs and high incidences of diseases (Perry et al., 2002). Therefore, survival (e.g., pre-weaning, post-weaning and adult animal) traits and reproductive traits are important under this system (Kosgey et al., 2005).

2.1.2 Marketing structures

Before the liberalisation of meat pricing in 1987, the Kenya government through its Livestock Marketing Division (LMD) controlled marketing of livestock and its products (Government of Kenya - GoK, 1987). Liberalisation led to diversified markets that were closer and with better opportunities for pricing. However, since the collapse of the Kenya Meat Commission (KMC) and disbanding of LMD, unreliable and exploitative intermediaries have dominated the marketing of livestock and its products (GoK, 1987). It is also evident that prices of livestock and its products have become dependent on animal characteristics and market supply conditions. Currently, goats and their products (especially meat) reach the consumers through four marketing channel levels identified by Otieno et al. (1993) (Figure 1). These levels are producers, assemblers, itinerant traders and retailers. The first two levels form the primary markets where production and re-sale are the main purposes, repectively. The remaning two levels are the distributive and terminal markets, repectively, where the main aim is re-sale of products to the consumer. At all the channel levels, the modes of transaction are by one-to-one bargaining. A few commercial organisations that have grading schemes and buy meat at advertised prices exist. However, the majority of meat from small ruminants does not pass through these official channels. Anteneh (1982) suggested that to accommodate small ruminants in slaughterhouses, special lines are required to avoid reluctance of organisations to provide for these livestock when the supply is not assured.

Development of marketing structures for goat milk is at infancy stage. Commercial processing of goat milk has been attempted with little success (Ragwa and Njuguna, 2000). Organisational infrastructure and inadequate milk supply was cited as the key limitation. In marketing of milk from cattle, milk is normally delivered to central co-operative centres from where processors access it in bulk. Such an arrangement does not exist for goat milk and processors are forced to collect milk directly from smallholder farmers located several kilometres apart. This attracts a lot of transaction and transport costs. This is worsened by the fact that most farm households in high potential areas only manage to release an average of 1.5 kg of milk since most of them keep on average 2 to 3 lactating does (Ragwa and Njuguna, 2000). Currently, there is no promotional strategy targeting marketing of goat's milk and meat. A free market supply and demand structure is operational and has a great potential for expansion.

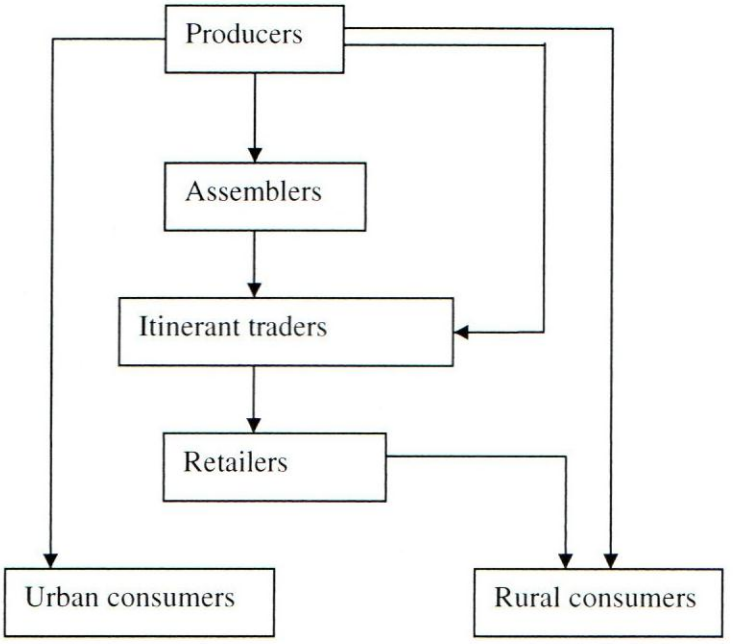


Figure 1. Small ruminant marketing channel levels

2.1.3 Breeding

In Kenya, two approaches have been used to genetically improve goats; the breeding station approach and buck station approach (MARD, 1996). The first approach is the commonest to livestock improvement in developing countries and involves producing males and females for distribution to farmers for rearing or breeding (Peacock et al., 1990). In Kenya, operational breeding stations are public institutions managed by Kenya Agricultural Research Institute (KARI) and Ministry of Livestock and Fisheries Development (MLFD) in various parts of the country. In this arrangement, genetic improvement is generated in breeding station, usually among a small fraction of the population. The breeding stations are responsible for selection, multiplication and distribution of different goat genotypes. Farmers obtain male replacements and breeding female foundation stock from these stations. The approach has been successful in Kenya because production costs are subsidised for farmers buying breeding stock. However, breeding stations have only managed to continuously release genetically superior male replacements whereas supply of superior females has been minimal. This is attributed to small population sizes in these stations due to inadequate funding to effectively run large scale programme. Therefore, long-term commitment in the breeding stations to secure funds on a sustained basis and to critically optimise the little resources that is availableare inevitable. The advantage of such an approach is that it can

allow implementation of more sophisticated breeding programmes (Turner, 1982). In Kenya, however, it is recommended that simple and easy-to-manage genetic improvement programmes be implemented.

The buck station approach on the other hand is probably the quickest and cheapest that simply produces crossbreds. An example of this approach was the Buck Lending Scheme. Unlike in the breeding station approach, genetically superior bucks are either imported (exotic breeds) or acquired from breeding stations or from contracted commercial goat farmers. The males are then distributed to farmers for breeding. However, there is increased risk of diseases and death for the bucks. The approach is advisable in cases where there is a surplus of cheap bucks and high standards of management (Peacock et al., 1990). This approach however failed because the bucks were either too expensive to buy or to manage. Inadequate or lack of sustained funding and lack of a central management scheme were a major limitation to the sustainability of this approach. It is therefore necessary to establish a sustainable central management scheme that will ensure the flow of improved genes into the population and at the same time be responsible for buck rotation and replacements to prevent inbreeding. Similar approach has been useful in dairy and beef cattle populations where dairy and beef bulls are kept at the Central Artificial Insemination Station (CAIS), Kabete. The CAIS is managed by Kenya National Artificial Insemination Services (KNAIS) and its major roles are to contract farmers for replacement males, semen testing and evaluation of bulls (Omore et al., 1999). However, unlike the buck station approach the CAIS utilises artificial insemination (A.I) technology to transfer improved genes into the dairy and beef cattle populations. Nevertheless, the use of A.I technology to genetically improve goat production in Kenya is non existent and need therefore arises for its establishment. Little has been reported on the Buck exchange approach, but the scheme is widely adopted within the East African region as the most practical for goat production, whereby community based dispersed nucleus breeding schemes are being established.

2.1.4 Constraints to production

Goat production in most areas is faced with several constraints. High prevalence of diseases and parasites are a serious constraint to goat production, particularly in the more humid areas. These cause high mortality amongst kids, diminishing benefits of the goats' high reproductive performance. In addition, external parasites weaken animals and thus cause extensive production losses (Semenye and Getz, 1993). Ticks and mites are the most serious external parasites. Haemoparasites transmitted by ticks are quite common. Shompole et al.

(1990) studied the incidence of *Anaplasma* species in goats in Kenya. The prevalence of the infection ranged from 22% to 87%. The high prevalence was attributed to the presence of a variety of possible vectors such as ticks and mites. The irritation and dermatitis that accompany mange infestation was also found to reduce the value of the skins and meat for sale. Internal parasitism also ranks high among the factors that limit the productivity of goats although its effect is often underestimated (Gatongi et al. 1993; Ademosun, 1994). Other diseases that limit the productivity of goats in Kenya include, among others, pneumonia, coccidiosis, contagious caprine pleuropneumonia (CCPP), ecthyma, caseous lymphadenitis and brucellosis (Rurangirwa and McGuire, 1991; Waruiru and Githigia, 1990; Michele, 1993; Semenye and Getz, 1993). The prevalence of these diseases has been difficult to quantify due to the lack of precise statistical records. Individually, however, these diseases might not constitute serious problems but combinations of them or their occurrence under marginal conditions could result in serious losses (Ademosun, 1994).

Inadequate feeding is another major limiting factor to goat production in Kenya. Forage quantity and quality is inadequate for most of the year due to the seasonal variations in rainfall. In addition, the browse species that can provide higher levels of energy and proteins are often sparsely dispersed in arid and semi- arid areas (Semenye and Getz, 1993). Land tenure system is also a limiting factor especially in pastoral production systems. In this system, pastures are usually communally owned and formal knowledge about pasture productivity is scarce (Gall and Huhn, 1980; Devendra, 1992). In addititon, there are no laws to limit usage or to prevent overgrazing.

Implementation of the simplest measures of selective breeding in goat production is nearly impossible (Gall and Huhn, 1980). Usually all females are mated indiscriminately leading to premature first conception or to inbreeding (Gall and Huhn, 1980; Nimbkar, 2000). The young sires are all too often carelessly selected and may even represent a negative selection because the better males are sold for slaughter (Gall and Huhn, 1980; Nimbkar, 2000). The possible extent of the damage caused by inbreeding is largely unresearched. These inadequacies give rise to the necessity to thoroughly analyse the real genetic potential of the local goat breeds that may be concealed by poor breeding practices (Gall and Huhn, 1980).

As already indicated in section 2.1.3, breeding stations in public institutions are responsible for supplying genetically improved male replacements and female foundation stock to farmers. However, the demand for replacement animals is higher than the supply. This has contributed negatively to genetic improvement in goats as farmers resort to using

own bred males or from neighbours, which are sometimes used longer than expected resulting in inbreeding. Besides that, there is a risk of disease transmission through natural mating. Genetic lag in flocks owned by farmers is most likely because the bucks are neither tested for superiority nor genetically or economically evaluated for important traits. It also clear that the breeding stations are only able to supply averagely performing males (and no females) for use in the commercial or farmers flocks. This has a negative impact in breeding because it will generate a genetic lag of two generations (about 7 years in goats) of selection response (Bichard, 1971).

In Kenya, artificial insemination is non-existence in goats. Use of AI technology can be an effective way of reducing the demand for male replacements and improving farmers' flocks. Technologies such as embryo transfer have been used in both exotic and local goat breeds (Mutiga, 1990; Mutiga and Baker, 1984). The technique made possible production of purebred Toggenburg kids by local goats but is currently non operational, possibly due to financial constraints. There is a need to carry out cost benefit analysis for using these technologies in goats breeding improvement.

2.2 Performance of goats in the tropics

Improvement in performance level of goats is essential for increased production efficiency and competitiveness with other species (Peters, 1989). In the tropics, the indigenous breeds are more adapted to the local stresses of high ambient temperatures, poor nutrition and high disease challenges than their exotic counterparts (Baker and Rege, 1994; Peacock, 1996). The performance of exotic and local goats kept under different production circumstances is variable. Table 2 presents the levels of performance of different goat breeds in the tropics. The performance is described by reproductive and survival (functional traits) and productive traits.

A comparison of the four-way cross with the purebred Toggenburg and Anglo-Nubian shows that it is more prolific with an average prolificacy (PR) of 1.7. The Galla and the West African Dwarf goats are superior to the four-way crosses in kidding rate (KR) (Table 2). Among the desert and tropical breeds, the Black Bedouin has the highest kidding rate while the Creole has higher PR (Odenya et al., 1984; Kimmes, 1992). This is because the more prolific small breeds have a relatively short kidding interval (KI) (Odenya et el., 1984; Okeyo et al., 1985). Similarly, the Boer goats in Kenya have a lower KR than in the country of origin (Angwenyi, 1984; Erasmus, 2000). On the other hand, PR estimates for the Creole goats reported by Kimmes et al. (1992) in Reunion Islands was higher than those in West

Indies (Alexandre et al., 2000). This implies that the average estimates for reproductive traits are highly dependant on the environment in which the breed is raised as conducted in a number of studies (Angwenyi, 1984; Odenya et al., 1984; Kimmes, 1992; Alexandre et al., 2000; Erasmus, 2000).

Table 2. Reproductive, survival and productive performance of different goat breeds in tropics

Genotype	Trait[a]								Country	Source
	KR (%)	PR	KS (%)	BW (kg)	WW (kg)	YW (kg)	MW (kg)	MY (kg/day)		
Alpine crosses		1.6		3.2	12.7			0.8	Kenya	Skea et al. (1990)
French Alpine	79	1.5	88	2.1	8.1			0.8	Egypt	Marzouk et al. (2000)
Balady	87	1.7	71	1.7	7.4			0.6	"	"
Angora				3.5	11.3				Kenya	Odenya et al. (1983)
Black Bedouin	92			2.2	7.8	15.3	25	0.3	Kenya	Odenya et al. (1984)
Boer	70		70	2.8	12.2	20.7	75		Kenya	Angwenyi (1984)
"	90	1.8	89		14.7	26.9		2.6	South Africa	Erasmus (2000)
Creole		2.3			10.2	20			Reunion Island	Kimmes (1992)
"	90	2.1	84	1.8	8.2				West indies	Alexandre et al. (2000)
Creole x Boer		1.8			12.8	27			Reunion island	Kimmes (1992)
Galla (G)	89	1.1	85	2.9	12.7	20.7	70	0.5	Kenya	Okeyo et al. (1985)
Small East African Goat (SEAG)	79	1.3	96	2.3	10.5	17.8	35	0.1	Kenya	Angwenyi (1984)
West African Dwarf	88		80	1.4	5.4				Guinea	Mourad et al. (2000)
G x SEAG			89	2.7	10.5	19.4			Kenya	Angwenyi (1984)
Toggenburg (T)		1.4		2.1	7.7		70	2.0	Kenya	Ahuya (1987)
Anglo-Nubian (N)		1.6					70	0.9	Kenya	Mwandotto et al. (1990)
T x SEAG				2.4	9.9	20.4		0.5	Kenya	Ahuya (1987)
T x G				2.9	10.6	18.5		0.5	Kenya	"
N x SEAG				2.3	7.5				Kenya	"
N x G				2.8	8.7				Kenya	Mwandotto et al. (1992)
4- Way crosses (N x G x T x SEAG)	82	1.7	85	3.3	10.7	18.6	70	1.1	Kenya	"
KDPG								1.3	Kenya	"

[a]KR, Kidding rate; PR, prolificacy; KS, kid survival; BW, birth weight; WW, weaning weight; YW, yearling weight; MW, mature weight; MY, milk yield.

In Table 2, it is also observed that the productive performance for the two-way crosses between the KDPG foundation breeds was lower than those of the four-way crosses.

The former had lower birth weights (BW), weaning weights (WW) and yearling weights (YW) than their four-way counterparts. The overall mean live weights at birth ranged from 1.4 to 3.5kg for all the breeds. Usually, meat breeds (SEAG) have a mature weight (MW) of about 35kg at 18 months of age (Angwenyi, 1984). This is in contrast to the large breeds like Galla, which weigh 58 to 70 kg (Odenya et al., 1984; Okeyo et al., 1985). Results also tend to support the potential milking ability of offspring derived from crosses of exotic and indigenous breeds (Ahuya, 1987; Mwandotto et al., 1990 and 1992). The KDPG and the four-way crosses have relatively higher milk yields (MY) than the indigenous breeds, but lower than their exotic counterparts.

The survival trait describes the flock's life and longevity of animals. It measures how well an animal suits the environment and is described by mortality rates at different periods. When compared to the indigenous breeds, exotic breeds and their crosses are not as well adapted to low management conditions prevailing in the tropics. Kid survival has been reported to be very high (96%) among the indigenous breeds and their crosses (Angwenyi, 1984; Okeyo et al., 1985).

2.3 Creation of the Kenya Dual Purpose goat

Following the realisation of the need by smallholder farmers, a dual-purpose goat (DPG) was created using baseline survey results from smallholder farms in western Kenya (Ruvuna et al., 1985). Four key criteria for an acceptable and sustainable goat breed were identified (Cartwright, 1984; Ruvuna et al., 1985): (i) if the forage resource was developed to its potential, it would be adequate to support the nutritional requirements of a DPG; (ii) on-farm and on-station studies indicated that indigenous goats had low genetic potential for growth and milk yield to be an acceptable base for developing a suitable DPG; (iii) from experience and research data, the exotic dairy breeds were not viable under the nutritional and management conditions of the smallholder farmer and (iv) although early research demonstrated that the F_1 from the indigenous and exotic genotypes performed satisfactorily (Table 2), a structured crossbreeding programme to continuously produce F_1's was not feasible for smallholder farmers. These criteria indicated that a practical breeding programme must include environmental adaptability and synchronise goats' potential for production with available feed supply and prevailing production conditions.

Therefore, a breeding programme was designed to produce the KDPG, a low maintenance, hardy, meat and milk producing goat breed, which could easily adapt to other local production environments. The strategies adopted in the development of the KDPG were

to retain indigenous breed adaptability and to increase milk by use of appropriate mating plans to incorporate exotic dairy stock (Ruvuna et al., 1985). Four breeds were subsequently inter-mated to gain and retain the advantage of hybrid vigour as well as combine the complementary traits of dairy breeds with fitness of native stock. Such synthetics have proved especially valuable as a means of incorporating improved productivity with fitness. Examples of synthetic goat breeds include the Boer goat (a cross of Milch goat and the local South African goats) (Erasmus, 2000; Malan, 2000) and the Anglo-Nubian (a cross of Egyptian Zairiby, Indian Jamnapuri and the local British goat) (Peacock, 1996).

The KDPG is a synthetic breed developed from four foundation breeds namely the Toggenburg, Anglo-Nubian, Galla and SEAG. Synthetic populations are established by crossing several breeds to end up with certain gene proportions in the final stabilised breed. The synthetic populations are important when the maintenance of rotational crossing systems is restricted by small management units and wide fluctuations between generations in additive genetic composition (Syrstad 1996; Kahi, 2000). This severely limits the achievement of optimum contributions by different breeds and therefore is difficult to synchronise climatic adaptability and performance appropriately. Although synthetic populations show maximum recombination loss, they are a useful alternative to rotational crossing for retaining direct and maternal heterosis and have increased genetic variation and greater selection intensity as a result of a higher reproductive rate due to heterosis (Dickerson, 1973). After stabilisation, synthetic breeds are managed as purebred populations.

The development of synthetic breeds has both intermediate- and long-term implications and consequently requires the projection of medium- and long-term input costs and output values (Trail and Gregory, 1981). The procedure can follow four general steps, basically considering the natural environment, management levels, economic feasibility and the relative importance of milk and meat as production goals (Kahi, 2000). The general steps involved are:

Step 1: Choice of foundation breeds

This involves decision on the number and foundation breeds based on performance under environmental conditions similar to those in which the synthetic breed will be maintained. The breeds to be chosen should have complementary effects (breeding value) for the traits of interest to produce the desired genotype. Within the four foundation breeds of the KDPG, the Toggenburg and Anglo-Nubian are both able to adapt to tropical climates, and are

successful in breed improvement in these areas (Peacock, 1996). The Galla and SEAG are native to Kenya and hence are adapted to the prevailing stresses.

