

DAIRY CATTLE BREEDING POLICY FOR KENYAN
SMALLHOLDERS: AN EVALUATION BASED ON A
DEMOGRAPHIC STATIONARY STATE
PRODUCTIVITY MODEL

BY

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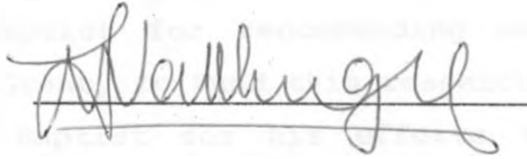
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DECLARATION

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



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Date 15/11/2001

This thesis has been submitted for examination with our approval as university supervisors.

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DEDICATION

This work is dedicated to the rural dairy farmers who toil to raise cattle to feed the nation.

TABLE OF CONTENTS

	Page
TITLE OF THESIS.....	i
DECLARATION	ii
ACKNOWLEDGEMENTS	iii
DEDICATION.....	iv
TABLE OF CONTENTS	v
LIST OF TABLES.....	x
LIST OF APPENDICES	xii
ABSTRACT	xiii
1.0 INTRODUCTION	1
1.1 Historical Perspectives of Dairy Development in Kenya.....	1
1.2 Present State of Dairy Industry in East Africa with Specific Reference to Kenya.....	3
1.3 Dairy Development Policies and Strategies in Kenya.....	8
1.4 Problem statement.....	10
1.5 Objectives and Hypotheses.....	14
2.0 LITERATURE REVIEW	16
2.1 Dairy Development Policies and Strategies in SubSaharan Africa.....	16
2.2 Constraints in Smallholder Dairy Sector in the Developing Economies.....	18
2.3 Breeding Programmes for Smallholder Dairy Cattle in the Developing Economies.....	23

2.4	Production Performance	29
2.4.1	Survival versus Production	29
2.4.2	Genetic Potential and Commercial Optimum	30
2.4.3	Genetic Correlation Among Milk Yield, Reproductive and Survival Traits	31
2.4.4	Economic Weights in Dairy Cattle Improvement	33
2.5	Livestock Productivity Models	34
2.5.1	The Roles of Models	34
2.5.2	Models Computer Package Application Capabilities	37
2.5.3	Efficiency and Sufficiency of Model Options	42
2.5.4	Model Sensitivity Analysis	43
3.0	MATERIALS AND METHODS	47
3.1	The Study Area: Environment, Farming and Time Period	47
3.2	Breeding and Management of Smallholder Grade Dairy Herds ..	49
3.2.1	Breed Groups	49
3.2.2	Herd Management	50
3.2.2.1	Extensive Open Grazing System	50
3.2.2.2	Semi-Zero Grazing System	51
3.2.2.3	Zero Grazing System	52
3.3	The Data Collection and Processing	53
3.3.1	Questionnaire	53
3.3.2	Coding	57
3.3.2.1	Base Record	57
3.3.2.2	Lactation Record	58
3.3.2.3	Climatic Record	58
3.3.2.4	Herd	59

3.4	The Structure of Data for Statistical Analyses	59
3.4.1	Statistical Analyses of Data	61
3.4.1.1	Production and Reproductive Traits and Produce Prices .	61
3.4.1.2	Selective Culling Rate and Survival Traits	65
3.5	Calculation of Productivity Index	68
3.6	Sensitivity Analyses	70
3.7	Milk Yield Trade-offs and Fitness Losses Evaluation	71
4.0	RESULTS	75
4.1	Lactational Milk Yield	75
4.2	Age at First Calving	77
4.3	Calving Interval	79
4.4	Selective Culling Rate of Heifers and Cows	79
4.5	Survival Rates by Age Groups	82
4.5.1	Calves (0-4 months)	82
4.5.1.1	Males	82
4.5.1.2	Females	82
4.5.2	Youngstock (5-30 months)	84
4.5.2.1	Heifers	84
4.5.2.2	Bulls	86
4.5.3	Adult Stock (31-144 months)	87
4.5.3.1	Cows	87
4.5.3.2	Bulls	88
4.6	Prices of Products and Stock	91
4.6.1	Milk	91
4.6.2	Cows	91
4.6.3	Calf Prices	93