Step 2: The contribution of each breed

The percentage of each breed chosen to obtain the genotype is decided on. The contribution of the breeds concerned is determined by the degree of environmental modification. Equality in the contribution of the foundation breeds is essential to retain high percentage of heterozygosity, while at the same time achieving optimum additive genetic composition. According to Dickerson (1973), retention of initial (F_1) heterozygosity after crossing and subsequent random (*inter se)* mating within the crosses is proportional to (n-1)/n where n is the number of breeds involved in the initial cross. This loss of heterozygosity occurs between F_1 and F_2 generations. If inbreeding is avoided, further loss of heterozygosity in an *inter se* mated composite population does not occur. This expression [i.e., (n-1)/n)] assumes equal contribution of each breed in the foundation breeds. Where the breeds used in the foundation composite breed do not contribute equally, the percentage of mean F_1 heterozygosity retained is proportional to $1-\sum_{i}^{n} P_i^2$ where P_i is the fraction of each of n contributing breeds to the foundation of a composite breed (Gregory et al., 1992). For example, heterozygosity retained in a four-breed composite formed from 3/8 breed A, 3/8 breed B, 1/8 breed C and 1/8 breed D can be computed as $1- [(3/8)^2 + (3/8)^2 + (1/8)^2 + (1/8)^2] = 68.8\%$. The maximum number of breeds that can be used to contribute to achieving an optimum additive genetic (breed) composition is preferred because retention of heterozygosity is a function of the number of breeds contributing to the foundation. However, use of a greater number of contributing breeds should be balanced against the potential loss in average genetic merit of including the additional breeds (Gregory et al., 1992). In the development of KDPG, each foundation breed contributed 25% of its genes. Therefore, the proportion of mean F_1 heterozygosity maintained was 75% (i.e., $1-[(0.25)^2 + (0.25)^2 + (0.25)^2 + (0.25)^2]$).

Step 3: Mating scheme

An efficient mating scheme is important since this determines the time it will take to reach the desired gene proportion of each breed in the shortest time possible. Figure 2 shows the mating design used in the development of the KDPG. The four types of F_1 crossbreds were produced following mating of the Toggenburg and Anglo-Nubian sires with Galla and

SEAG dams. The resulting crossbreds were mated *inter se* to produce the four-way F_2 generation. These four-way crosses were mated to produce large numbers of this synthetic breed.

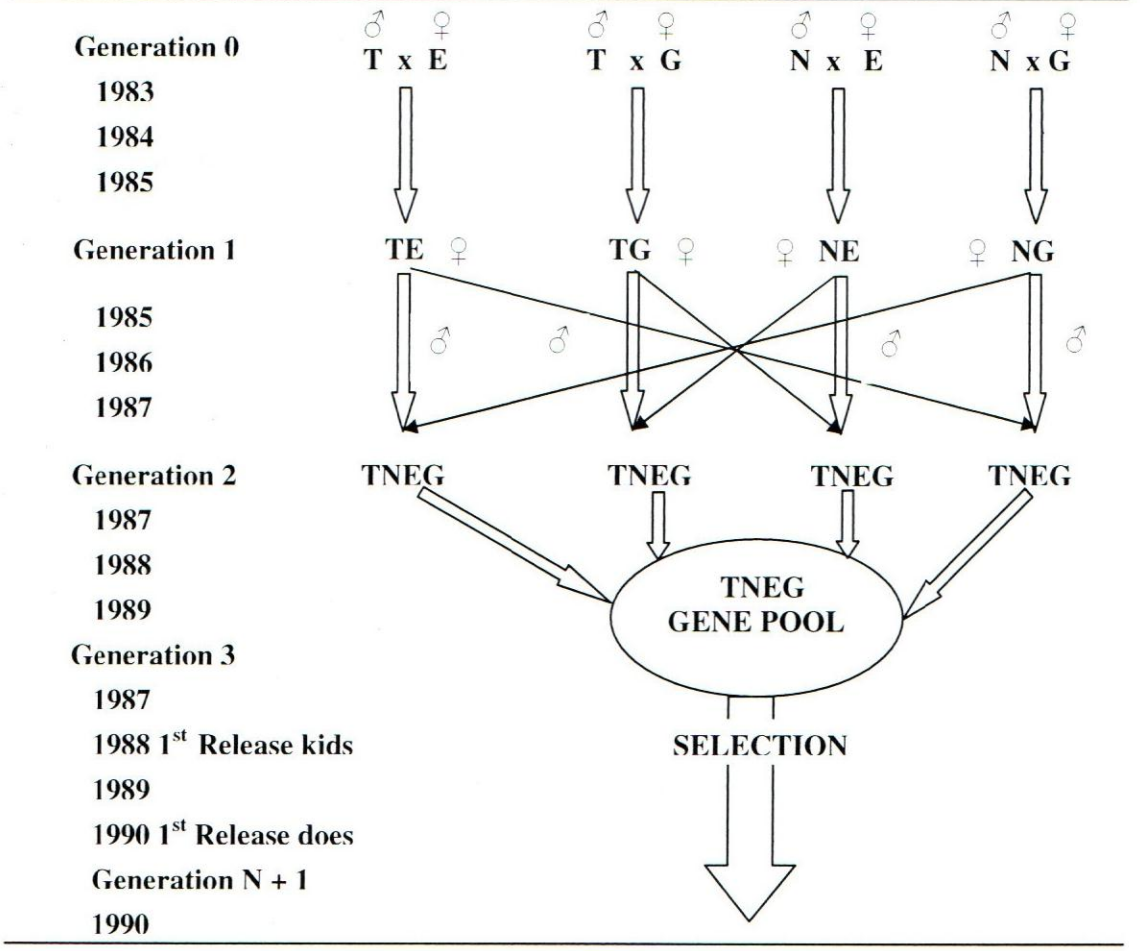


Figure 2. Mating design used to establish the KDPG (T =Toggenburg; N =Anglo-Nubian; G =Galla; E= SEAG) (Adapted from Cartwright, 1984).

Step 4: Record keeping

Recording of traits of interest is important. Such information is used for evaluation of performance and estimation of genetic and phenotypic parameters used in genetic evaluation to guide future selection decisions. For the KDPG, records on performance are available at the nucleus station (Ol' Magogo Farm, Naivasha) (Muhuyi and Siamba, 2000). This includes information on milk production, reproductive and growth traits.

When applying records of traits of interest, they must be adjusted for environmental sources of variation so that differences between records reflect genetic differences more accurately (Wiggans, 1982). Other environmental influences are removed by expressing trait

values as deviations from contemporary groups (Wiggans, 1982). Such deviated records can be the basis for selection. It is however important to incorporate economic importance of traits when making selection decisions in any breeding programme. This can only be possible if efficient breeding goals are developed that take into account both the biological and economic importance of traits within production systems of interest.

2.4 Development of breeding goals

The aim of animal breeding is to change the genetic merit of animals in the next generations such that they will produce the desired products more efficiently (relative to the present generation) under future farm economic, natural and social circumstances (Groen et al., 1997). Animal breeding achieves this systematically in three major steps (Harris et al., 1984; Groen et al., 1997). Firstly, is the definition of the breeding goal: this involves setting up the aggregate genotype and deriving cumulative discounted expressions and economic values. Secondly, is the breeding value estimation: deciding on what traits to be included in the information index, derivation of regression coefficients to be used in the information index, estimation of information index value, i.e., the estimated breeding value for each trait and for each potential breeding animal. Thirdly, is the breeding programme optimisation: optimising the organisation to routinely gather information on potential breeding animals and/or their relatives, and select and mate breeding animals to produce the next generation.

A systematic selection programme relies upon definition of an appropriate breeding goal (Fewson, 1993a; James, 1993). A false definition of breeding goal has disadvantageous consequences for animal production and in extreme cases, there will be no benefit from breeding at all. Often, a badly chosen goal may lead to sub-optimal genetic progress and in the worst case, may even lead to economic deterioration of the population and undermine the effectiveness of efforts put into other phases of the breeding programme (James, 1992; Ponzoni, 1986). The breeding goal can be defined as a statement of economic worth of an animal from genetics perspective (Harris et al., 1984; Harris and Newman, 1994). In general, it is a combination of economically important traits each weighted by its economic value and breeding value. The development of breeding goals involves four phases (i) specification of breeding, production and marketing system, (ii) identification of sources of revenues and costs, (iii) determination of biological traits influencing revenues and costs and (iv) derivation of economic value of each trait (Ponzoni, 1986). The detailed descriptions of these phases are presented in the following sub-sections.

2.4.1 Specification of breeding, production and marketing system

Breeding system

Specifying the breeding or mating system involves defining the role of the breed in the production system for which the breeding goal is being developed (Harris et al., 1984; Ponzoni and Newman, 1989; Barwick, 1992; Barwick and Fuchs, 1992). This also involves determining whether the animals are to be utilised as purebred or as crossbred. In the production system, these roles influence the fraction of genes present in various segments of it. The function of the animals could be single or dual purpose, corresponding to the needs of the livestock producer. Within each of these functions, animals could serve a general purpose role, as a maternal or terminal sire line. The reproductive performance, for example, is much less important in sire lines than in dam lines whereas growth and carcass traits (production traits) are important in sire lines. In crossbreeding, the terminal sire lines are used to produce animals for slaughter. For the KDPG, it seems appropriate to assume a general-purpose role when defining the breeding goal.

Production and marketing system

Details on the description of production and marketing systems can be found in Harris et al. (1984). In describing the prevailing production and marketing systems, the level of inputs and value of outputs should be quantified. Market situation requirements have major impacts on breeding goals (Annor, 1996). Goat breeders must therefore respond directly to both current and predicted market movements. This makes it necessary to consider the environment and marketing situations prevailing in the target areas of the breeding programme.

The description should include the specification of the life cycles of the different classes of animals which include determining the ages of breeding, feeding and management regime, replacement policy and average age and weight for the different categories sold for slaughter (Ponzoni and Newman, 1989; Ponzoni and Gifford, 1990; Urioste et al., 1998). The nature of feed, labour, land, equipments and buildings, and the corresponding cost in various stages all are necessary to describe the system fully.

2.4.2 Identification of sources of revenue and costs

Total costs can either be variable or fixed. Variable costs include expenses on feed, husbandry and marketing, which vary with the level of production of the flock. Fixed costs

represent the expenses that do not vary with the level of production such as rates, interest and living costs (Ponzoni and Newman, 1989). Sources of revenue include surplus offspring, milk and cull-for-age does. Others sources of revenues include manure and intangible returns (financing, insurance and risk aversion) (Kosgey et al., 2004). The implications of these additional roles of livestock on biological productivity are often disregarded in favour of technical facets such as nutrition and reproduction probably due to the difficulty of measuring and valuing them (Bosman et al., 1997).

The identification of revenues and costs in the flocks enables the development of a profit equation, where profit (P) is a function of revenues (R) and costs (C)

$$P = R - C \quad (1)$$

For simplicity, different classes of goats (i.e., offspring and parents) should be distinguished. Within each class, products that lead to R and activities that result in C should be identified. For example, for goats and following the approach of Ponzoni and Gifford (1990), the revenues could be estimated as:

R = milk yield x price per kg + surplus offspring x price per individual + cull-for-age does x price per individual.

and costs as:

C = offspring (birth to yearling age) feed intake x feed cost per kg + breeding does feed intake x feed cost per kg + offspring husbandry costs + breeding does husbandry costs + milk yield x cost of marketing per kg + surplus offspring x cost of marketing per individual + cull-for-age does x cost of marketing per individual + fixed costs.

Alternatively, R and C could be a ratio expressed as:

$$E = R/C \quad (2)$$

or

$$Q = C/R \quad (3)$$

where E is the economic efficiency (Harris, 1970) and Q is the cost per unit product (Dickerson, 1970).

All traits that perceptibly contribute to P and E should be considered for inclusion in the breeding goal regardless of their heritability and/or measurement problems (Annor, 1996). The implication of combining R and C in different ways has been examined (e.g., Smith et al., 1986; Ponzoni, 1988). When R and C are combined as a difference, fixed costs do not affect the economic value of the traits in the breeding goal, whereas they do when combined as a ratio. However, if economic profit is set to zero, the same economic values are obtained whether revenues and costs are expressed as a difference or as a ratio. Ponzoni

(1992) gave an example with the Pelibuey sheep in which fixed costs were ignored because R and C were combined as a difference. Terms not involving the traits in the breeding goal vanish when obtaining the partial derivative of P with respect to each trait. This would be difficult in developing goat sectors, particularly if goats are integrated with other farming activities or share some of the facilities with other species (e.g., sheep) (Kosgey et al., 2003). Thus the advantage of using efficiency, or its reciprocal value, where the fixed costs are included and economic efficiency depends more on minimizing the average total costs than reducing the marginal costs which are variable (Pirchner, 1993).

In developing livestock industries, the production systems are not stabilised and clearly defined. This makes the explicit estimation of the cost of feeding very difficult. Given the difficulties one is likely to encounter when trying to explicitly cost feed, the resorted assumption is that the total amount of feed available is constant (Ponzoni, 1992). Controversy arises on how to account for changes expected in feed intake. Often, feed costs are ignored in the breeding goal as it is difficult to measure. Land, labour and capital associated with feed are difficult to apportion to any segment of the flock (Upton et al., 1988). Nevertheless, feed costs, whether prepared feed or range forage, should not be ignored from the breeding goal because they are often the largest of all costs (Barwick, 1992; Harris and Newman, 1994). Ideally, feed intake should be included as a trait in the breeding goal, but a shortage of genetic parameter estimates and reliability of available estimates for this trait often prevent this approach (Barwick, 1992).

Several authors have highlighted the effect of removal of feed intake from the breeding goal. For instance, when feed intake is ignored in the breeding goal for beef cattle, selection response is shifted to growth related characters with a consequence of increasing feed intake at the expense of reproduction traits (Ponzoni and Newman, 1989; Newman et al., 1992). In these studies, the correlation between goals ignoring and between those not ignoring feed costs was 0.66 and 0.69, respectively. In Cashmere goats, when feed intake was set to zero, selection response shifted from down-weight towards reproduction and live-weight with a consequent increase in feed intake (Ponzoni and Gifford, 1990). The correlation among indices ignoring feed costs and ignoring all costs in this study resulted in efficiency losses of, respectively, 3% and 4% relative to the base index. Considering the loss of predictive value between the two goals (ignoring versus not ignoring feed costs) in the breeding goal for beef cattle and Cashmere goats, there is a great justification for including feed intake as a major input of the production system in the description of breeding goals.

2.4.3 Determination of biological traits influencing revenues and costs

Mostly, emphasis is put on productive and growth traits rather than reproduction and survival. However, the latter two traits are important in the tropics (Kiwuwa, 1992). Normally, more emphasis is put on traits that have considerable effects on profitability. However, some of these important traits are neglected. A trait like feed intake is difficult to quantify and is therefore usually ignored. However, ignoring this trait could consequently increase the effects of other traits in the breeding goal. Largely, biological traits that are regarded as important differ depending on expectations of the industry. For example, a trait like fat-depth in beef cattle has low economic value in the tropics because tropical markets consider beef quantity rather than quality (Urioste et al., 1998).

2.4.4 Derivation of economic values of traits in the breeding goal

In bio-economic modelling, a profit function including all biological traits influencing revenues and costs is required. Different methods are available for the computation of economic values. These include: partial budgeting (Dekkers, 1991), partial differentiation (Melton et al., 1979; Brascamp et al., 1985; Ponzoni, 1986; Smith et al., 1986; Beckman and van Arendonk, 1993; Visscher et al., 1994) and regression (Schroeder et al., 1992) methods. Partial budgeting involves accounting for unit changes in returns (marginal returns) and costs (marginal costs) arising from the improvement of a trait. The profitability is compared before and after genetic improvement. In partial differentiation, the partial derivative of profit (or efficiency) with respect to the trait of interest is obtained. The partial derivative approach is similar to the partial budgeting approach, but the former is preferred for its simplicity and generality (Dekkers, 1991). However, it can only be used when the relationship between animal traits and efficiency of production can be described by a single profit equation. This makes the latter a more efficient method of deriving economic values especially in production systems with complex relationships among and between animal traits and production factors, which cannot be described by a single equation. In this case, a bio-economic model is needed (Tess et al., 1983).

The other approach, regression method, is based on an analysis of performance testing or data collection (Fewson, 1993b). An appropriate economic target parameter is chosen (dependent variable, e.g., net output) which includes all input and output components. The objective traits being investigated are considered as independent variables. A multiple regression analysis enables estimation of the marginal value of each trait. However, such an analysis can sometimes be very complex especially where breeding values for the different

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traits are highly correlated, making interpretation of the results very difficult (Amer, 1994). When deriving relative economic values using this approach, knowledge of the expected market trends is desirable because current prices and costs are used and inconsistent over time. Prediction of future prices and costs is essential in this process, given that the current selection will produce benefits in the future.

Production efficiency in any system is a function of costs and revenues. Costs are the total value of production factors required for production, and revenues are the total value of products resulting from production within a system. The physical amounts of each and their values per unit constitute the inputs and outputs. The way of defining inputs and outputs differentiates between biological and economic efficiency. That is, in biological definition, costs and returns are expressed in energy and /or protein terms while it is performed in monetary terms in the case of economic definition (Groen and Ruyter, 1990). The biological approach has the advantage of being independent of changes in the production requirements or conditions as well as of changes in prices and costs (Fewson, 1993a). However, the economic definition is important because not all costs and revenues are expressed in energy and/or protein terms. Hazel (1943) defined economic values as the effect of efficiency on production of a marginal unit increase in genetic merit of the trait, independent of changes in other traits included in the linear breeding goal. The efficiency of production is considered to be economic efficiency. In many circumstances profit maximisation is the goal, but in tropical agriculture especially in smallholder systems, minimisation of costs is important due to limitations in inputs (Kahi, 2000).

The goal of animal breeding is to increase economic efficiency of livestock production through selection (Dekkers, 1991). Efficiency of production can be affected by a large number of animal traits, which may be combined into a linear breeding goal for selection purposes (Hazel, 1943). The potential increase in efficiency of production through selection is determined in part by the relative emphasis put on the traits in the linear breeding goal (Smith, 1983). Relative weights that lead to maximum change in efficiency are quantified by a trait economic value (Dekkers, 1991). In case of different expressions of traits, economic values should be adjusted for the time and frequency of the future expression of a superior genotype originating from the use of a selected individual in a breeding programme by multiplying the economic value by the cumulative discounted expression (McClintock and Cunningham, 1974) or diffusion coefficient (McArthur and Gonzalez, 1990), consequently giving the discounted economic value. In terms of the selection index theory, knowledge of the (co)variance structure of the breeding goal and selection criteria

traits are required in order to calculate the optimal weighting in the selection criterion (Hazel, 1943).

2.5 Genetic and phenotypic parameters

Genetic and phenotypic parameters are essential in the design and implementation of genetic improvement programmes. These parameters need to be estimated before weighting factors for the selection index can be calculated. These estimates also enable the prediction of response to selection for the objective and index traits within the production system (Annor, 1996). Parameters for productive, reproductive and adaptive traits have been estimated for goats in the tropics. However, estimates for specific goat breeds, environment and for several important traits are scarce. Table 3 shows the estimates of genetic and phenotypic parameters for growth and reproductive traits for goats.

Heritability is the proportion of phenotypic variance that is due to heredity. The estimated heritabilities for the traits varied across the populations, the breeds and the environment where the data was obtained. Heritability estimates are partitioned into maternal and direct heritability attributed to maternal and individual animal genetic effects (Koots et al., 1994a). As shown in Table 3, maternal heritability estimates are higher than direct heritability since maternal genetic variance is larger than the direct genetic variance. This could be due to high influence of the dam on the performance of its progeny. Reproduction traits (KR, conception rate, KI and age at first kidding) have lower heritabilities than production traits (MY, BW, WW and YW). This is because female reproductive traits are highly influenced by the environment whereas high heritability estimates for productive traits are due to the high genetic variances attributed to these traits (Koots et al., 1994a). These imply that the reproduction traits can be improved more through manipulation of the production environment than selection. For most production traits, selection plays a major role in their improvement.

Table 3. Estimates of genetic parameters for production and reproduction traits for goats.

Population	Trait 1[a]	Trait 2[a]	Model[b]	Parameter estimates[c]				Country	Sources
				h_d^2	h_m^2	r_p	r_g		
Feral	GR	18WW	AM			0.28	0.79	Australia	Restall (1984)
Cashmere	LW		AM	0.26				Australia	Gifford et al. 1990)
	CR		"	0.16				Australia	Saithanoo et al. (1990)
	KR		"	0.21				"	"
	TR		"	0.51				"	"
Creole	BW		AMM	0.25	0.43			West Indies	Mandonnet et al. (1998)
	WW		"	0.12	0.31			"	"
	BW	WW	AM			0.39	0.51	"	"
	FEC	LW	AMM	0.26	0.52		-0.25	"	"
Hill	BW		AM	0.53				Nepal	Neopane et al. (1998)
	WW		"	0.35				"	"
	BW	WW	"			0.43	0.58	"	"
Boer	BW		AM	0.35				Namibia	Els (1998)
	WW		"	0.60				"	"
	YW		"	0.36				"	"
Saneen	MY		AM	0.09				Brazil	Ribeiro et al. (2000)
	LL		"	0.06				"	"
	AFK		AM	0.14				"	"
	KI		"	0.19				"	"
	MY		AM	0.38				"	Queiroz et al. (2000)
Sirohi	MY		AM	0.48				India	Khan et al. (2000)

[a]GR, growth rate; LW, live weight; CR, conception rate; KR, kidding rate; TR, twinning rate; BW, birth weight; WW, weaning weight; YW, yearling weight. 18MWW, 18 month weaning weight; FEC, faecal egg count.
[b]AM, animal model; AMM, maternal animal model.
[c]h_d^2, direct heritability; h_m^2, maternal heritability; r_p, phenotypic correlation; r_g, genetic correlation.

The estimates of correlations are essential in genetic improvement programme and are partitioned into phenotypic, genetic and environmental correlations (Koots et al., 1994b). They define the extent to which one trait will change if a correlated trait changes. Correlations can also be positive or negative implying positive and negative relationship, respectively. For instance, a positive correlation for BW and WW means that selection for high BW will result in increased WW. High and positive genetic correlation between growth rate (GR) and 18 month weaning weight (18WW) (0.79) indicates that selection for increased GR will result in animals with heavier 18WW. Negative genetic correlation between faecal egg count (FCE) and live weight (LW) imply that selection for FEC may lead to a decrease in LW. The estimates of correlations between production and reproduction traits in goats are scarce and there is the need therefore to design effective experiments for their estimation.

2.6 Response to selection

Selection response is the mean phenotypic value between the selected parents and that of the complete parental generation before selection. It is a measure of rate of genetic change resulting from selection. 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). Response to selection can be useful when predicting the effects of choosing different combinations of animals in an existing population of animals. However, interest is not on a particular group of existing animals but in predicting response to selection in future generations or in the consequences of different designs of animal breeding programmes (Gibson and Dekkers, 2003). To predict the genetic superiority of the selected parents, information in a selection programme i.e., fraction or a number of males and females that are selected and the criterion on which they are selected is a prerequisite.

2.6.1 Selection criteria

In section 2.4, breeding goal was defined as a statement of traits that affect the profit of a producer. However, certain traits in the goal are sometimes expensive to measure or not measurable, poorly inherited or may not show until selection decisions are made. In such a case, secondary indicator traits are required to aid in selection decisions. The indicator traits are generally referred to selection criteria. The selection criteria are measurable characters that enable prediction of breeding values for traits targeted for improvement (Annor, 1996). However, selection criteria should be adjusted for identified environmental variations (non-genetic effects), such as those for age-of-dam, date of birth or age and sex effects, thereby making selection more accurate (Harris et al., 1984). Selection accuracy can be optimised by increasing the information sources as well as including more characters in the criteria (Pirchner, 1983).

In small ruminant production, different criteria have been applied when selecting for growth and reproduction traits (Ponzoni, 1986; Ponzoni and Gifford, 1990). For example, live weight at 12-months for instance can be evaluated using BW and WW as criteria for selection while age at first kidding (AFK), KI and KR can reflect reproductive performance. Survival traits could be taken as indicators for disease resistance and can be evaluated using mortality rates and tolerance to disease and parasite. However, relating survival traits to disease resistance explicitly assumes that all deaths are as a result of diseases that we can breed

against. The traits that are used as selection criteria should be weighted and included in an equation known as the selection index (Hazel, 1943). The weights should be chosen to maximise the correlation between the index and the breeding goal.

2.6.2 Selection index theory

The selection index method involves separate determination of the value of each of the traits to be selected for. Weighted combinations of these values are added to give a total score for all traits (Dickerson, 1970). In general, selection indexes can be derived as (Hazel, 1943);

$$b = P^{-1}Ga \qquad (4)$$

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-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 work of the selection indexes can be divided into two parts (Melton and Colette, 1993). The $P^{-1}G$ part is handled by genetic prediction of breeding values, which deals with parameter estimation and utilisation of phenotypic information on relatives to predict the genetic value of animals for multiple traits. The "a" component, determining the relative economic weightings, is handled through the definition and parameterisation of the breeding goal. This describes the bio-economic relationships between traits and the net output (in monetary value) of the production system.

Selection index weights can be computed for each trait as a function of genetic and phenotypic parameters and economic values of traits (Smith, 1983). The availability of precise estimates of these parameters and economic values of many traits in a given population and selection measurements may be limiting factors in practical implementations. When selecting genotypes, it is thus desirable to use indices based on several traits weighted by their economic values (Smith, 1983). In this way, selection can be performed considering the main components of the productive process and its contribution to the expected value of net economic returns.

2.6.3 Best linear unbiased prediction

Best Linear Unbiased Prediction (BLUP) is a procedure that is used to calculate genetic indexes. It is a prediction 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). This statistical tool is used to give estimated breeding values (EBVs) for traits that help in selecting animals with higher genetic merit for the traits of interest. It has the same capabilities as the selection index, plus a lot more. Unlike the selection index which uses information from defined sources (individual records), BLUP optimally uses all the available records on the individual and its relatives while simultaneously adjusting for environmental effects (e.g., herd-year-season), such that the EBV is maximised. However, the selection index theory still remains a useful tool for approximating the accuracy of BLUP selection and predicting selection response. The methodology requires variances of traits for single trait evaluation and variance/covariance matrixes for multiple traits (Gibson and Dekkers, 2003).

2.7 Breeding strategies and structures

2.7.1 Breeding strategies

Breeding strategies can be defined as tactics designed to integrate new technologies and to improve the old ones, for the purposes of maximising performance of existing stock (Gibson and Dekkers, 2003). Breeding strategies for small ruminants should be aimed at improvement of productivity without loss in adaptation to the environment. Small ruminant breeds for harsh environments must be able to survive prolonged droughts, walk and cover long distances and utilise course forages for growth, reproduction and lactation (Mucuthi and Munei., 1996). The contrasting management practices, environment and social-cultural attributes within household, region and country demonstrate the complexity in developing effective breeding strategies for goat production (Shretha and Fahmy, 2005). This is attributed to goats being raised in small and large multi-species groups under nomadism and semi-nomadism in agro-pastoral production systems, arid rangelands and within the perimeter of the farm or in the vicinity of homesteads in smallholder farming systems. Basic principles of genetics for livestock improvement are fairly well known and can be applied for meat and milk production in goats. These are: (i) selection within breeds, (ii) selection among breeds (breed substitution) and (iii) crossing between breeds (Taneja, 1982).

Within breed selection is a strategy of genetic improvement usually carried out in individual populations and is intended to increase the average level of genetic merit of the population (Kosgey et al., 2005). Selection within breeds depends, for its successful application, on the presence of genetic variation and ability to detect it. It also depends on the proportion of parents that are needed to produce the next generation. Larger proportions

result in lesser genetic progress and vice-versa. The rate of progress also depends on the speed with which successive generations (not only successive offspring) that can be produced (Taneja, 1982). For example, progress by selection must be expected to be moderately high for a trait like growth rate, which is moderately heritable.

Replacing one pure breed for another might be contemplated if the difference in performance is large. However, the performance of the new breed should be assessed along with the old breed under the conditions in which the breed will be kept (Taneja, 1982). This strategy can achieve rapid genetic change when there are large genetic differences between breeds (populations) in traits of importance (Simm et al., 1996). On the national scale involving a very large number of animals, breed replacement by importation is impracticable, even impossible, to achieve over a reasonable period of years.

Crossbreeding is a means of producing animals that are expected to be on average halfway of their parental breeds in their performance. Crossing may be between indigenous breeds or between indigenous breeds and exotics. Crossbred animals provide an opportunity for upgrading to the better parental breed by back-crossing with males of that breed. However, crossbreeding depends on a number of circumstances which include: (i) the genetic combination best suited to the conditions under which the animals must live and (ii) the extent to which the F_1 is actually better than the average of the parents, i.e., the extent to which it manifests the hybrid vigour (Taneja, 1982). The two circumstances may change with time as a result of changes in the environment. In the past, it was often assumed that exotic breeds from temperate areas, with high production in their homelands, would automatically raise productivity when crossed with local breeds in tropical areas. This assumption led to the failure of some small ruminants projects that promoted the use of exotic breeds within the constraints of the prevailing farming conditions in the tropics (Kosgey et al., 2005). The exotic breeds, therefore, should be carefully evaluated in the field before widespread crossing is undertaken. Such evaluations should include comparisons with indigenous breeds.

2.7.2 Breeding structures

The establishment of breeding goals should involve input from nucleus breeders, commercial farmers, consumers, processors and retailers who together form the industry structure (Blair and Garrick, 1994). Breeding structures allow for efficient flow of genetic material from the top to the base. A livestock industry structure consists of units that are typically structured in such a way that a small proportion form nucleus or stud units (where selection within a breed is undertaken) and other units (multiplier and commercial, who

manage and purchase a higher proportion of the animals, mainly sires from the stud breeders) (Harris et al., 1984; Blair and Garrick, 1994). It resembles a pyramid, with the stud unit at the peak and other units at the base.

Breeding structures may consist of either simple isolated sub-populations or complex populations with flow of genes from the nucleus to the field populations and *vice-versa*. Through appropriate breeding structures, there is transfer of improved genes from the nucleus to the entire population (Cunningham, 1980). A nucleus is either open or closed. The former implies that the replacement stock for the nucleus population is being selected from both the nucleus and commercial population, leading to a two-way flow of genes. A closed nucleus means that replacement stock for the nucleus flocks are selected only within the nucleus and no importation is done from the commercial population, resulting in a one way flow of genes. The open or closed nucleus flocks can either be dispersed or centralised. The open nucleus schemes are beneficial when offspring in the commercial tiers are superior to the average of their parents and when selecting for lowly heritable traits (Garrick, 1993). The movement from the commercial to the nucleus flocks ensures continuous screening of the commercial females transferred into the nucleus. However, closing the nucleus has the advantage of blocking unimproved genetic material from commercial populations.

In small ruminant production a number of nucleus based breeding schemes exist. For instance, there is a two-tier open nucleus breeding scheme for improving growth and live weight in the local Djallonké sheep in Ivory Coast (Yapi-Gnoaré, 2000). Assessment of the scheme did not indicate a large rapid genetic progress for weight, but the genetic trend was positive in the desired direction (Yapi-Gnoaré, 2000). In India, a scheme involving the local Deccani sheep started its operations in 1996 (Nimbkar et al., 2002). The aim of the scheme was to get a sheep with a modest to manageable prolificacy and optimum body size for meat production, as well as being worm resistant. Unlike the Djallonké sheep breeding scheme, the scheme involving the Deccani sheep is still at nascent stage and it is difficult to clearly state its fate because the resulting genotypes are yet to be assessed for their suitability to the local production system (Kosgey et al., 2005).

In French West Indies, various hair sheep breeds from the Caribbean and mixed Martinican farms were grouped to form a population of Martinik hair sheep (Naves et al., 2000). The success of this sheep programme and dissemination of selected animals is attributable to the strong professional structures (breeding associations) and initial financial support from the European structural funds. Successful non nucleus based breeding schemes also exist. For example, the sheep and goats project in south and south east Asia which uses

an integrated approach to control gastro-intestinal parasites with aim of reducing mortality in young goats (TAGAR, 2002). In this scheme, good bucks were provided to the farmers to improve breeding in focus farms. Farmers were informed on the negative effects of inbreeding and introduced to animal management and controlled breeding.

The lessons learnt from these projects are important for any future breeding programme for KDPG. However, success of any programme can be determined by factors that are beyond the control of the animal breeder and hence the need for a multidisciplinary approach. Genetic improvement programmes will be successful if developed as an integrated livestock production package and not in isolation (Kahi et al., 2005). There is demand for using KDPG in different production systems and therefore any attempt at developing a breeding programme will not be futile. When developing the breeding programme for KDPG, the setbacks above should be addressed. Such a programme should be based on the use of less complicated but effective technologies that can be sustained using local financial resources and technical capacities.

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CHAPTER THREE

DEVELOPMENT OF BIO-ECONOMIC PROFIT FUNCTIONS

3.1 Introduction

During the development of the KDPG, it was assumed that the goat could be economically utilised in any smallholder production system. However, these systems are variable and are found in different agro-ecological zones with varying production potentials (low, medium or high) (Mwandotto, 2000). Therefore, good knowledge of the production system in which the KDPG could be economically utilised is needed when promoting this goat. In addition, recommendation for KDPG utilisation has to be made after considering the needs of the target groups if the risk of it being neglected, being unproductive or not performing its intended functions is to be reduced.

The needs and aspirations of the target farmers in both the smallholder and pastoral production systems for small ruminants have been studied before (Kosgey et al., 2005). The importance of different traits for the dual purpose goats as perceived by farmers were ranked in order of importance as; fertility, GR, size, disease tolerance, shape, PR, drought tolerance and heat tolerance. Therefore, it is important to model the variable smallholder production systems taking into account the needs of the farmers and local production circumstances since these will influence the level of utilisation of this goat. Deterministic models offer numerous possibilities for evaluation of production systems in the tropics (James and Ellis, 1979). Such models can be used to investigate different prices and levels and sizes of the production systems (Groen et al., 1997). The aim of this chapter was to develop a deterministic model for the evaluation of biological and economic variables that characterise smallholder production systems utilising the KDPG.

3.2 Materials and methods

3.2.1 General model

The model described was developed for evaluation of both biological and economic aspects of the KDPG under smallholder production systems varying in potential production. Smallholder production systems were defined based on agro-ecological zones and management regime as: smallholder low-potential (SLP), smallholder medium-potential (SMP) and smallholder high-potential (SHP). The model assumed absence of genetic

variation among animals, as well as seasonal variations in animal performance within the same system (e.g., SHP) that may translate into the different qualities and quantities of the final products. The model focused on each phase of the life cycle of the KDPG, from kid development through weaning, yearling, replacement to breeding stages. A schematic representation of a typical KDPG production structure in SMP and SHP is presented in Figure 3. Within the structure, inputs into each phase, relative number of animals through the cycle and outputs out of each phase can be determined.

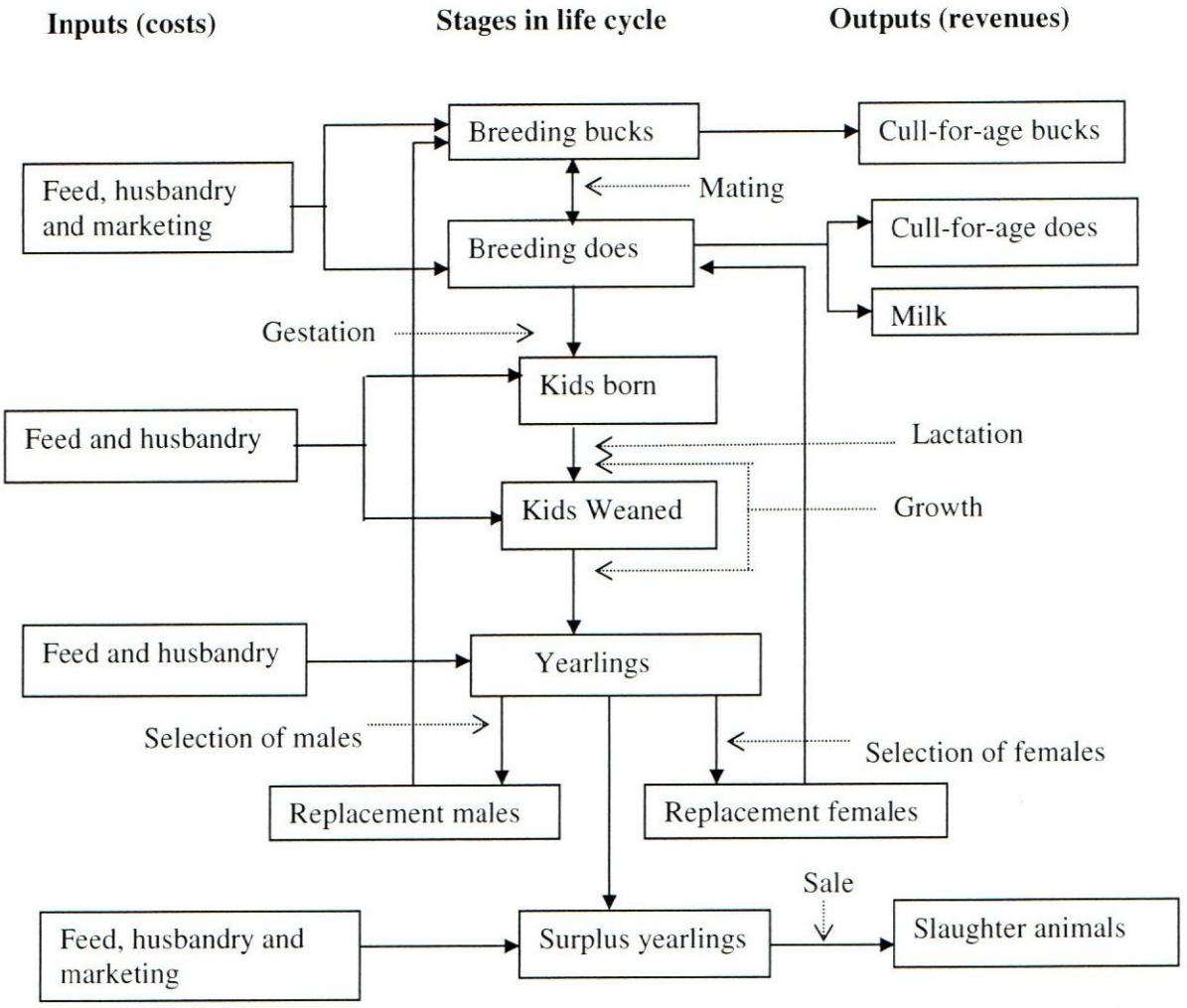


Figure 3. Life cycle of animals in SMP and SHP

In the model, the profitability of the system was described where the total annual profit of the flock was derived as the difference between revenues and costs. Annual revenues and costs of the production systems were considered, and expressed on a per doe per year basis to account for both production and reproduction. The expected costs and revenues were

based on the outputs and inputs of the production system. The latter are further described in the following sections of this chapter.

3.2.2 Breeding, production and marketing system

To serve the goat industry in Kenya, the KDPG could be used exclusively as a pure breed. The KDPG could serve single or dual-purpose roles, corresponding to the objectives of the producer. It was assumed that the breed could be utilised both as a dam and sire line in all the production systems. It was assumed that farmers obtained male replacements and breeding female foundation from government breeding stations, which in Kenya are responsible for the selection and multiplication of the KDPG.

Management

Table 4 presents the production and management input variables used in the model for the three production systems. To simplify the calculations, some of the production variables (e.g. twinning rate) were assumed to be the same for all the systems, although this may not always be true because management and production may differ from one system (agro-ecological zone) to another (Mwandotto, 2000). The standard management practices considered for the three production systems were labour, veterinary services, dipping and helminth control. Labour supply was set fixed per year per animal. Labour was considered to be equal for all animal categories except for the does in SMP and SHP that required extra labour for milking. Opportunity cost for the farmer's labour for other farm tasks in the smallholder systems was used to arrive at the labour cost (e.g. Kosgey et al., 2003).