4.6.3.1 Bull Calves	93
4.6.3.2 Female Calves	94
4.7 Breed Group Productivity	96
4.7.1 Optimal Culling Strategies	96
4.7.2 Feed Energy Efficiency (FEE) Index	96
4.7.3 Sensitivity of Breed Groups	99
4.7.4 Trade-Offs: Milk Yield and Fitness Losses	101
5.0 DISCUSSION	104
5.1 Milk Production	104
5.2 Reproductive Traits	107
5.2.1 Age at First Calving	107
5.2.2 Calving Interval	109
5.3 Selective Culling Rate of Breeding Females	110
5.4 Survival Rates	112
5.5 Prices of Products and Stock	114
5.6 Breed Group Performance	118
5.6.1 Factors Affecting Breed Group Productivity	118
5.6.2 Breed Group Choice	120
5.7 Breeding of Dairy Cattle in Smallholder Herds	124
5.7.1 Economic Weights in Breeding Objectives	125
5.7.2 Breeding Policy Evaluation	129
6.0 CONCLUSIONS AND RECOMMENDATIONS	136
6.1 Conclusions	136
6.2 Recommendations	137
7.0 REFERENCES	139

8.0 APPENDICES 162

LIST OF TABLES

Table No.	Title	Page
1:	Nairobi middle class consumer price index in the period 1980-1992.....	56
2:	The structure of the data	60
3:	Estimated least squares means and standard errors for lactational milk yield by breed groups	76
4:	Estimates of least squares means and standard error for AFC and CI, by breed groups	78
5:	Maximum likelihood estimates and standard errors of selective culling rate in heifers and cows by breed groups (converted from logit model) ...	81
6:	Maximum likelihood estimates and standard errors of survival rates of calves (0-4 months) (converted from logit model)	83
7:	Maximum likelihood estimates and standard errors of survival rates of young stock (5-30 months) by breed groups (converted from logit model)	85
8:	Maximum likelihood estimates and standard errors of survival rates of adult stock (31-144 months) by breed groups (converted from logit model)	90
9:	Estimates of least squares means and standard errors for the prices of milk, cow, heifer and bull calves, by breed groups	92
10:	FEE Index and the cull-for-age of threshold for breeding female, surplus female	

and male by breed groups 98

11: Sensitivity of the FEE Index to changes in the
productivity components of breed groups 100

12: Lactational milk yield trade-off for marginal
loss in fitness traits of dairy breed group 103

LIST OF APPENDICES

Appendix No.	Title	Page
1:	Kenya smallholder dairy herd data field questionnaire	162
2:	Analyses of variance of lactation milk yield	163
3:	Analyses of variance of calving interval (CI) and age at first calving (AFC)	164
4:	Maximum likelihood analyses of variance for selective culling rate for heifers and cows (from logit model)	165
5:	Maximum likelihood analyses of variance of survival rates for calves (0-4 months) (from logit model)	166
6:	Maximum likelihood analyses of variance for young stock survival rates (5-30 months) (from logit model)	167
7:	Maximum likelihood analyses of variance of adult stock survival rates (31-144 months) (from logit model)	168
8:	Analyses of variance for prices of milk, cow, bull calf and heifer calf	169