Veterinary services were assumed to be optimal for all the stages of the animal's life cycle and therefore representative average costs have been used for SLP, SMP and SHP. Dipping or spraying for control of external parasites (e.g. fleas, mange and ticks) were assumed to be optimal for all animal categories. Kids were assumed dipped or sprayed after 2 weeks of birth because of the high prevalence of external parasites. Spraying of the kid's pens was done twice per week while the breeding does and bucks were sprayed once a month in the wet seasons and twice a month in the dry seasons.

Table 4. Production, management and feed intake variables used in the model for the three production systems

Variables	Unit	Abbreviation	Production system[a]		
			SMP	SLP	SHP
Production variables					
Milk yield	kg/day	MY	1.30	0.60	2.00
Consumable meat	meat weight x (100/carcass weight) (%)	CMP	60.00	60.00	60.00
Average daily gain kids	g/day	dg	90.00	85.00	80.00
Average daily gain yearlings	”	dg	65.00	55.00	55.00
Birth weight	kg	BW	2.40	2.90	2.00
Weaning weight	”	WW	10.90	12.68	9.00
Yearling weight	”	LW	26.50	24.60	23.20
Mature weight does	”	DoWT	35.00	33.00	31.60
Mature weight bucks	”	LW_b	45.00	42.80	41.40
Kidding rate	kids born per number of breeding does per year (%)	KR	83.00	78.00	80.50
Pre-weaning survival rate	kids surviving to weaning as a percentage of kids born (%)	PrSR	81.00	76.00	78.50
Post-weaning survival rate	kids surviving to one year as a percentage of kids weaned (%)	PoSR	85.00	80.00	82.50
Doe Survival rate	does surviving as a percent of does present over years	DoSR	90.00	85.00	87.50
Twinning rate	number of kids born as twins as a percent of does (%) per year	tr	17.70	17.70	17.70
Replacements survival rate	replacements surviving as a percent of does or bucks present	Rosr	90.00	85.00	87.50
Management variables					
Age at mature weight	months		18.00	20.00	19.00
Age of doe at first kidding	”		18.00	20.00	19.00
Kidding interval	”	ki	8.00	10.00	9.00
Age at first mating	”		12.00	14.00	13.00
Age of selecting replacement stock	”		12.00	14.00	13.00
Age of selling surplus yearlings	”		12.00	14.00	13.00
Kidding frequency	average number of kiddings per doe per year	KF	1.50	1.20	1.33
Doe culling age	years		8.00	8.00	8.00
Buck culling age	”		2.00	2.20	2.10
Feed intake variables					
Energy content in pastures	kg DM	ne_p	4.00	4.00	6.52
Energy content in browse	”	ne_b	9.00	7.00	-

[a]SMP, smallholder medium-potential; SLP, smallholder low-potential; SHP, smallholder high-potential.

Kids were assumed to be dewormed at three weeks of age, at weaning and once after weaning in SMP, SLP and SHP, respectively. Deworming was set to be twice a year before and after the rains for breeding animals and once for replacement animals. Relative to the adult animals, the dosing for kids was assumed to be a quarter at three weeks of age and half at weaning while it was assumed to be three quarters for yearlings.

Marketing and prices

Marketing was assumed to be on-farm and therefore farm-gate prices for the animals and milk were considered for SHP and SMP. Milk was excluded in SLP as this system assumed no sale of milk. However, there are marketing costs incurred between buying and selling of animal products to the consumers and are charged to the farmer because traders intrinsically reduce the price of milk and of live animals by the same margin (Kosgey et al., 2003). The marketing costs include transport (for milk to the processing plant and for animals to the slaughterhouse) and marketing levies. The costs were assumed to be uniform for all animals sold for slaughter, irrespective of the stage in the life cycle. These were calculated as the sum of the average costs incurred between the buying of a live animal and the selling of its carcass (Kosgey et al., 2003).

Flock composition and replacement policy

Defining the flock composition aids in identifying age and numerical distribution of the flock (Ponzoni and Newman, 1989; Ponzoni and Gifford, 1990). The flock composition for SMP is shown in Figure 4. The flock structure also applies for the other systems (SLP and SHP) but with modifications on the parameters used (Table 4). It was assumed that the flock consisted of a constant number of N breeding does present over the entire period. Different categories of goats were distinguished according to age: kids (0-3 months old); yearlings (4-11 months); replacement males (12 months old); replacement females (12-18 months old); breeding does (>18 months old) and breeding bucks (>12 months old). The size of the flock (number of animals relative to the number of does present) was kept constant over time, by equating the number of replacement females with culled does and their respective survival rates. The ratio of breeding bucks to breeding does was assumed to be 1:50. The KR and tr's were assumed to be 83% and 17.7%, respectively (Okeyo et al., 1985a) while the expected ratio of males to females born was assumed to be 1:1 (Skea, 1989).

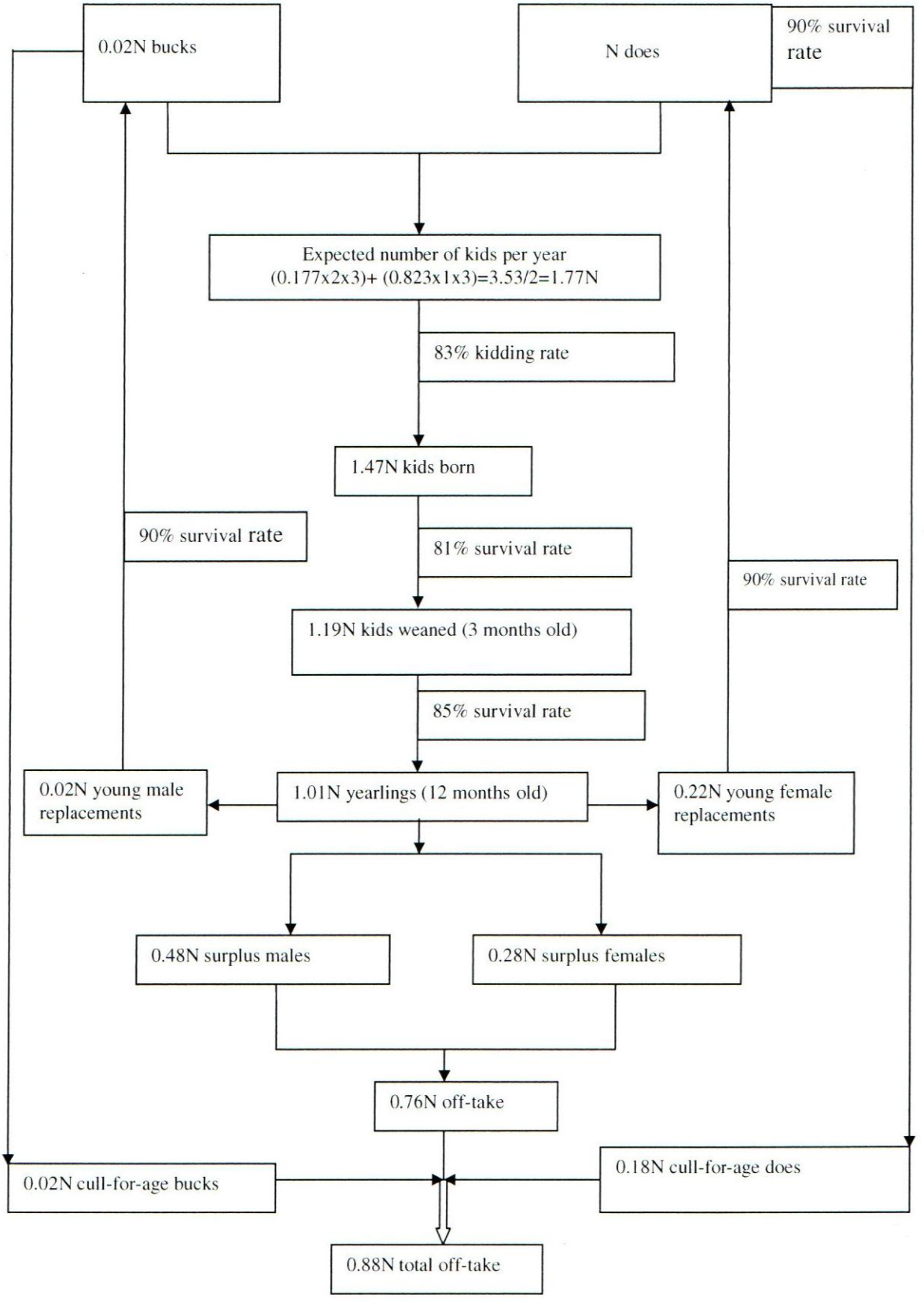


Figure 4. Flock dynamics of the KDPG in SMP

The young female replacements were assumed mated at 12 months of age so that they kid for the first time at 18 months of age and remain in the breeding flock for nine kidding seasons. A ki of 8 months (5 months gestation plus 3 months pre-weaning lactation) was assumed (Skea, 1989). The does were assumed to be culled-for-age at approximately 8 years old (Skea, 1989). The young male replacements are required every year to coincide with the males culled after one productive year at 24 months of age. The kid mortality rate was 19% (Ruvuna et al., 1985), and the corresponding values for yearlings, replacements, and breeding animals were 15%, 10% and 10% (Baptist and Badamana, 1990; Carles et al., 1990).

Feeding regime and feed intake

The feeding regime assumed was that of browsing and/or grazing animals, consistent with the fact that goat production in Kenya is almost entirely from pastures and browse. The kids were assumed to consume insignificant amounts of solid feed within six weeks of birth (Skea, 1989). At that time, the energy and protein requirements are realised from milk. Suckling of one teat was allowed twice per day for SMP and SHP while for SLP, full suckling occurred twice per day. After weaning, the goats grazed predominantly *Themendra triandra, Tarchonanthus camphoratus (leleshwa)* species and several shrubs found in both SLP and SMP (Okeyo et al., 1985b). *Pennisetum clandestinum* (Kikuyu grass) was the common species grazed in SHP. The animals were assumed to realise 70% and 30% of their energy requirements from browse and pastures, respectively, in both SMP and SLP, whereas in SHP energy required was realised only from pastures (Wilson, 1969; Mathuva et al., 1985). The lactating does were fed 0.25 and 0.1 kg of concentrates while grazing in the field in SHP and SMP, respectively and not in SLP.

In all systems, feed intake was defined in terms of dry-matter (DM) intake and composition of feed intake. DM requirement was calculated from estimates of the mean intake of energy value of a feed expressed in terms of metabolisable energy (ME), which is the actual energy available in the feed to be used by the goat. The amount of energy in a feed was expressed in mega joules (MJ) of ME per kg of DM; the DM contains the energy. These estimates were calculated for different age and physiological categories and weights of animals grazing and /or browsing on natural feed resources (e.g. Kosgey et al., 2003). Within this rationale, a sensitivity analysis of the targeted systems to changes in feed related parameters was done. These parameters included weaning weight, energy content in browse

and pastures. These parameters were each increased or reduced at a unit level and the average changes in feed intake for the categories of animals modelled.

3.3 Model description

In general, total profitability of the flock per year (P_f) (KSh) was expressed as a function of k biological traits (that are to be genetically improved) with the related costs and output values as follows:

$$P_f = \sum_{i=1}^{k} n_i (R_i - C_i) t_i - F \qquad (5)$$

where n_i is the number of expressions for trait *i* in a year, R_i is the revenue per unit per expression of trait *i* (t_i), C_i, is the cost per unit per expression of trait *i* (t_i), and F is the fixed costs. The model was then expressed by grouping terms of categories of goats (i.e., kids, yearlings, replacement females, replacement males, breeding does and breeding bucks). Unit prices and cost variables used in the base situation are presented in Table 5. All the costs and prices are stated in Kenya Shillings (KSh). The study considered the 2005 prevailing market prices. Any fluctuations in costs and prices were ignored. Currently, the payment system for milk (litres or kg) and meat (kg) is largely based on quantity of the products and not quality. Therefore it was assumed that each product fetched the same price regardless of the composition (for milk) and grades and different cuts for the carcasses (Kosgey et al., 2003). The biological traits assumed to influence revenues and costs are listed in Table 6. Biological traits are variables that are partly determined by the genotype of the animals and are considered potential breeding goal traits.

Table 5. Unit prices and cost variables used in the three production systems[a]

Variable	Unit	Abbreviation	Production system[a]		
			SMP	SLP	SHP
Costs					
Milk marketing costs	KSh/kg	m_{milk}	3.20	-	3.20
Milking labour costs	"	$clab_{milk}$	5.00	-	5.00
Labour costs	KSh/head/month	lab	459.00	459.00	459.00
Dipping costs	KSh/head/year.	dip	120.00	112.00	127.00
Veterinary costs	"	vet	100.00	90.00	110.00
Helminth control costs	"	hel	117.00	107.50	133.25
Slaughter animal's marketing costs	KSh/head.	m_a	170.25	190.50	152.00
Prices					
Milk price	KSh/kg	P_{milk}	25.00	-	25.00
Meat price	"	P_{meat}	180.00	180.00	180.00
Concentrate price	"	P_c	12.00	-	12.00
Roughage price	KSh/kg DM	P_f	3.00	3.00	3.00

[a]SMP, smallholder medium-potential; SLP, smallholder low-potential; SHP, smallholder high-potential.
US$ = 75 Kenya Shillings (KSh).

Table 6. Biological traits that influence revenues and costs

Trait	Unit	Abbreviation
Milk yield	kg	MY
Live weight at 12 months	"	LW
Consumable meat percentage	%	CMP
Pre-weaning survival rate	"	PrSR
Post-weaning survival rate	"	PoSR
Kidding rate	"	KR
Doe weaning rate	"	DoWR
Doe survival rate	"	DoSR
Mature doe live weight	"	DoWT
Residual feed intake yearlings	kg DM	RFI_y
Residual feed intake does	"	RFI_d
Kidding frequency	number	KF
Number of kids weaned	"	NKW

3.3.1 Calculation of revenues

The sources of revenues in all production systems were surplus yearlings, cull-for-age bucks and cull-for-age does. Milk was an additional source of revenue in SMP and SHP. Intangible roles (source of manure, skins, insurance and prestige) of goats were not included in the model. For simplicity, the following variables were introduced:

$$DoWR = KF \times KR \times PrSR \times \left(1 + \frac{tr}{100}\right) \quad (6)$$

$$NKW = DoWR \times DoSR \quad (7)$$

and

$$N_y d_y = PoSR \times NKW \quad (8)$$

where KF = kidding frequency i.e. average number of kiddings per doe per year (obtained by dividing number of days in a year by the kidding interval in days, ki); DoWR = doe weaning rate (kids weaned relative to the number of does present per year), (%); KR = kidding rate (kids born per number of breeding does per year), (%); PrSR = pre-weaning survival rate (%); tr = twinning rate (number of kids born as twins as a percent of does) (%); NKW = number of kids weaned per doe per year; DoSR = doe survival rate (%); $N_y d_y$ = number of yearlings per doe per year; PoSR = post-weaning survival rate (%).

1. Revenues from surplus yearlings (R_y)

Assuming a sex ratio of 0.5 (Skea, 1989), the number of male yearlings per doe per year ($N_{my}d_y$) attaining selection age was:

$$N_{my} d_y = 0.5 \times N_y d_y \quad (9)$$

and those culled for sale (i.e., surplus yearlings) ($N_{my}d_{y:\,cull}$) were calculated as:

$$N_{my} d_{y:\,cull} = N_{my} d_y - R_m d_y \quad (10)$$

where $R_m d_y$ = number of male replacements per doe per year. The number of female yearlings per doe per year ($N_{fy}d_y$) attaining selection age is equal to $N_{my}d_y$ and those culled for sale (i.e., surplus yearlings) ($N_{fy}d_{y:\,cull}$) were derived by:

$$N_{fy} d_{y:\,cull} = N_{fy} d_y - R_f d_y \quad (11)$$

where $R_f d_y$ = number of female replacements per doe per year. The total number of yearlings per doe per year culled for sale ($N_{fy}d_{y:\,cull}$) was derived by:

$$N_y d_{y:cull} = N_{my} d_{y:cull} + N_{fy} d_{y:cull} \quad (12)$$

and therefore the total revenue from yearling (R_y) was calculated as:

$$R_y = N_y d_{y:cull} \times LW_y \times CMP \times P_{meat} \quad (13)$$

where LW_y = average live weight of yearlings at 12 months (kg); CMP = consumable meat percentage (meat weight per carcass weight)(%); and P_{meat} = price per kg of meat (KSh).

2. Revenues from cull-for-age breeding bucks (R_b)

The revenue from breeding bucks (R_b) is attained from cull-for-age bucks. The number of replacement bucks per doe per year (R_bd_y) was derived by:

$$R_bd_y = R_md_y \times Rosr \quad (14)$$

where Rosr = survival rate of replacements to breeding (%). Therefore

$$R_b = R_bd_y \times LW_b \times CMP \times P_{meat} \quad (15)$$

where LW_b = average live weight of bucks at culling (kg).

3. Revenues from breeding does (Rd)

The total revenue from breeding does in the three production systems was calculated as:

$$Rd = Rd_{meat} + Rd_{milk} \quad (16)$$

where Rd_{meat} = revenue from cull-for-age does; $Rd_{milk,}$ = revenue from milk. For SLP, Rd_{milk} = 0. In SMP and SHP, Rd_{milk} was calculated as:

$$Rd_{milk} = 0.5 \times MY \times d_{milk} \times P_{milk} \quad (17)$$

where MY =average daily milk yield per doe (kg); d_{milk} = number of days in milk; P_{milk} = price per kg of milk (KSh); and the ratio 0.5 means that only one teat is being milked twice per day. The number of doe replacements per doe per year (R_dd_y) was represented as:

$$R_dd_y = R_fd_y \times Rosr \quad (18)$$

and therefore

$$Rd_{meat} = R_dd_y \times DoSR \times DoWT \times CMP \times P_{meat} \quad (19)$$

where DoWT = average live weight of does at culling (kg).

3.3.2 Calculation of costs

Costs arose from marketing of products, husbandry, feeds and fixed assets

1. Marketing costs

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

$$M = \left[\left(N_yd_y + R_bd_y + \left(R_dd_y \times DoSR\right)\right] \times m_a \quad (20)$$

where m_a is the marketing cost per animal (KSh). Marketing costs for milk (M_{milk}) for SMP and SHP was derived by:

$$M_{milk} = 0.5 \times MY \times d_{milk} \times m_{milk} \quad (21)$$

where m_{milk} = marketing cost per kg of milk (KSh).

2. Husbandry costs

Average husbandry costs (CH_i) per animal were described by the following equation:

$$CH_i = N_i \times [lab_i + vet_i + dip_i + hel_i] \quad (22)$$

where *i* = animal class; N = number of animals in category i present; lab = labour costs per animal per year (KSh); vet = veterinary costs per animal per year (KSh); dip = dipping costs per animal per year (KSh); and hel = helminth control costs per animal per year (KSh). For SMP and SHP, milking labour costs ($clab_{milk}$) were included and calculated as:

$$clab_{milk} = 0.5 \times MY \times lab_{milk} \times d_{milk} \quad (23)$$

where lab_{milk} = cost of milking labour per kg of milk (KSh).

3. Feed costs

Calculation of feed costs was based on the actual feed intake expressed in kg DM. Feed intake was calculated from estimates of the mean intake of energy value of a feed expressed in metabolisable energy (ME). The energy content in pastures and browse in the three production systems is shown in Table 4. The amounts of energy required by goats for different physiological and weight categories are those given by Agricultural and Food Research Council (AFRC) (1995) and were calculated using the equations below. The recommendations given include a 5% safety margin considered on a statistical basis (AFRC, 1995). For maintenance requirements, an additional energy allowance for activity is included (AFRC, 1995). The energy requirement for maintenance (MEm) was derived by:

$$ME_{m_i} = \frac{E_m}{K_m} = \frac{0.315w^{0.75} + 0.024w}{0.35q_m + 0.53} \quad (24)$$

where E_m = energy required for maintenance (MJ/kg DM), w = live weight of the animal (kg); and K_m = efficiency of utilisation of ME_m. Metabolisability of gross energy (GE) of a diet (i.e., MJ/kg DM in a feed), at maintenance (q_m) was derived by:

$$q_m = [ME]/[GE] \quad (25)$$

where ME = metabolisable energy (MJ/kg DM) of a feed or diet. Energy requirements for growth (ME_g) were calculated as:

$$ME_{g_i} = \frac{dg \times [4.92 + 0.3274]}{0.78q_m + 0.006} \quad (26)$$

where dg = daily live weight gain (kg). Energy requirements for pregnancy (ME_c) were calculated as:

$$ME_{c_i} = \frac{0.25w_o\left[E_t \times 0.07372e^{-0.00643t}\right]}{k_c} \quad (27)$$

and the net energy content of concepta at time *t* (E_t) in MJ was derived by:

$$\log_{10}E_t = 3.322 - 4.979e^{-0.00643t}$$

where w_o = total weight of kids at birth (kg); t = number of days from conception; e = exponential function using base e; and k_c = efficiency for growth of the concepta (= 0.133). Energy requirements for lactation (ME_l) was calculated as:

$$ME_l = \frac{3.335MY}{0.35q_m + 0.420} \quad (28)$$

Feeding costs per animal (FC_i)

Feeding costs per animal (kids, yearlings, replacement males, replacement females and breeding bucks) were derived from equations below. Feed intake (FI_i) for the animals in SLP and SMP was derived as:

$$FI_i = \left(\frac{0.3}{ne_p} + \frac{0.7}{ne_b}\right)\sum_{i=1}^{d_i}\left(ME_{m_i} + ME_{g_i} + ME_{c_i}\right) \quad (29)$$

and feed intake for the animals in SHP was calculated as:

$$FI_i = \left(\frac{1}{ne_p}\right)\sum_{i=1}^{d_i}\left(ME_{m_i} + ME_{g_i} + ME_{c_i}\right) \quad (30)$$

where d_i = number of days an animal is present in a year; ne_p = net energy content in pasture (MJ/kg DM); and ne_b = net energy content in browse (MJ/kg DM). Therefore,

$$FC_i = N_i \times FI_i \times P_f \quad (31)$$

where P_f = price of roughage feed per kg (KSh)

Feeding costs for breeding does (FC_d)

Feed intake for does (FI_d) was derived as the sum of the feed intake during lactation (FI_d1) and dry period (FI_d2). For SHP, the feed intake during lactation and FI_d2 were derived as:

$$FI_d1 = \left(d_{milk} \times \frac{1}{ne_p} \times ME_l\right) - \left(0.89 \times conc \times d_{milk}\right) \quad (32)$$

and

$$FI_d2 = \left(365 - d_{milk}\right) \times \left(\frac{1}{ne_p}\right)\left(ME_{m_i}\right) \quad (33)$$

where FI_d1 = total feed intake during lactation (kg DM); conc = average daily intake for concentrates during the milking period (kg); and 0.89 = the % DM of concentrates; FI_d2 = total feed intake for the does during dry period (kg). The feed costs for the does in this system were therefore derived as:

$$FC_d = \left(FI_d \times P_f\right) + \left(0.89 \times conc \times d_{milk} \times P_c\right) \quad (34)$$

where P_c = price of concentrate (KSh). For SLP and SMP, the feed intake during lactation (FI_d3) and in the dry period (FI_d4) were derived as:

$$FI_d3 = d_{milk} \times \left(\frac{0.3}{ne_p} + \frac{0.7}{ne_b}\right)\left(ME_l\right) - \left(0.89 \times conc \times d_{milk}\right) \quad (35)$$

and,

$$FI_d4 = \left(365 - d_{milk}\right) \times \left(\frac{0.3}{ne_p} + \frac{0.7}{ne_b}\right)\left(ME_m\right) \quad (36)$$

where ME_l = energy for lactation (MJ/kg DM).The feed costs for the does in these systems was derived as for the SHP.

3.4 Results and discussion

3.4.1 Revenues, costs and profitability

Revenues, costs and profits are presented in Table 7 for SMP, Table 8 for SLP and Table 9 for SHP. The values presented are weighted by proportions of each animal class with respect to number of does present, and the totals are expressed on a per doe per year basis. The values obtained for each system also depend on the flock structure used since the three systems were assumed to have different flock composition and replacement policies (see section 3.2.2). On average per doe per year, the use of KDPG was profitable in SMP (KSh 315.48 per doe per year) and not in SLP (KSh –1352.75) and in SHP (-80.22). However, this could be an underestimate. In practice, the roughage feed is free where land is available, and rarely do smallholder farmers invest in the production of pasture for small ruminants. Further, husbandry costs could be overestimated. Feed expenses if coupled with grazing/browsing costs represent a major constraint to profitability (Hamadeh et al., 2001). The low profits obtained in the two systems (SLP and SHP) may indicate a rise in labour cost since an opportunity cost was assigned to family labour. The opportunity cost for labour is absent when children and sometimes adult provide labour which has no alternative use. Studies have shown that inclusion of own labour cost as an opportunity cost in economic evaluation largely inflates the total costs with negative effects on profitability (Hamadeh et al., 2001).

Helminth control costs in the SLP and SMP systems where browse is available could also be overestimated. Feeding behaviour and availability of browse has some influence on the prevalence of endoparasites in goats (Hoste et al., 2001). Goats are innately more susceptible to nematode parasites when only pasture is available to graze (Promroy et al., 1986). If costs for control of helminths (in SLP and SMP), labour and feed are assumed to be 50% less than the original costs used for estimating profits in the three systems, higher profits in all the systems could be expected. In that case, the current profits for the three systems would be KSh 1972.00 (SMP), KSh 138.82 (SLP) and KSh 1460.84 (SHP). However, these profits may be reduced due to losses incurred in forgone yearlings and live weights from premature (emergency) sale of live animals. Further losses may also occur during dry periods due to feed scarcity. In these periods, most farmers may want to dispose of their animals, fetching relatively low prices due to glut in the market (Kosgey et al., 2003).

Table 7. Estimated revenues, costs and profit (KSh) per doe per year in the base situation (i.e., smallholder medium-potential (SMP))

	Animal category[a]									
	Kids	Yearlings off-take	Replacement females	Replacement males	Breeding does	Cull does[b]	Breeding bucks	Cull bucks[b]	Total[c]	Percentage of the total
Proportion of animals to does	1.08	0.76	0.22	0.02	1.00	0.18	0.02	0.02		
Input										
Feed	49.34	194.28	76.03	1.38	1280.04		10.91		1611.99	35.12
Husbandry	953.64	739.87	160.46	16.05	149.91		15.14		2035.07	44.33
Milking labour					438.75				438.75	9.56
Marketing (milk &meat)		115.37			280.80	30.29		3.06	429.51	9.36
Fixed costs	12.50	12.50	12.50	12.50	12.50		12.50		75.00	1.62
Total (a)	1015.48	1062.02	248.99	29.93	2192.29		41.61		4590.32	100.00
Output										
Meat		1942.22				673.59		96.23	2712.05	55.29
Milk					2193.75				2193.75	44.72
Total (b)		1942.22			2867.35			96.23	4905.00	100.00
Profit (b-a)	-1015.48	880.20	-248.99	-29.93	675.06		54.62		315.48	

[a]See text for description of animal categories.
[b]Accounted for in the breeding groups.
[c]Weighted by animal proportions.

Table 8. Estimated revenues, costs and profit (KSh) per doe per year in the smallholder low-potential (SLP)

	Animal category[a]									
	Kids	Yearlings off-take	Replacement females	Replacement males	Breeding does	Cull does[b]	Breeding bucks	Cull bucks[b]	Total[c]	Percentage of the total
Proportion of animals to does	0.72	0.46	0.22	0.02	1.00	0.18	0.02	0.02		
Input										
Feed	33.88	120.80	73.56	1.30	983.52		10.52		1223.59	42.25
Husbandry	697.14	479.59	156.24	15.24	145.96		14.74		1509.30	52.12
Marketing (meat)		56.99				28.60		2.89	88.49	3.06
Fixed costs	12.50	12.50	12.50	12.50	12.50		12.50		75.00	2.59
Total (a)	743.52	669.88	242.30	29.04	1170.58		40.65		2896.00	100.00
Output										
Meat		890.70				566.50		86.44	1543.63	100.00
Milk										
Total (b)					566.50		86.44		1543.63	100.00
Profit (b-a)	-743.52	220.82	-242.30	-29.04	-604.08		45.79		-1352.75	

[a]See text for description of animal categories.
[b]Accounted for in the breeding groups.
[c]Weighted by animal proportions.

Table 9. Estimated revenues, costs and profit (KSh) per doe per year in the smallholder high-potential (SHP)

	Animal category[a]									
	Kids	Yearlings off-take	Replacement females	Replacement males	Breeding does	Cull does[b]	Breeding bucks	Cull bucks[b]	Total[c]	Percentage of the total
Proportion of animals to does	0.88	0.56	0.22	0.02	1.00	0.18	0.02	0.02		
Input										
Feed	44.75	233.11	81.31	1.45	1616.16		11.82		1988.61	40.76
Husbandry	810.79	592.87	158.35	15.83	147.94		14.94		1740.73	35.68
Milking labour					585.00				585.00	11.99
Marketing (milk &meat)		82.25			374.40	29.45		2.97	489.08	10.02
Fixed costs	12.50	12.50	12.50	12.50	12.50		12.50		75.00	1.54
Total (a)	868.04	920.73	252.16	29.78	2765.45		42.23		4878.41	100.00
Output										
Meat		1212.28				574.84		86.07	1873.17	39.04
Milk					2925.00				2925.00	60.96
Total (b)		1212.28			3499.00		86.07		4798.17	100.00
Profit (b-a)	-868.04	291.55	-252.16	-29.78	733.55		43.84		-80.22	

[a]See text for description animal categories.
[b]Accounted for in the breeding groups.
[c]Weighted by animal proportions.

Variable costs were the most important cost of production with husbandry costs being the highest. Smallholder farmers rarely invest in fixed assets (i.e. buildings, equipments, feeding and watering troughs, etc.) for small ruminants and where available, they are likely to be shared with other livestock species (Kosgey et al., 2005). In this study, husbandry costs accounted for 35% (SHP) to 52% (SLP) of the total costs, and were higher than the feed costs except for the SHP system. On average, kids contributed more to the total husbandry costs because of the fact that kids are delicate and therefore require more care at early age in order to increase their survival rates. This is especially evident in the low potential areas (SLP, Table 8), where the percentage contribution of husbandry to the total costs was high. Higher husbandry costs were also experienced in the yearlings and does (milking labour costs included) while the replacement males and breeding bucks had the lowest.

Feed costs accounted for 35% in SMP, 42% in SLP and 41% in SHP of total production costs (Tables 7, 8 and 9), which is lower than reported in extensive small ruminant production systems. In these systems, feed costs could account for 49% (Hamadeh et al., 2001) and 57% (Kosgey et al., 2003) of the total costs. In the present study, high feed costs were associated with the use of concentrates by lactating does (SMP and SHP) while low feed costs was associated with browsing and grazing without supplementation (SLP). In all the three systems, breeding does contributed the highest and the replacement males the lowest to feed costs. The highest contribution of breeding does is due to their high numbers throughout the year.

Amongst all animal categories, revenues were highest from does and yearlings. Surplus yearlings sold for meat contributed higher revenue because of the high off-take. The SMP system contributed the highest meat revenues from surplus yearlings compared to other systems and this was due to their high proportions relative to the does present (i.e. 0.76). Does had an advantage over the other categories of animals because of the extra revenue from milk in SMP and SHP. Revenue from meat accounted for about 55% and 39% of the total output while approximately 45% and 61% of the revenue was from milk in SMP and SHP, respectively. This is congruent with the fact that KDPG is a dual-purpose animal and therefore revenue from both products in SMP was almost equal. In SHP (Table 9), most of the revenue was from milk, approximately 61% of the total revenue, and the remaining from surplus yearlings and cull-for-age breeding animals sold for meat. This can be attributed to better feeding (both pastures and concentrates) of the lactating does because generally the system is in the high potential areas. All the revenue from SLP was from meat (100%), as this system assumed no sale of milk.

3.4.2 Prediction of feed intake

The predicted feed intake (weighted by proportions of each animal class with respect to number of does present with the totals expressed on a per doe per year basis) for all categories of animals are presented in Figure 5. The estimated feed intake was highest in SHP. The low energy content in pastures when compared to the browse contributed to higher estimates of feed intake in SHP than in SLP and SMP, respectively. Feed intake for does was higher because of the extra energy for production and reproduction. In this study, estimates of feed intake were determined by nutrient requirements, which do not always hold. Feed intake was included in the model due to the fact that feed costs form a large proportion of the total production costs (Tables 7 to 9). However, residual feed intake was considered as the biological trait influencing revenues and costs. Residual feed intake is an appealing characteristic to reflect production efficiency since its a linear function of feed intake, production and maintenance of body weight (van der Werf, 2001).

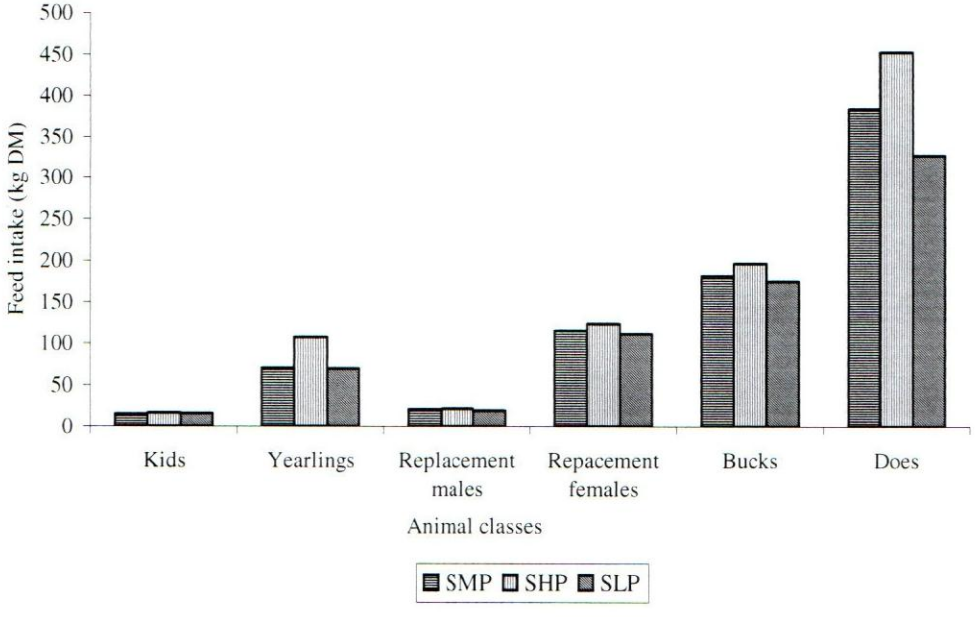


Figure 5. Predicted feed intake for all categories of animals in the smallholder medium potential (SMP) smallholder high potential (SHP) and smallholder low potential (SLP) (see text for description of the systems).

3.4.3 Sensitivity analyses

Sensitivity of feed intake for the different categories of animals to changes in weaning weight and energy content in pasture and browse was tested. A sensitivity analysis of feed

intake to changes in weaning weight and energy content was necessary for the developed model. The analysis was done to ascertain the flexibility of the intended systems to changes in these parameters. Since the trends of these analyses were similar in the three production systems, only results from SMP are presented. The sensitivity analyses showed that feed intake was generally linearly related to weaning weight (Figure 6). Rewe et al. (2005) reported linear relationship between feed intake and weaning weight in the Boran cattle, which is in agreement with the results of the current study. The observed positive relationship between weaning weight and feed intake suggests that WW could be an indirect indicator of feed intake (Kahi et al., 2003). However, more studies under different field conditions are required to quantify the strength of the relationship between weaning weight and feed intake.

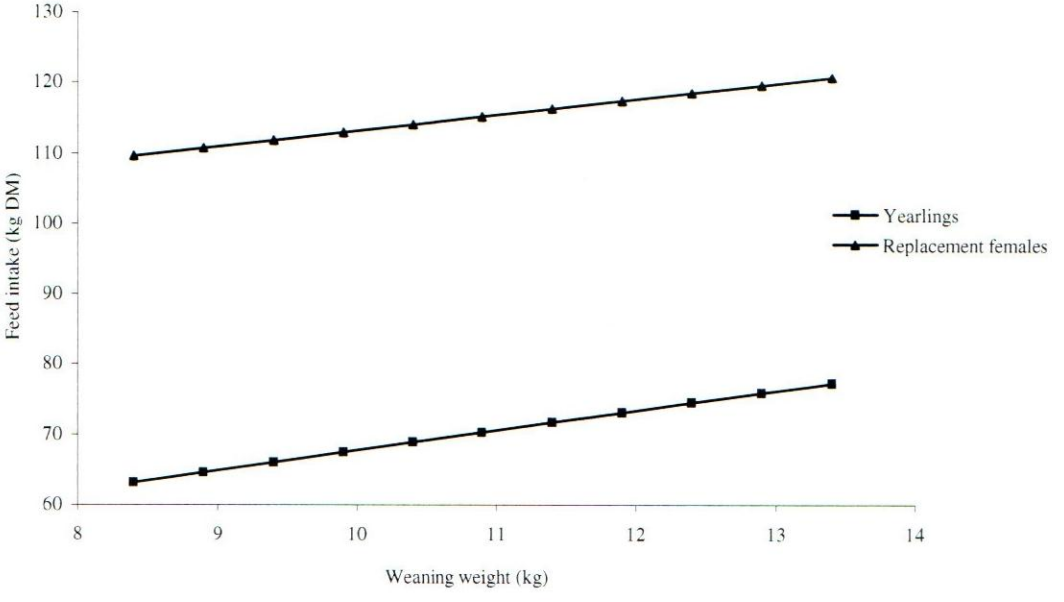


Figure 6. Sensitivity of feed intake of yearlings and replacements to changes in weaning weights in smallholder medium potential system (SMP).

Generally, there was a reduction in feed intake due to an increase in energy content in browse and pastures (Figure 7). However, the effect was more pronounced in pastures than in browse. This effect could be attributed to the difference in nutritive values of feed resources (browse and pastures) in the systems. This also can be in accordance with the assumption that goats are generally browsers and therefore the bulk of the feed is from browse rather than pastures. Pasture quality is directly affected by seasonal patterns and agro-ecological zones and thus the energy content of pasture may change seasonally or from one agro-ecological zone to the other while browse is slightly affected by both.