ABSTRACT

A study was done based on records generated in the period 1980-1992 in 398 smallholder herds in 23 districts located in the high and medium potential areas at low, medium and high altitudes to evaluate two long term breeding policy options in the smallholder grade dairy cattle populations by use of a demographic stationary state productivity model-PRY. The first option was the current policy, where there was equal sharing of imported and locally progeny tested AI semen for breeding both the large- and small-scale herds. The second option was whereby there would be use of semen of bulls bred and progeny tested within the smallholder herd environment. The inputs to the productivity model were estimated by least squares analysis procedures. The grade dairy breed groups were Friesian, Ayrshire, Guernsey, Jersey, Nondescript, two F_1 crossbreds of Friesian or Ayrshire (F_L) and Jersey or Guernsey (F_S) with zebu and their respective backcrosses R_L and R_S ; and the Kilifi breed. The respective overall means and standard deviations for lactational milk yield, calving interval, age at first calving and selective culling rate of heifer and cow were 2430.71 and 477.71 kg, 13.88 and 1.64 months, 39.48 and 8.10 months, 9.20 and 5.0 %; and 23.40 % and 6.03 %. The respective overall means and standard deviations for survival rates were 83.80 and 30.90; 83.20 and 21.31; 84.30 and 32.66; 88.02 and 28.38; 80.01 and 30.21; and 84.36 and 31.02% for pre-weaning period of female and male calf; post-weaning period of young stock female and male; and for cows and bulls. On basis of productivity model, the R_L was found not to be sustainable under the smallholder environment. The overall productivity in Ksh/kg dry matter intake per animal-year were 1.322, 1.501, 1.896, 2.369, 1.967, 1.950, 2.257, 2.218 and 2.176 for Friesian, Ayrshire, Guernsey, Jersey, Nondescript, F_L , F_S , R_S and Kilifi respectively. These results confirmed the suitable breed groups choices to be Jersey, F_S , R_S , Kilifi, F_L , Nondescript

and Guernsey since they had outstanding lactational milk yield, fitness and production efficiency. Sensitivity analyses indicated rank of traits by relative economic values, in descending order, to be lactational milk yield, age at first calving, selective culling rate, calving interval and post-weaning survival rate in females. The trade-offs of potential milk yield increment for fitness loss in the pure breeds were greater than realised annual genetic increment of 6.29 kg milk yield under the current breeding programme. The results also showed that in the projected future, where smallscale farmers will have access to and heavy reliance on imported semen, resulting in the expected annual genetic gain of 38 kg of milk, Jersey will be favoured but the rest of pure breeds will require the alternative breeding policy option. The study has established the existence of the genotype-environment interaction with respect to dairy breed groups kept on smallscale farms. Therefore, it was recommended that breed choice and breeding programme be modified to match the environment attainable in the majority of smallscale farms.

INTRODUCTION

1.0

1.1 *Historical Perspectives of Dairy Development in Kenya*

Kenya is a country with a land area of 582,644 km² located on the Equator within East Africa. There is a wide range of agro-climatic zones, but much of the country is dry. More than 80% of the country receives less than 700 mm of rain per year. However, the area under irrigation is quite small. Hence only about 20% of Kenya can be regarded as land suitable for rainfed agriculture (Jaetzold and Schmidt, 1983).

The human population is estimated at 28.6 million. About 90% of this are employed in agriculture, of which 10% are pastoralists. Cattle are widely distributed in the country with 50% being located in the rangelands and the rest are in settled agricultural lands (MALDM, 1996).

The establishment of the colonial regime in Kenya in the early part of the 20th century was accompanied by great changes in structures of land ownership and access to land use. A large-scale farm sector producing for local and export markets emerged and was separated from mainly subsistence African agriculture by the division of the country into "scheduled" areas, reserved exclusively for actual or potential use of European settlers, and "non-scheduled" or "reserve" areas for African use (Hopcraft et al., 1976). In all about 20% of the arable land area was set aside for European use.

At first, all agricultural policies and research were entirely

there was gradual shift of emphasis to the development of African agriculture such that in the 1940s some Africans began introducing grade cattle in their farms. But it was not until the 1954 Swynnerton Plan that opposition to this introduction was abandoned (Hopcraft et al., 1976).