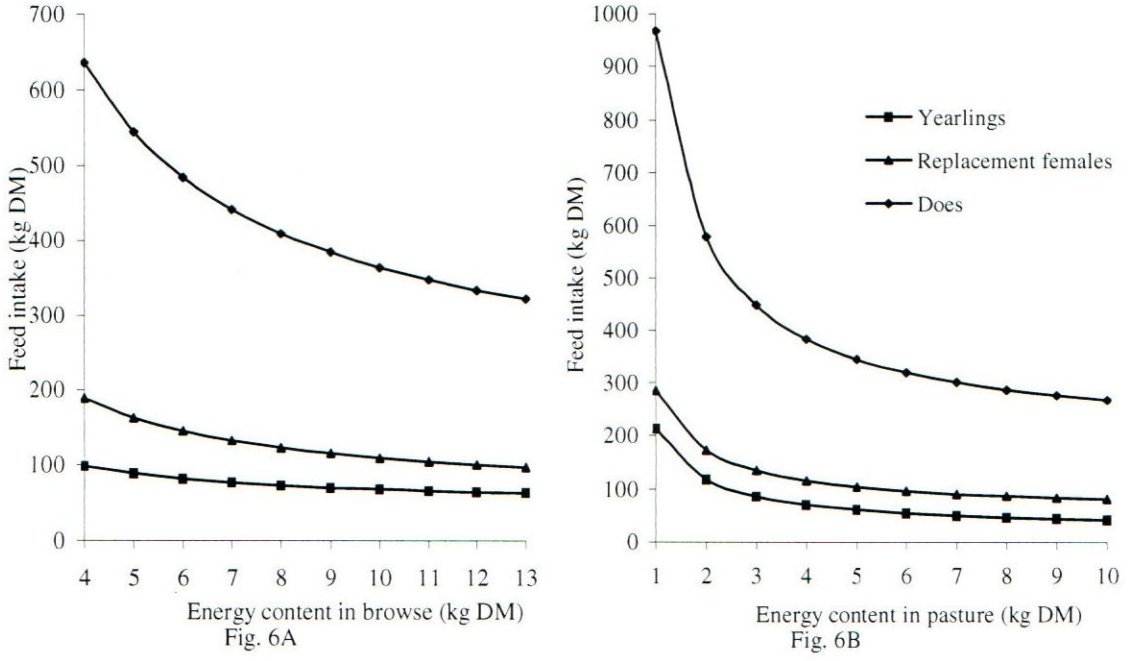


Figure 7 Sensitivity of feed intake of yearlings, replacement females and does to changes in energy content in browse (A) and pasture (B) in smallholder medium potential system (SMP).

3.4.4 Implications

In this study, a model was developed and applied to describe the biological and economic aspects of smallholder goat production systems in Kenya. The proposed model allowed estimation of feed intake, revenues and costs and profitability of the smallholder systems utilising the KDPG breed. The model provided information on both biological (e.g. traits) and economic characteristics of the KDPG production systems and can estimate the impact of changing input parameters on the economic efficiency of these systems. These input parameters can be changed easily to adapt to other situations in the tropics. The approach used in the present study assumed optimal management practises and feeding strategy based on nutrient requirements. Similar approach has been used in several studies in the tropics (e.g. Kosgey et al., 2003; Kahi and Nitter, 2004; Rewe et al., 2005). Elsewhere, different models have been used to predict feed intake based on dynamic model of digestion (Vargas et al., 2002) and performance on the basis of availability and quality of grass and other supplements (Hirooka et al., 1998) and to optimise insemination and culling policies (Koots and Gibson, 1998; Vargas et al., 2002). Use of such models can be difficult when

there is insufficient knowledge of the production system under analysis (Groen et al., 1997), as is the case for goat production systems in Kenya. The model used in the current study can therefore be refined when more information on the breed under different production systems and circumstances becomes available.

The present results have clear implication for application of the model to the smallholder production systems in Kenya. Based on profitability, it seems that there is a possibility of utilising the KDPG in SMP. Profitability and utilisation of small ruminants in the smallholder and pastoral systems in the tropics have been reported before (Upton, 1985; Panin and Mahabile, 1996; Jaitner et al., 2001; Kosgey et al., 2004). Likewise, the importance of the breed in SLP and SHP cannot be overlooked, the negative profits notwithstanding. Similar studies in the traditional management systems in the tropics found either low or negative profitability (Seleka, 2001; Kosgey et al., 2003). The many roles small ruminants play (i.e. bank, socio-cultural reasons, insurance and manure) rather than just for production of meat and milk were suggested as the reasons contributing to low or negative profits in these systems (Bosman et al., 1997; Kosgey et al., 2004; Baker and Gray, 2005). Bosman et al. (1997) and Kosgey et al. (2004) reported profitability after incorporating these additional roles in the evaluation of the systems.

This study has shown that KDPG can be utilised profitably by smallholder goat farmers. This calls for definition of a simple but practical breeding goal for this breed under the prevailing production circumstances. Identifying the characteristics of the individual animals (flock) that contribute to change in profit and their relative worth, is what is referred to as defining the breeding goal (Barlow, 1987). Currently, there are no appropriate breeding goals for the breed. The primary objectives of most smallholder farmers would be to improve the net profit from their farm flock. The breeding goal should therefore be defined in terms of economic performance and directed towards the improvement of profit (Annor, 1996). In addition, it is important to define these goals bearing in mind the overall objectives of the target groups who are the crucial link in the use of genetically improved animals (Amer et al., 1998; Sölkner et al., 1998). Participation of animal owners among other stakeholders in the process of formulating a breeding goal will ultimately reduce the risk of the breeding goal being neglected, being unsustainable or losing its meaning (Amer et al., 1998).

Breeding goals combine both the genetic and economic worth of an individual and is stated as an equation based on breeding values and economic values. The economic value expresses the value of a unit change in the trait while keeping other traits in the aggregate genotype constant (Hazel, 1943; Beckman and van Arendonk, 1993). Economic values are

needed for each trait in the breeding goal to ensure that selection emphasis is proportional to the economic importance of each of these traits (Amer et al., 2001). Economic values for traits in the breeding goal for KDPG were estimated and their influence on genetic improvement in a framework of a breeding programme assessed in the subsequent chapter.

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CHAPTER FOUR
ESTIMATION OF ECONOMIC VALUES FOR TRAITS AND ASSESSMENT OF THEIR INFLUENCE ON GENETIC IMPROVEMENT

4.1 Introduction

Animal breeding is largely concerned with selection of animals based on well-defined breeding goals, which should fit the future farm production and market requirements. A breeding goal provides the basis for breeding programme design and combines economically important traits each weighted by its economic and breeding value. The economic value expresses the value of a unit change in the trait while keeping other traits in the aggregate genotype constant (Hazel, 1943; Beckman and van Arendonk, 1993). Economic values are needed for each trait in the breeding goal to ensure that selection emphasis is proportional to the economic importance of each of these traits (Amer et al., 2001). In the tropics however detailed economic assessments of costs and revenues are scarce probably due to illiteracy, lack of records and small flock sizes (Kosgey et al., 2003). Other factors are lack of consistency in recording and sub optimal animal evaluation (Rewe et al., 2005). In Kenya, economic values have been estimated for meat sheep (Kosgey et al., 2003) and dairy (Kahi and Nitter, 2004) and beef cattle (Rewe et al., 2005), but are lacking for goats. The aim of this chapter was to derive economic values for traits of the KDPG in low to high potential smallholder production systems. The influence of these economic values on genetic improvement in traits of the KDPG was also assessed.

4.2 Materials and methods

4.2.1 Derivation of economic values

Economic values can be derived using either the partial budgeting or the partial differentiation method (Brascamp et al., 1985; Ponzoni, 1986; Smith et al., 1986; Dekkers, 1991; Beckman and van Arendonk, 1993; Visscher et al., 1994). In the partial budgeting method, unit changes in returns (marginal returns) and costs (marginal costs) arising from improvement of a trait are accounted for. The profitability of the flock is compared before and after genetic improvement. In the partial differentiation method, the partial derivative of profit (or efficiency) with respect to the trait of interest is obtained. In this study, economic values for traits in the breeding goal were estimated using the partial budgeting method and applying the model developed in chapter 3. An additional section was added to the model to calculate economic values based on previous research (Kosgey et al. 2003; Kahi and Nitter

2004). The traits in the breeding goal included production (MY, LW and CMP) and functional (DoWT, NKW, KF, KR, DoWR, DoSR, PoSR, PrSR, RFIy and RFId) traits. For all production systems, economic values were estimated under two different production circumstances: the fixed flock-size and fixed feed resource scenario. Estimating economic values under different production circumstances is recommended since this may lead to a diversification of the breeding goal (Groen, 2000).

The fixed flock-size scenario simulates a situation where the flock size cannot be increased due to the other constraints apart from feed resources, such as limited financial resources, farm size, structures, management, etc. The economic values under fixed flock-size were calculated from the equation:

$$EV_{\text{flock-size}} = \left[\frac{\delta R - \delta C}{\delta t}\right] \quad (37)$$

where, $EV_{\text{flock-size}}$ is the economic values per unit change in the trait of interest, δR and δC are the marginal changes in revenues and costs after a 1% increase in the trait of interest and δt is the marginal change in trait after 1% increase.

The fixed feed resource scenario assumes that the flock-size is restricted due to limitation in the amount of feed resources available. This situation adequately represents most production systems, especially smallholder system, in the tropics where feed scarcity is a major limiting factor (Semenye and Getz, 1993; Kosgey et al., 2003; Kahi and Nitter, 2004). Therefore, the economic values assuming a fixed feed resource were estimated as:

$$EV_{\text{fixed feed resource}} = \left[\frac{\delta R - \delta C}{\delta t}\right] - \left[\frac{\delta FI}{\delta t} \times \frac{P_d}{FI}\right] \quad (38)$$

where FI is the feed intake per doe before genetic improvement, δFI is the marginal change in feed intake per doe after genetic improvement (kg DM) and P_d is the profit per doe per year before genetic improvement.

The potential bias in the calculation of economic values restricted to the animal, herd or farm level can be tested by sensitivity analyses to market prices and production levels (Groen et al., 1997). Sensitivity of economic values to price levels of inputs or products gives the likely direction of future genetic improvement, and production system which has important implications for practical breeding programmes (Groen, 2000; Kosgey et al., 2003). Given the uncertainties associated with prices, an additional study was carried out on the sensitivity of the economic values to changes in pricing levels. This was done under all the production circumstances and systems. Changes of ±20% with respect to prices of feed,

meat and milk were considered. The changes were performed one at a time, keeping all other parameters constant.

4.2.2 Assessment of the influence of economic value on genetic improvement

Since not all traits in the breeding goal are expressed at the same time or with the same frequency, economic values were adjusted for this. To correct for delays in time of expression of the traits, the annual economic values were adjusted for the time lag. This was achieved using the discounted gene-flow method (McClintock and Cunningham, 1974). This method takes into consideration the number of times a trait is expressed, the time of expression, and converts the expression to the present value by applying a discount rate (Ponzoni, 1992). Discount rates of 0% and 5% were applied and a period of 15 years and all generations in which there was trait expression was considered.

Phenotypic and genetic parameters

The relevant parameters of heritabilities, genetic and phenotypic correlations assumed among all the breeding goals traits and criteria are presented in Table 10. Reliable estimates from literature were consulted confining our sources to the tropics as much as possible (Restall, 1984; Gifford et al., 1990; Saithanoo et al., 1990; Els, 1998; Mandonnet et al., 1998; Neopane and Pollot, 1998; Bishop and Allain, 2000; Goncalves and Wechsler, 2000; Khan et al., 2000; Neopane, 2000; Quieroz et al., 2000; Ribeiro et al., 2000; Kosgey, 2004). A thorough search of literature was necessary because current local estimates of variance components for goats were lacking. The resulting variance covariance matrices were then tested to make sure they were positive definite.

Table 10. Assumed heritabilities (h^2), phenotypic standard deviations (σ_p), phenotypic correlations (above diagonal) and genetic correlations (below diagonal) among selection criteria and breeding goal traits

	Traits[a]																	
	LWd	LWm	DoWT	MY	CMP	NKW	KF	KR	DoWR	DoSR	PoSR	PrSR	RFIy	RFId	BW	WW	KI	AFK
Units	(kg)	(kg)	(kg)	(kg)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(kg)	(kg)	(kg)	(kg)	(days)	(month)
h^2	0.26	0.04	0.58	0.38	0.40	0.15	0.07	0.17	0.15	0.10	0.05	0.02	0.33	0.33	0.25	0.13	0.17	0.14
σ_p	2.93	0.88	4.08	3.01	0.14	0.94	1.23	0.36	0.36	0.5	0.29	0.29	0.01	0.01	0.45	3.02	0.51	0.71
LWd																		
LWm	0.00																	
DoWT	0.76	0.00																
MY	0.34	0.00	-0.02															
CMP	0.15	0.00	0.30	0.00														
NKW	0.00	0.00	0.00	0.00	0.00													
KF	0.10	0.00	0.00	0.00	0.09	0.46												
KR	0.00	0.00	0.00	0.00	0.00	0.67	0.11											
DoWR	0.00	0.00	0.05	0.00	0.00	-0.04	0.00	0.00										
DoSR	0.00	0.00	0.20	0.00	0.80	0.12	0.12	0.20	0.00									
PoSR	0.72	0.00	0.91	0.00	0.48	0.00	0.00	-0.48	0.00	0.42								
PrSR	0.10	0.00	0.20	0.00	0.10	0.48	0.12	0.57	0.00	0.10	0.30							
RFIy	-0.15	0.00	-0.30	0.00	-0.40	0.00	0.00	0.00	-0.05	0.00	0.00	0.00						
RFId	-0.15	0.00	-0.30	0.00	-0.40	0.00	0.00	0.00	-0.21	0.00	0.00	0.00	0.65					
BW	0.10	0.00	0.10	-0.42	0.60	0.00	0.00	0.10	0.00	0.94	0.05	0.25	0.20	0.20		0.40	-0.56	-0.10
WW	0.76	0.00	0.73	0.00	0.28	0.00	0.00	0.41	0.00	0.00	0.04	0.45	0.45	0.40	0.45		0.00	0.00
KI	0.00	0.00	0.00	0.11	0.00	0.52	0.91	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		-0.02
AFK	0.00	0.00	0.04	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	-0.03	

[a]LWd, live weight direct; LWm, live weight maternal; DoWT, doe live weight; MY, average daily milk yield; CMP, consumable meat percentage; NKW, number of kids weaned; KF, kidding frequency; KR, kidding rate; DoWR, doe weaning rate; DoSR, doe survival rate; PoSR, post-weaning survival rate; PrSR, pre-weaning survival rate; RFIy, residual feed intake yearlings; RFId, residual feed intake does; BW, birth weight; WW, weaning weight; KI, kidding interval; AFK, age at first kidding.

Choice of selection indices and criteria

To predict genetic gain for the breeding goal traits, eight different selection indices were constructed. These indices were chosen because of their relevance to practical breeding programmes and were constructed with economic values derived in all the smallholder production systems. The first (I_0) and second (I_5) indices were constructed with economic values from both scenarios discounted at 0% and 5%, respectively. The third ($I_{FI \times 1.20}$) and fourth ($I_{FI \times 0.80}$) indices were constructed using economic values derived from the fixed flock-size scenario by increasing and reducing feed costs by 20%, respectively. Similarly, the fifth ($I_{M \times 1.20}$) and sixth ($I_{M \times 0.80}$) indices resulted from the application of economic values derived from the fixed flock-size scenario by increasing and reducing goat meat prices by 20%, respectively. The seventh ($I_{ML \times 1.20}$) and eighth ($I_{ML \times 0.80}$) indices were similar to the latter indices except that they resulted from the application of economic values derived by increasing or reducing milk prices by 20%, respectively.

The selection index methodology was used. The selection index coefficients were derived as follows;

$$b = P^{-1}Ga \qquad (39)$$

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 goal and 'a' is a vector of economic values of the traits in the breeding goal to be estimated. Assuming a selection intensity of one, the genetic gain (g) achieved by one round of selection on the index is calculated as;

$$g = \frac{b'G}{\sigma_I} \qquad (40)$$

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

The characters chosen as traits in the selection criteria need to be heritable, correlated with traits in the breeding goal and cheap, and easily measurable (Barlow, 1987). The set of traits included in the selection criteria were BW, WW, ki and AFK. These traits are usually recorded in some smallholder goat production systems in Kenya. In all animals, the

information sources included available records of BW and WW on the individual, sire and dam. In females, additional information sources included records of ki and AFK.

4.3 Results

4.3.1 Economic values for traits

Economic values per unit increase in genetic merit for the breeding goal traits are given in Table 11 for all smallholder production systems considered. Under fixed flock-size and fixed feed resource bases of evaluation, economic values were highest in SMP apart from the economic values for feed intake related traits (RFIy and RFId). The economic values for production traits (LW, MY and CMP) were positive in all the production systems apart from MY in SLP. Positive economic values for the traits were entirely due to an increase in net returns from meat and milk production. Economic value for MY in SLP system was negative since the trait was only associated with costs (i.e. no revenue from milk). In all production systems, MY was used in estimating feed intake for does. Selection for increased MY would result in increased feed intake by the doe as a result of increased energy requirements for lactation.

Apart from the economic values for RFIy and RFId (in all the systems), DoWT (in SLP and SHP) and KF and KR (in SHP), economic values for functional traits were positive. Among the functional traits, DoSR and PoSR had the highest positive economic values in all the production systems. Improvement for these traits will result in a greater influence on revenues than on costs in these systems mainly because of the increased off take. Survival traits influence the flock composition and the replacement rates in a production system. Consequently, an increase by one unit in genetic merit of DoWR, NKW and PrSR resulted in positive economic values. Negative economic values for the feed intake related traits (RFIy and RFId) was expected because an increase in genetic merit of the traits did not affect revenues, but resulted in an increase on feed costs only. In SHP, KF and KR had negative economic values of KSh –0.08 and KSh -2.44, respectively.

Table 11. Economic values (KSh per doe per year) per unit increase in genetic merit of traits for all smallholder production systems

Production system[a]	Trait[b]												
	LW	DoWT	MY	CMP	NKW	KF	KR	DoWR	DoSR	PoSR	PrSR	RFIy	RFId
SMP													
Fixed flock-size	71.61	2.12	20.90	45.20	13.68	3.61	6.52	12.39	22.96	22.87	13.18	-2.76	-3.00
Fixed feed resource	73.28	19.24	29.39	45.20	16.91	4.76	9.45	13.84	25.67	25.15	16.19	-2.76	-3.00
SLP													
Fixed flock-size	34.52	-2.80	-8.64	25.73	11.61	1.29	1.33	10.61	14.97	13.77	6.58	-1.72	-2.99
Fixed feed resource	36.20	17.16	-0.03	25.73	13.85	2.13	3.31	11.26	16.78	15.27	8.61	-1.72	-2.99
SHP													
Fixed flock-size	50.34	-1.15	14.11	31.13	9.48	-0.08	-2.44	7.74	14.78	14.38	5.87	-2.17	-3.01
Fixed feed resource	52.25	18.19	19.41	31.13	12.80	1.82	1.01	10.46	18.40	17.30	9.50	-2.17	-3.01

[a]SMP, smallholder medium-potential; SLP, smallholder low-potential; SHP, smallholder high-potential.
[b]LW, live weight; DoWT, doe live weight; MY, average daily milk yield; CMP, consumable meat percentage; NKW, number of kids weaned; KF, kidding frequency; KR, kidding rate; DoWR, doe weaning rate; DoSR, doe survival rate; PoSR, post-weaning survival rate; PrSR, pre-weaning survival rate; RFIy, residual feed intake yearlings; RFId, residual feed intake does.

A comparison of the economic values for most traits estimated under both production circumstances showed that they were higher under the fixed feed resource scenario than in the fixed flock-size scenario. The increase in economic values for traits may have occurred as a result of restriction of total energy supply that was not used for production and reproduction purposes. The economic values for CMP, RFIy and RFId remained the same under both production circumstances. This suggests that breeding for these traits in situations where feed is limited will not reduce the profits per doe per year for the systems. The economic value for CMP was not affected since it was not used when estimating feed intake for the different categories of animals.

4.3.2 Sensitivity of economic values to changes in prices

Table 12 shows the sensitivity of economic values for the traits to changes in prices of feed, milk and meat under a fixed flock-size base of evaluation. Since the trend in the three production systems were similar under fixed flock-size and fixed feed resource scenarios, only results from SMP under fixed flock-size are presented. The economic values for most of the traits were sensitive to changes in prices of feed, milk and meat. Increasing the price of feed had a large effect on the economic value for DoWT. The economic value for CMP was not sensitive to changes in the feed price because the trait was not included in the estimation of feed intake for the different categories of animals. Increasing the price of milk caused a large rise in the economic value for MY only. This suggests that future uncertainties associated with prices of milk may not affect economic values for the other traits. Changes in meat prices had major effects on the economic values for all traits except for MY, RFIy and RFId. This was expected because the traits involved are those that determine the off-take (NKW, KF, KR, DoWR, DoSR, PoSR and PrSR) and the amount of meat that is sold (LW, DoWT and CMP).

Table 12. Sensitivity analysis for the smallholder medium potential production system under fixed flock-size

Input/ Output	Price level (%)	Trait[a]											
		LW	DoWT	MY	CMP	NKW	KF	KR	DoWR	DoSR	PoSR	PrSR	RFIy	RFId
Fixed flock-size		71.61	2.12	20.90	45.20	13.68	3.61	6.52	12.39	22.96	22.87	13.18	-2.76	-3.00
Feed	-20	71.95	5.54	22.60	-	14.13	3.94	7.11	12.79	23.51	23.33	13.79	-2.20	-2.40
	+20	71.26	-1.30	19.21	-	13.24	3.30	5.94	11.52	22.43	22.42	12.59	-3.30	-3.60
Milk	-20	-	-	12.15	-	-	-	-	-	-	-	-	-	-
	+20	-	-	29.65	-	-	-	-	-	-	-	-	-	-
Meat	-20	56.95	-1.73	-	36.16	8.85	0.09	0.17	7.71	15.61	16.67	6.68	-	-
	+20	86.26	5.96	-	54.24	18.50	7.14	12.87	16.10	30.32	29.07	19.69	-	-

[a]LW, live weight; DoWT, doe live weight; MY, average daily milk yield; CMP, consumable meat percentage; NKW, number of kids weaned; KF, kidding frequency; KR, kidding rate; DoWR, doe weaning rate; DoSR, doe survival rate; PoSR, post-weaning survival rate; PrSR, pre-weaning survival rate; RFIy, residual feed intake yearlings; RFId, residual feed intake does.

4.3.3 Assessment of the influence of economic values on genetic improvement

Table 13 shows the genetic gain in individual traits estimated from different indices. Only the results from SMP under fixed flock-size are presented. Genetic gain in individual traits was achieved by one round of selection on the index with selection intensity (i) of one. Most of the correlations among indices derived in this study were near unity (Table 14). The correlation between I_0 and I_5 was near unity and therefore, I_5 was used as a basis of comparison with other indices.

Application of $I_{FI \times 1.20}$ reduced the genetic gain in all the production traits except CMP (Table 13). Use of this index resulted in an increase in the genetic gain in most functional traits apart from DoWT and PrSR. The converse index $I_{FI \times 0.80}$ had a positive effect on the genetic gain in all production (except LWm and CMP) and functional traits. The results suggest that accurate estimation of feed costs is important because alteration in feed will change the genetic gain in several traits especially those related to production. However, the effect of changing feed costs did not cause any efficiency losses relative to the base index since the correlation between these indices and I_5 was unity (Table 14). However, the correlation between $I_{FI \times 1.20}$ and $I_{FI \times 0.80}$ was 0.9784 (Table 14).

Table 13. Genetic gain in individual traits estimated from different indices for the smallholder medium potential (SMP) production system under fixed flock-size

Index[b]	Traits in the breeding goal[a]													
	LWd	LWm	DoWT	MY	CMP	NKW	KF	KR	DoWR	DoSR	PoSR	PrSR	RFIy	RFId
I_0	0.3315	0.1457	0.6623	0.5000	-0.0203	-0.0347	-0.0521	0.0059	-0.0072	-0.0055	-0.0193	0.0004	-0.0002	-0.0006
I_5	0.3239	0.1425	0.6470	0.5000	0.0214	-0.0336	-0.0504	0.0057	-0.0073	-0.0055	-0.0200	0.0004	-0.0001	-0.0007
$I_{FI\ x\ 1.20}$	0.2790	0.1226	0.5579	0.4000	-0.0190	-0.0060	-0.0090	0.0097	-0.0062	-0.0055	-0.0159	0.0003	-0.0004	-0.0003
$I_{FI\ x\ 0.80}$	0.3251	0.1381	0.6491	0.5000	-0.0139	-0.0002	-0.0004	0.0140	-0.0054	-0.0051	-0.0133	0.0003	-0.0004	-0.0001
$I_{M\ x\ 1.20}$	0.4376	0.1823	0.8697	0.2000	0.0036	-0.0263	-0.0394	0.0167	-0.0029	-0.0021	-0.0060	0.0004	-0.0006	-0.0002
$I_{M\ x\ 0.80}$	0.4300	0.1831	0.8546	0.1000	0.0061	-0.0241	-0.0362	0.0168	-0.0025	-0.0019	-0.0035	0.0004	-0.0010	-0.0003
$I_{ML\ x\ 1.20}$	0.0671	0.0337	0.1384	0.5000	-0.0267	0.0168	0.0252	0.0028	-0.0059	-0.0059	-0.0159	0.0002	-0.0001	-0.0004
$I_{ML\ x\ 0.80}$	0.0671	0.0337	0.1384	0.5000	-0.0267	0.0168	0.0252	0.0028	-0.0059	-0.0059	-0.0159	0.0002	-0.0001	-0.0004

[a]LW, live weight; DoWT, doe live weight; MY, average daily milk yield; CMP, consumable meat percentage; NKW, number of kids weaned; KF, kidding frequency; KR, kidding rate; DoWR, doe weaning rate; DoSR, doe survival rate; PoSR, post-weaning survival rate; PrSR, pre-weaning survival rate; RFIy, residual feed intake yearlings; RFId, residual feed intake does.

[b]I_0, index derived using undiscounted economic values; I_5, similar to I_0 but with discount rate equal to 5%; $I_{FI\ x\ 1.20}$ and $I_{FI\ x\ 0.80}$, indices constructed with economic values derived from increasing and reducing feed costs by 20%, respectively; $I_{M\ x\ 1.20}$ and $I_{M\ x\ 0.80}$, indices resulted from the application of economic values derived from increasing and reducing goat meat prices by 20%, respectively; $I_{ML\ x\ 1.20}$ and $I_{ML\ x\ 0.80}$, indices resulted from the application of economic values derived from increasing and reducing goat milk prices by 20%, respectively.

Table 14. Correlations between different selection indices for the smallholder medium potential (SMP) production system under fixed flock-size

Index[a]	Index[a]						
	I_5	$I_{FI \times 1.20}$	$I_{FI \times 0.80}$	$I_{M \times 1.20}$	$I_{M \times 0.80}$	$I_{ML \times 1.20}$	$I_{ML \times 0.80}$
I_0	0.9997	1.0000	1.0000	0.6839	0.6622	0.9313	0.9313
I_5		1.0000	1.0000	0.6659	0.6427	0.9445	0.9445
$I_{FI \times 1.20}$			0.9784	0.6213	0.5917	0.9134	0.9134
$I_{FI \times 0.80}$				0.7523	0.7242	0.8154	0.8154
$I_{M \times 1.20}$					1.0000	0.3080	0.3080
$I_{M \times 0.80}$						0.2595	0.2595
$I_{ML \times 1.20}$							1.0000

[a] I_0, index derived using undiscounted economic values; I_5, similar to I_0 but with discount rate equal to 5%; $I_{FI \times 1.20}$ and $I_{FI \times 0.80}$, indices constructed with economic values derived from increasing and reducing feed costs by 20%, respectively; $I_{M \times 1.20}$ and $I_{M \times 0.80}$, indices resulted from the application of economic values derived from increasing and reducing goat meat prices by 20%, respectively; $I_{ML \times 1.20}$ and $I_{ML \times 0.80}$, indices resulted from the application of economic values derived from increasing and reducing goat milk prices by 20%, respectively.

Use of $I_{M \times 1.20}$ and $I_{M \times 0.80}$ resulted in an increase in the genetic gain in all traits apart from MY and CMP. The results were similar in these two indices because of the high correlation between them (Table 14). Relative to the base index, the results indicate that the efficiency of selection will be reduced by 33% when meat prices are increased ($I_{M \times 1.20}$) and by 36% when meat prices are reduced ($I_{M \times 0.80}$). The gains achieved in MY were more when meat prices were increased ($I_{M \times 1.20}$) than when they were reduced ($I_{M \times 0.80}$). This indicates that MY increases in importance when meat prices are high in systems both meat and milk are sources of revenue. Application of $I_{ML \times 1.20}$ and $I_{ML \times 0.80}$ resulted in gains that were similar in all traits. A comparison of the different selection indices showed that use of $I_{ML \times 1.20}$ and $I_{ML \times 0.80}$ resulted in the lowest genetic gains in LWd, LWm, CMP, DoWT, KR, DoSR and PrSR. This indicates that the importance of these traits will not be affected when milk prices change. Relative to the base index the efficiency of selection will be reduced by 6% when milk prices are either increased or reduced.

4.4 Discussion

In this study, economic values for biological traits in the three systems were estimated under two bases of evaluation characterising most of the smallholder production systems in Kenya. In addition, the influence of economic values on genetic improvement gain was also assessed. Assessment of the influence on economic values on genetic gain was based on indices that are of relevance to practical breeding programmes. These indices maintained the

direction of genetic change in several traits. The magnitude of genetic gain for each trait was however dependent on the index applied (Table 13). The consequences of selection can change depending on the selection index and criteria used. In practice selection will not necessarily be carried out based on the formal indices, but their development provides a reliable guide to the identification of relevant traits to be included in the breeding goal and the relative emphasis to be placed on each trait (Ponzoni and Newman, 1989).

The two bases of evaluation (fixed flock-size or fixed feed resources) simulated production circumstances that largely influence the flock composition (i.e. replacement policy) of the animals. However, the assumption that the flock-size is constant may not always be true because generally animals are kept in small flocks with fluctuating numbers in the smallholder systems. Likewise, well-defined replacement policies are not apparent and some animals may stay longer in the flock than sound production practise would justify. Under both evaluation bases, the SMP system recorded the highest economic values for traits since this system had the highest revenues (chapter 3).

Production traits increase efficiency by influencing the output. In all systems, economic values for LW and CMP were positive, but were only positive for MY in SMP and SHP (Table 11). The positive values indicate that genetic improvement of these traits would have positive effect on the profitability in these smallholder production systems. However, improving LW could be difficult under conditions in Kenya since marked seasonal changes in the trait may occur due to feeding. In addition, unpredictable date of animal disposal and seasonal variation in animal markets may affect their prices (Bennison et al., 1997; Seleka, 2001). Under these systems, MY was positively related to growth and survival of kids. Therefore, improving MY would be beneficial in influencing the number of animals available for replacement and for slaughter. The importance of survival of the animal in relation to milk and meat production in a production system has been reported (Bennison et al., 1997). This has a number of implications for the way animals are managed within the flock because first, farmers might aim at maximising on the numbers even if the individual productivity is low and second, some traits found to be important might not be perceived by farmers as being of primary importance.

Depending on the base of evaluation, the economic values for functional traits were either positive or negative (Table 11). The positive economic value for DoWT in all systems

under fixed feed resource and in SMP under fixed flock-size indicate that breeding for increased DoWT can still increase the profitability of does in the smallholder production systems. Positive economic value for DoWT has been reported under fixed feed resource in sheep (Kosgey et al., 2003). However, it would be necessary to determine the optimum size of a doe under smallholder production systems where feed is scarce and its availability is variable. The negative economic value for DoWT in SLP and SHP under fixed flock-size agrees with other studies that have estimated negative values for this trait in sheep (Kosgey et al., 2003) and in cattle (Beckman and Van Arendonk, 1993; Visscher et al., 1994). Negative economic value for mature body weight arise when the marginal costs associated with increased maintenance requirements of lactating animals exceed the marginal increase in revenues obtained by selling of culled ones (Groen et al., 1997).

The positive economic values for NKW and DoWR in all systems and for KF and KR in SMP and SLP, stress the importance of improving the reproductive efficiency in these production systems. Inclusion of these traits in the breeding goal would increase the flock off-take which is a tool to change the product output levels of the flock and replacement rates. An increase by one unit in genetic merit of DoSR, PoSR and PrSR resulted in an increase in profit per doe per year in all systems. The effect of these survival traits is exerted through changes in the flock composition, rather than changes in individual performance. In all systems, improvement of survival later in life (DoSR) resulted in higher profits than a similar improvement in survival early in the life of an animal (PrSR). The presence of a large population of young animals that competes for feed and labour with breeding females reduces the overall profitability of a system since this category generally does not contribute to revenues (Ayalew et al., 2003). In general, improving survival and reproduction traits in economic terms in the face of multiple stresses has been proved to be important in subsistence tropical systems (Upton, 1985; Baker and Rege, 1994).

The negative economic value for residual feed intake was expected since an increase in genetic merit of RFIy and RFId only affected costs. Feed intake as a trait in the breeding goal increases cost of feeding animals (Ponzoni, 1992). Since feed is a major input in the smallholder production system, breeds that can cope with the environment, the quality and quantity of available feed, the management and the prevailing diseases are necessary

(Kosgey, 2004). However, increasing feed intake capacity of ruminants may enable the use of lower quality feeds that are less costly (Amer et al., 1998).

4.5 Conclusions

In this chapter, most of the production and functional traits were found to be important, justifying their inclusion in the breeding goal to improve on the overall production efficiency of the smallholder production systems utilising the KDPG. The positive economic values for most traits under fixed flock-size scenario and fixed feed resource indicates that a unit increase in genetic merit for the traits would have a positive effect on the profitability of the systems. A challenge however remains on how to balance higher productivity with improved functional traits such as survival, health, reproductive and feed intake related traits at the same time in order to achieve a more sustainable production. There is the need to provide an optimum breeding programme for the improvement of the KDPG. The results obtained in this chapter indicate that there would be improvement in traits of economic importance even by using simple selection criteria. The primary policy would therefore be to encourage the establishment of easy-to-manage genetic improvement programmes that can later be upgraded when experience is gained.

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CHAPTER FIVE
GENERAL DISCUSSION AND CONCLUSIONS

5.1 Rationale for this study

The KDPG was developed through crossbreeding of two local female (Galla and SEAG) and two exotic male (Toggenburg and Anglo-Nubian) goat breeds firstly to retain indigenous breed adaptability and secondly to incorporate high milk yield potential of exotic dairy goats (Ruvuna et al., 1985). The KDPG development targeted smallholder households with the goal of increasing both meat and milk productivity to contribute towards increased income. However, the inherent variation in smallholder production potential (low input, medium input or high input) and production constraints that often influence the level of utilisation of animal genotype were not adequately considered in the development of KDPG. The potential of KDPG can only be realised if breeding programmes are designed that adequately consider the production potential and constraints in different smallholder production systems. The first step in the design of effective breeding programme is the definition of breeding goals. This study therefore developed breeding goals for the KDPG in Kenya. Firstly, it evaluated biological and economic variables that characterise smallholder production systems utilising the KDPG to gain insights into which production system the KDPG could be better economically utilised. Secondly, it estimated economic values for production and functional traits of KDPG in those production systems in order to identify traits of importance and their relative importance in the breeding goal.

5.2 Methodological approach

5.2.1 Model outline

The deterministic model developed evaluated the utilisation of KDPG in a variety of smallholder production systems. These systems represented those utilising the KDPG in Kenya. The relationships between different activities were described by the flow of inputs and outputs in the system (Figure 3). The flock composition including the life cycle of the doe and the age structure in the flock at a given time clearly defined in Figure 4 is related to product output and resource input in the KDPG smallholder systems. The common inputs and outputs of activities in the system were directly and/or indirectly related to animal traits that influence

efficiency of production. This approach was very useful in understanding the production system, the variables and their relationships (mathematical functions).

5.2.2 Model outputs

The model was able to predict profitability (including revenues and costs) and feed intake for all categories of the animals in the smallholder systems utilising the KDPG. The model described allows the evaluation of both biological and economic aspects of the KDPG within a wide range of management, production, feeding and marketing circumstances. In addition, a section was added to the model to calculate economic values for production and functional traits under two different production circumstances: the fixed flock-size and fixed feed resource scenario. Economic values for traits were obtained using the partial budgeting method where profitability of the flock was compared before and after genetic improvement. Selection index methodology was used to derive response to selection for the breeding goal traits. One round of selection on the index with selection intensity (i) of one in individual traits was used to derive the genetic improvement gain. To determine the change in genetic gain per trait, the assigned economic values were varied subjectively giving rise to a set of selection indices.

5.2.3 Strength and limitations of the model

The approach used was deterministic indicating that the results in the study are completely determined by the input parameters (i.e. biological, economic and management variables). A requirement is that the parameters in the model are changed based on the breed, production systems and production circumstance in question. The model provided vital information on economic and biological characteristics of the KDPG production systems and can estimate the impact of changes in production factors on the economic efficiency of those systems and on economic values of traits.

The model assumed that management was optimal and estimated feed intake based on nutrient requirements. In most of the tropics, especially in smallholder production systems rarely are management regimes optimal. The management levels under such systems are determined by feed resources, flock size, financial resources, farm size, structures and production levels. Estimating feed intake based on nutrient requirements explicitly assumes

that no differences in efficiency of feed utilisation between genotypes exist (Kahi et al., 1998). Making such assumptions in estimating feed intake is better than assuming that feed intake is zero. The model does not provide adequate description of the KDPG performance on the basis of availability and quality of feed resources. The use of integrated models (e.g. Vargas et al., 2002) that include interaction between management practises, nutritional and genetic potential of does needs to be given more attention because of their important impact on estimates of economic values.

5.3 Utilisation of the Kenya Dual Purpose goat

This study showed that it is more profitable to utilise KDPG in SMP systems than in SLP and SHP systems. The differences in profits relate to level of inputs (management, production, feed and economic variables) and output in the systems. Tables 7 to 9 reveal that husbandry costs formed a large proportion of the total production costs in the SMP and SLP system while feed costs were high in the SHP system. Marketing and fixed costs were the lowest in all the systems, respectively.

Better profitability in SMP system is due to higher proportion of the yearling off take. The SLP system had the lowest profits because of a single source of revenue (meat) and lower proportion of yearling off take. It was established that the categories yearlings, breeding does and bucks (culls included) were associated with both revenues and costs while the remaining categories (young animals and replacement flock) were only associated with costs. The latter categories are a form of investment for sustaining the flock population, hence the opportunity cost and revenues associated with these categories are the marketing costs and revenues accruing from the sale of the yearlings and salvage breeding animals.

The traits found to be most important economically are production traits (LW, CMP and MY in systems that sell milk as the second source of revenue) and functional traits (DoSR and PoSR). These were expected because the study reveals that the traits influencing numbers influenced mostly the husbandry costs in the systems while traits influencing weights influenced the feed costs. The producer can therefore concentrate on these traits because they either influence the smallholder systems directly (i.e. increase flock off take and meat sold) or indirectly (i.e. reduce the production costs).

5.4 Profitability of breeding goals

As shown earlier, utilisation of KDPG was more profitable in SMP than in SLP and SHP. Therefore, this system has been used here for the purpose of demonstrating the difference in revenues, costs and profitability both before and after genetic improvement. The values for revenue, costs and profits before genetic improvement were adopted from Table 7 in Chapter 3 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 goal traits produced from the application of the selection indices. Table 15 presents estimated revenues, costs and profits before genetic improvement and after genetic improvement resulting from the application of different selection indices.

Table 15. Estimated revenues, costs and profits per doe per year before and after genetic improvement in the smallholder medium-potential production system.