Just before independence, plans were made for the settlement of Africans on sub-divided large scale mixed farms. The settlement process was accomplished between 1961 and 1971. This process has resulted in a number of different land holdings:-

- i) large plantations and ranches, many of which produce for both the domestic and export market;
- ii) large-scale mixed farms, most of which are owned by individual Africans or groups through societies or cooperatives;
- iii) small scale individual farms in former reserve areas;
- iv) the extensive arid lands, communally owned by pastoralist and nomadic tribes.

Today there is large scale/small scale farm dualism with tendency to sub-divide more large scale farms into smallholdings. The large scale farms are averaging 600-700 hectares in striking contrast to the small-scale farms in which a majority are less than 1.5 hectares and very few are more than 5 hectares (MALDM, 1994).

The dairy development thrust, which started within the large scale farms in 1920s in the scheduled areas, aimed at importation of grade cows and bulls from Europe, cross breeding

exotic dairy breeds with Zebu cattle and disease control. A total of 100,000 grade dairy cattle existed by 1935, rising to about 600,000 by 1963. This cattle population was the main supplier of milk to urban areas and for export (Hopcraft et al., 1976).

Dairy development in the post-independence era has been mainly oriented to the small-farm sector. The settlement schemes made it possible for many small scale farmers to own thousands of grade cattle in the former scheduled areas (Hopcraft et al., 1976). Artificial insemination (AI), disease control and improved husbandry programmes have facilitated the upgrading of the indigenous cattle to exotic dairy breeds. Credit facility policies have also made it possible for many smallscale farmers to obtain grade animals. Thus through government support dairy cattle husbandry has become primarily a small scale farm enterprise.

1.2 Present State of Dairy Industry in East Africa with Specific Reference to Kenya

Reliable statistics on livestock numbers, including dairy cattle, are not available. This lack of statistics implies that dairy development plans are more often based on estimates (Wakhungu and Baptist, 1992a).

Kenya's cattle population is estimated at 13 million head, 20% of which form the national grade dairy herd consisting mainly of the European dairy breeds and their crossbreds with the zebu (MALDM, 1996). Nonetheless, reliable estimates of European

breed populations are lacking, although their crossbreds with zebu were estimated at 38% of the national grade dairy herd in 1990 (MLD, 1990).

The grade dairy herd is concentrated within the medium to high potential arable zones, with 80% of it located in the Rift Valley and Central provinces, while the rest is spread variably over the other provinces (MALDM, 1996).

The importance of the grade dairy herd is reflected in its contribution of 60% compared to that of 21, 15 and 4% by zebu cattle, camels and goats, respectively, to the national total milk production estimated at over 2448.4 million litres (MALDM, 1997). The small scale grade dairy herds in high potential areas contributed to over 80% of the over 1000 million litres sold through the formal market channels (MALDM, 1996).

Approximately 75% of the herd is located on mixed crop-livestock small scale farms (Wakhungu and Baptist, 1992a). Hence small scale dairy herds in high potential areas continue to be highly emphasized in the National Livestock Development Policy (Kayongo et al., 1992).

Traditional dairy production systems which comprise the largely subsistence dairy sub-sector include pastoralism and the agro-pastoralism. Both of these are characterised by low inputs with resultant low productivity. Nevertheless, these systems depend on large numbers of animals (FAO, 1995).

The improved dairy production systems in high potential areas consist of the intensive crop-livestock smallholder units, peri-urban units and semi-intensive medium/large scale units. They mark the point of market-orientation and the application of improved technology for improved and sustainable production (Olaloku et al., 1990). Thus, currently, dairying in high potential areas is regarded as one of the best means of providing resource-poor smallholders with regular incomes (Yates, 1988).

Following the adoption of the economic structural adjustment programme (SAP), the opportunities for increased domestic dairy production have improved due to high farm gate prices for milk (MALDM, 1994). In addition, the government's decision to liberalize the domestic dairy market has brought with it experiences that indicate that smallholder production systems provide the best basis for increasing sustainable domestic production (MALDM, 1995). However, milk yield per cow from smallholder systems in high potential areas of the country is well below the potential demonstrated on commercial large scale farms (MALDM, 1996).