Selection indices[a]	Total revenue (KSh)	Total cost (KSh)	Profit (KSh)
Before genetic improvement	4905.00	4590.32	315.48
After genetic improvement			
I_0	5492.92	4662.34	830.58
I_5	5487.20	4662.68	824.52
$I_{FI \times 1.20}$	5507.69	4696.89	810.80
$I_{FI \times 0.80}$	5628.93	4751.37	877.56
$I_{M \times 1.20}$	5050.84	4536.98	513.86
$I_{M \times 0.80}$	4709.29	4311.80	397.49
$I_{ML \times 1.20}$	5644.42	4789.42	854.99
$I_{ML \times 0.80}$	5644.42	4789.42	854.99

[a] I_0, index derived using undiscounted economic values; I_5, similar to I_0 but with discount rate equal to 5%; $I_{FI \times 1.20}$ and $I_{FI \times 0.80}$, indices constructed with economic values derived from increasing and reducing feed costs by 20%, respectively; $I_{M \times 1.20}$ and $I_{M \times 0.80}$, indices resulted from the application of economic values derived from increasing and reducing goat meat prices by 20%, respectively; $I_{ML \times 1.20}$ and $I_{ML \times 0.80}$, indices resulted from the application of economic values derived from increasing and reducing goat milk prices by 20%, respectively.

Genetic improvement of breeding goal traits resulted in an increase in profitability for the indices. Most of the indices produced similar results in terms of revenues, costs and profitability mainly because of the correlation among them. The profits were more when feed prices were reduced ($I_{FI \times 0.80}$) than when they were increased ($I_{FI \times 1.20}$). The opposite was also true for indices $I_{M \times 0.80}$ and $I_{M \times 1.20}$. Use of index $I_{FI \times 0.80}$ produced the highest profits while the lowest profits were observed in $I_{M \times 0.80}$. This suggests that reducing the costs of feed and increasing meat prices have a greater influence on the revenues than costs of the system. Application of $I_{ML \times 1.20}$ and $I_{ML \times 0.80}$ resulted in profits that were similar indicating that

changes in future milk prices have little effect on the genetic improvement of the breeding goal traits in the system.

5.5 Design of sustainable breeding programme for the Kenya Dual purpose goat

Sustainable production is environment specific and is therefore important in different ways for smallholder goat farmers in Kenya. Results from the study have shown that the utilisation of the KDPG breed in the smallholder households needs to match with production objectives of the farmer, the management potentials and with the environment. Therefore, production systems, farmers' constraints and available infrastructure must be considered seriously during the implementation of a sustainable breeding programme. In the tropics, the number of sustainable breeding programmes utilising the indigenous stock of small ruminants is limited (Kosgey et al., 2005). Despite the considerations given for developing breeding programmes in the tropics, most of them have often failed. Lack of participation of farmers and other stakeholders in the planning and decision-making process of livestock improvement programmes is most likely the major cause of failure (Wollny, 2003; Kosgey, 2004). Failure of breeding programmes can thus be minimised when the present production system and breeding goals are derived through participation of the target group (Jaitner et al., 2001).

There is evidence of operational breeding programmes for smallholder systems utilising crossbred dairy goats in Kenya e.g. Kenya Alpine Dairy goat. For the KDPG breed, the breeding programme has not been very successful probably due to constraints related to uncommitted stakeholders, sub-optimal prevailing policies on small ruminant development and unclear breeding goals for the breed. This means that the existing breeding programme need to be redefined so as to satisfy a majority of KDPG farmers in Kenya given that there is a high demand for a dual purpose goat breed in the smallholder and pastoral production systems.

5.5.1 Current status of Kenya Dual Purpose goat

The KDPG breed has a potential to produce milk and meat in the smallholder production systems. Currently, KARI's National Animal Husbandry Research Centres in Naivasha, Perkerra and Katumani have the mandate to select, stabilise and distribute the

breed. The overall selection process at the main breeding station has resulted in an average mature size of 38kg at 2 years of age in 90% of the animals while 75% of the animals are stable in terms of milk yield of at least 1kg per day above the kid requirements (Muhuyi and Siamba, 2000). Selection for increased milk production is on going in an attempt to target 4kg per day at peak lactation. Currently, the breed has a population size of about 300 animals in Naivasha and about 100 animals in the other two stations which serve as multiplication centres. In all the centres the stabilisation of the breed is at its intermediary stages. However, small numbers limits rapid stabilisation and distribution of the breed to smallholder farmers. Stabilisation of the breed has been going on since the establishment of the four-way crosses in the early 1990s. It should be noted that the KDPG remains so far the only synthetic livestock breed ever developed in Kenya, therefore negligence through improper genetic conservation and other husbandry measures that would lead to depletion of such a valuable genetic resource should be minimised.

5.5.2 Choice of breeding structure

Due to the small population sizes of the KDPG flock and scarcity of resources in the smallholder production systems it is critical to optimize the little that is available. This is possible if the genetic improvement is generated in a small fraction of the population (referred to as the nucleus), while at the same time controlling the pedigree (i.e. inbreeding) (Kosgey et al., 2005). This will guarantee adequate performance testing, pedigree and trait recording and genetic evaluation (Jaitner et al., 2001). Since all of these will be done in the nucleus, high costs arising from these components in the field populations are evaded (Smith, 1988). The genetic progress in the nucleus can be disseminated to the participating herds through use of males originating from the nucleus. The programme should address how these superior genes can be disseminated at the shortest time possible throughout the whole population. This will depend on the amount of recording and degree of genetic gain aimed for, and the number of improved animals required for dissemination (Kosgey, 2004).

To maximise genetic improvement, reduce inbreeding rate and reduce the total recording costs in the participating herds, a 2-tier breeding structure is recommended for establishment (Bondoc and Smith, 1993). The flock(s) owned by the government can be considered as the central nucleus, while other smallholder flocks can be considered to be the

participating or commercial flocks. The nucleus can be opened to allow introductions from the participating flocks or closed completely to importation from outside. In the tropics, 2-tier open nucleus breeding schemes for small ruminants have been found useful and often successful e.g., the improvement of growth and live weight of the local Djallonké sheep breed (Yapi-Gnoaré, 2000).

5.5.3 Choice of selection criteria

In the KDPG breeding programme selection to stabilize the breed was initially based on the individual performance records, with some attention to progeny and parental information (Ruvuna et al., 1985). The criteria used for selection was optimal growth (weight/age through life time) and lactation (milk production/lactation) established as optimal by system analysis from western Kenya. However, no justification is given for selection of the traits or the definition of breeding goal and improvement of growth and milk yield of the breed, while reproduction and adaptation are neglected. In this study, breeding goals for the breed have been clearly defined while a simple selection criterion was used in the prediction of response to selection of traits. A number of traits and sources of information were considered in these selection criteria. These could be expanded to increase accuracy of selection in future. Information sources on half sibs, full sibs, and relatives could be included while more characters such as scrotal circumference in sires (e.g., Rewe, 2004), slaughter weight and dressing percentage (in relatives) can be introduced. However, the high costs associated with the 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).

5.5.4 Proposal for establishment of a breeding programme

The initial objective would be to stabilise the breed and this would involve breeding within a closed nucleus until the numbers to run an efficient breeding programme is realised. The aim would be to run a programme that would include 2500 does in the nucleus with over 50,000 does in participating farmer flock after a number of generations. To start with, apparently superior males and female foundation animals would be screened from the current population of 400 animals. The superior animals would be expected to contribute to the

improvement of the gene pool of a whole population of animals in the nucleus. Animals in the nucleus would be ordered according to performance using the available performance measurements and identification systems. The better performing animals are expected to have superior genes for the traits of interest. Efforts would be made to have a wide selective mating in the nucleus to minimise co-ancestry (restrict inbreeding) among selected individuals and appropriately optimise the minimum population size during stabilisation. After several generations of breeding, it is expected that the flock would eventually be more 'uniform', reflecting the breeding goal.

To realise this objective under the current production scenario, KARI's NAHRC Ol' Magogo station in Naivasha would be the nucleus. Since the demand for this breed is high and KARI is the only source, we need multiplication centers. These centers would be KARI's station located in Katumani and Perkerra. Males from the nucleus would be mated to a group of females (surplus females) to form a multiplier flock. The progeny born from the multiplier dams would then be used or disseminated as foundation stock to the commercial farmers. This would be done when the nucleus attains about 2500 animals after a number of generations. The biological and technical parameters are outlined in the example below.

A closed nucleus breeding scheme supplying young breeding animals to the multiplication flocks is assumed. The nucleus size is 300 does. There is rigorous recording of performance and/ or pedigree in the nucleus population. Natural mating is assumed with a mating ratio of 1:30. With this mating ratio, a broad selective mating in the nucleus can be realised since a total of 10 bucks is required for mating. The bucks are used for breeding when they are one year old and culled at 24 months of age. The does are mated at 12 months of age so that they kid for the first time when they are 18 months old. The generation interval for the bucks and does is 2 years. Figure 8 shows an outline of the structure of this breeding programme plus the assumed population parameters. These parameters are similar to those presented in Table 4 for SMP. Unless otherwise stated, the number of animals are estimated using information in Figure 4 with N = 300 in this case. Since the aim is to increase the flock size, a high number of females is required for replacement. This has been assumed to be 0.44N here while the number of surplus females assumed to be 0.067N.

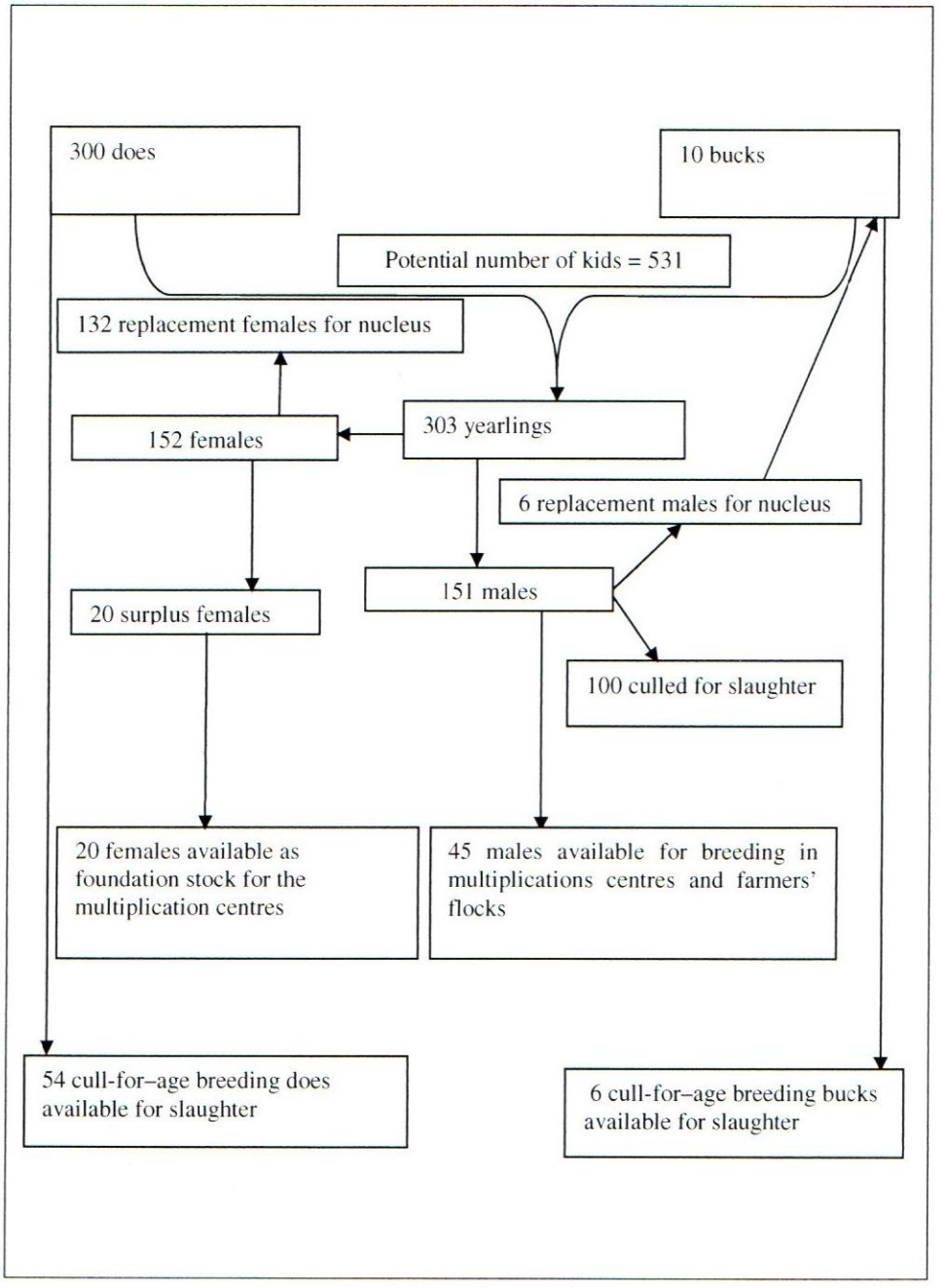


Figure 8. Outline of the structure of the breeding programme

Since the productive lifetime of the bucks is 2 years, 6 bucks are needed each year (i.e. 6/151), this gives a selection intensity of 2.15. Since the aim is to increase the number of does in the nucleus, 90% of the 12 months old females are selected for breeding in the

nucleus. Therefore, the selection intensity for females is low, 0.27 (i.e., 132/152). In the breeding programme, a simple breeding goal and selection criteria is considered. The breeding goal assumes that the breed serves a dual purpose role producing both meat and milk. Five traits relevant to the smallholder systems are included in the breeding goal i.e., LW, MY, DoSR, PoSR and NKW. Economic values estimated for the base situation (SMP) are presented in Table 11. A simple selection criteria is assumed and consists of measurement of WW on all animals and MY and KI in females. In dam's dam, paternal half sib of sire and paternal half sib of dam, information sources included records of MY and KI. While in sire's dam, information sources included records of WW and MY. Estimates of heritability, phenotypic standard deviation and correlation for the breeding goal and selection criteria traits for this assumed scenario is shown in Table 10.

Four selection pathways of genetic improvement are assumed. In the sires of sires (SS) pathway, only the top 2% of the tested sires will be selected. This is because sires can mate many females so only a few bucks would be required to produce young males in each generation. The top 10% of the young bucks are selected in the sires to dam (SD) pathway since there are several does to be bred and many more bucks are required for mating. Accuracy of selection is similar in the SS and SD pathways because they are chosen on the same basis of the information sources. In the dams to sires (DS) pathway, only the best 5% are selected because there are several does and only a few sons would be tested. The top 90% of all does are required for breeding in the dams to dams (DD) pathway because there is little room for selection of dams of daughters. The doe has barely sufficient time to produce a replacement before she leaves the flock after about five lactations.

Table 16 shows the genetic gain in the breeding goals traits in each selection pathway. The SS pathway has the highest and DD pathway the lowest genetic gains. This stresses the importance of sire selection in any breeding programme. These results show that with a single nucleus of 300 does, there can be genetic progress in the breeding goal traits by simply selecting young does and bucks using simple selection criteria. Of great importance is the predicted direction of genetic change in the breeding goal traits in the selection pathways which is consistent with what would be perceived as desirable long-term changes for the KDPG breed. Further gain in these traits is anticipated with an increase in the population size.

Table 16. Genetic gain in the breeding goals traits in each selection pathway

Breeding goal traits[b]	Selection pathways[a]				
	SS	SD	DS	DD	Total gain
LW, kg	0.5916	0.4278	0.4735	0.0378	1.5307
MY, kg	0.7374	0.5313	0.5879	0.0470	1.9036
DoSR, %	0.0626	0.0453	0.0501	0.0040	0.1620
PoSR, %	0.0257	0.0186	0.0205	0.0016	0.0664
NKW	0.1442	0.1043	0.1154	0.0092	0.3731

[a]SS, sires of sires; SD, sires of dams; DS, dams of sires; DD, dams of dams.
[b]LW, live weight; MY, milk yield; DoSR, doe survival rate; PoSR, post weaning survival rate; NKW, number of kids weaned

With a starting population size in the nucleus of 300 ewes and the assumed population parameters, the flock size will increase by 78 does in the first year. As a result, the number off springs to be selected as breeding females in the next generation is increased. In the first year of the programme, the population of does in the nucleus will be 378 and the multiplication centres will be supplied with 20 females as the foundation stock (Figure 8). Only one (i.e. 0.067 x 20) doe will be available for the commercial sector. Table 17 shows the predicted number of does in subsequent years in the different breeding tiers. 10 years after the start of the breeding programme.

Table 17. Predicted number of does in different breeding tiers

Tier	Years										
	Start	1	2	3	4	5	6	7	8	9	10
Nucleus	300	378	476	600	756	953	1,201	1,513	1,906	2,402	3,027
Multiplication		20	50	95	160	253	383	563	810	1149	1609
Commercial		1	4	11	25	49	88	149	242	382	589

These values have been obtained using the same biological parameters in all the breeding tiers. The number of does in subsequent years in each breeding tier is calculated as:

Nucleus

$$N_i^n = N_{i-1}^n + \left(0.44N_{i-1}^n - 0.18N_{i-1}^n\right) \quad (41)$$

Multiplication flocks

$$N_i^m = N_{i-1}^m + \left(0.44N_{i-1}^m - 0.18N_{i-1}^m\right) + 0.067N_i^n \quad (42)$$

Commercial flocks

$$N_i^c = N_{i-1}^c + \left(0.44N_{i-1}^c - 0.18N_{i-1}^c\right) + 0.067N_i^m \quad (43)$$

where N_i = total number of does in the current year, N_{i-1} = total number of does in the previous year, $0.44N_{i-1}$ = number of females for replacement, $0.18N_{i-1}$ = number of cull-for–age breeding does and $0.067N_i$ = number of surplus females and superscript n, m and c represent the nucleus, multiplication and commercial tiers, respectively.

The required population size in the nucleus would be attained within the 9th year. As expected, the number in the lower tier would increase slowly because of the emphasis placed on increasing the size of the nucleus. Alternatively, the does culled in the nucleus due to age could also be utilised in the lower tiers. After attainment of the required nucleus size, the emphasis would be to maintain the size thereafter during which the population in the lower tiers would be increased drastically. In the 15th year of the programme, the population in the multiplication and commercial sectors would be 10,966 and 4,938, respectively. The corresponding population in the 20th years would be 19,956 and 53,880.

In a large population size, low inbreeding and high selection intensities are expected. When the population size is large enough, use can be made of different breeding structures for the improvement of KDPG. The closed nucleus can be opened for replacements from the farmers' flocks there by increasing variance in the population. However, in the long run use of any breeding structure should first address the logistics of applying them (Gicheha et al., 2005).

5.6 Conclusions

Bio-economic profit functions suitable for the prediction of profitability were constructed for each of the three smallholder systems utilising the KDPG. The models were able to simulate the utilisation of this breed in the different smallholder production systems i.e. predicting feed intake, revenues and costs of the systems. This study has demonstrated that this evaluation models can be a useful tool for the management, production and marketing strategies in the KDPG enterprise and can therefore provide a more realistic platform to propose sound improvement interventions.

The results from this study provided essential information about the potential profitable use and the types of traits that should be considered in a breeding goal for the KDPG under the smallholder production systems in Kenya. The traits found to be most important economically were the production traits (i.e. LW, CMP and MY in systems that sell milk as the second source of revenue) and functional traits (DoSR and PoSR).

The genetic efficiencies in the traits of economic importance for the different selection indices applied were desirable in the systems studied. As expected, breeding goals differed in their effects on profits and genetic improvement gain in the KDPG genotype. These indices were developed to provide a reliable guide to the identification of relevant traits to be included in the breeding goal and the relative emphasis to be placed on each trait. The current study did not include disease resistance, adaptation traits and intangible roles in the breeding goal. Further work on the estimation of economic values for such traits and their influence on genetic improvement is needed.

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