The Livestock Development Department in the Ministry of Agriculture has set up and supported dairy cattle recording schemes to promote dairy production (MALDM, 1996). These schemes are beset with organisational and financial problems which lead to poor delivery of feedback to assist producers to improve their herd management (CAIS, 1999). Most of the recording schemes have not addressed adequately the smallholder

herds which are increasingly dominating the dairy industry.

In high potential areas where intensification of dairy production systems is necessary, animal feeds and other inputs continue to be either unavailable or too expensive for the farmer (MALDM, 1995). Animal diseases continue to take unacceptable toll of the dairy production potential due to the recent introduction of SAPs in animal health services.

Estimates of adult dairy cattle mortalities range from 15 to 30% while in calves it may be as high as 30% (MALDM, 1996). However, artificial insemination and veterinary services are being privatised to meet the demands of a liberalised dairy industry (KNAIS, 1995).

The infrastructure for delivery of inputs in a majority of cases has broken down, e.g the poor state of roads and railway transport. Most of the roads are impassable during the wet season coinciding with the milk surplus period (MALDM, 1994). Also the marketing of milk and dairy products in newly emerging dairying regions in Coast, Nyanza and Western provinces has been left unorganised (MALDM, 1996).

The first national step in the genetic improvement of the dairy cattle in Kenya can be seen in the re-organisation of the National AI Service in 1966. The growth of this service has been very rapid until recently when major bottle-necks arose with the introduction of economic structural adjustment Programmes (KNAIS, 1996). This among other problems has

adversely affected the performance of the National Dairy Cattle Breeding Programme.

For the national dairy cattle breeding programme, the Livestock Recording Centre (LRC), the Kenya Milk Records (KMR), the Kenya Stud Book (KSB), the Central Artificial Insemination Station (CAIS) and the Breeders' Societies are institutions involved in its operation. The LRC calculate and provide proofs of sires to be used for AI Service in the dairy cattle herds (CAIS, 1999).

The breeding programme covers the four exotic dairy cattle breeds, i.e Friesian, Ayrshire, Guernsey and Jersey. It aims at breeding AI bulls from the Kenya grade dairy cattle population which are adapted to the local environment (LRC, 1994).

The semen used in contract mating scheme in the programme is from the most outstanding proven bulls (imported or locally bred). The cows (bull dams) used in this scheme are also outstanding as shown in their records at KSB and KMR (CAIS,1999).

The young bulls born out of the contract mating are progeny tested in large scale commercial dairy herds environment. The semen from the bulls with outstanding proofs is collected, processed and packaged by the CAIS and distributed to dairy herds, an increasing majority of which are located on smallholder farms (CAIS, 1999).

The current state of the National Dairy Cattle Breeding

programme organizational description, as alluded to above, leads to the identification of the main pillars of the current genetic improvement policy in smallholder dairy cattle herds. The policy could be defined as being the breeding of AI bulls by contract mating of cows (bull dams) and progeny testing of young AI bulls under large scale commercial farms environment. Hence, in its set-up, the breeding programme ignores the fact that the large scale farms environment is substantially different from that provided for dairy cattle herds on smallscale farms.

1.3 Specific Dairy Development Policies and Strategies in Kenya

The dairy sub-sector is one of the fastest growing within the livestock sector in Kenya. The introduction of the School Milk Programme in 1979 and the recent introduction of economic structural adjustment measures have resulted in an increase in demand in the total marketed milk. The following is a summary of the long-term policies in the sub-sector (MLD, 1981; MALDM, 1993) aimed at national self sufficiency and export of surplus animal products:-

(a) Increasing the dairy herd mainly by:-

- i) the use of A.I. and bull schemes to upgrade zebu cattle;
- ii) a ban on slaughter of breeding dairy stock particularly heifers; and
- iii) reduction of mortality and calving intervals through improvement in the animal husbandry, feeding and disease control.

(b) Productivity improvement through:-

- i) research and breeding for higher milk yields;
- ii) attention to improved feeding, i.e fodder, concentrates and minerals;
- iii) regular price adjustments (the milk price has been liberalised since 1992) which give farmers incentives to maintain the viability of dairy enterprises;
- iv) provision of credit to purchase and maintain grade cattle.

(c) Improvement in the marketing of milk through:-

- i) regular maintenance of the rural access roads by improvement in funding of rural works programmes;
- ii) the improvement of cooperative management as well as the establishment of a series of milk collection and cooling centres.

(d) Intensification of the production system through:-

- i) extension; (ii) research; and (iii) training

The strategies to realise the development of the dairy sub-sector are based on the analysis of the ecological potential and its related infrastructural development (MLD, 1981; MALDM, 1993). Nevertheless, their rate of implementation solely depends on government budgetary constraints. In summary they include:-

- (a) In high potential and highly developed dairying districts of Central and Rift Valley provinces the main emphasis is on intensified production supporting services;

- (b) In high potential districts with under developed marketing infrastructures, the emphasis is on road development, intensified production systems, A.I. and disease control programmes;
- (c) In districts of medium dairy potential at various levels of infrastructure development, the emphasis is on disease control, especially tick borne diseases;
- (d) In areas with only sections that are suitable for dairy development, the main emphasis is on substantial investments in dairy production through provision of credit facilities by commercial banks and the Agricultural Finance Corporation; and
- (e) In arid and semi-arid areas with seasonal milk surpluses, the emphasis involves tapping of the excess milk during the wet seasons from cattle, camels and goats.

1.4 Problem Statement

Smallholder dairy production in Kenya is carried out on small-scale farms with mean herd size of 2.5 mature cows. On these farms, dairy cattle are integrated to food and cash crop enterprises with the aim of exploiting the available resources of production for the good of the entire farming system.

Most of the small scale dairy farms are not well endowed with resource inputs (Muinga, 1992). Thus the grade dairy cattle can only realise their full potential for milk yield when increased resource inputs are devoted to production of quality forage, purchase of concentrate feeds and drugs.

The rise in human population density on smallholdings, in the recent decade, has necessitated increased allocation of land to food crops at the expense of fodder crops and pasture (MALDM, 1996). If this trend continues unabated into the future the net result will be the high priority on production of staple foods.

The staple crops on farms undergo fractionation into human diet components and crop residues. Hence the general strategy will mainly consist of matching cattle genotypes and breeding programmes with available feeds, which will consist mainly of the crop residues and low amounts of fodder.

In the recent decade, appreciable research effort has been directed at generating technologies, which could improve utilization of the crop residues on small-scale dairy farms (Preston and Leng, 1987). Nonetheless, the technologies have not been sufficiently simplified for adoption by the majority of small-scale farmers. Thus, the crop residues have continued to be fed untreated as the main feed or supplemental feed to napier grass and available grazing pastures.

Crop residues fed as main diets, with little concentrate supplementation, barely meet nutritional requirements for maintenance and milk production in small-scale dairy cattle cows (Potter and Anindo, 1989). The net result being highly noticeable in the low lactational milk yield (< 2500 kg), which is less than 50% of the potential expected of the high-grade dairy cattle breeds.

The current dairy cattle breeding policy in Kenya continues to be based largely on the genetic improvement of herds on small and large-scale farms through the use of semen from bulls progeny tested entirely under large-scale herd environment. This policy includes frequent importation of semen for contract mating from high performing breeding programmes of the developed countries (Phillipson et al., 1988). It has achieved lactational milk yield per cow of at least 5000 kg on large-scale farms, at expected annual genetic progress of 6.29 kg (Rege and Mosi, 1989).

With the recent government policy of liberalisation of the dairy industry, coupled with the implementation of privatization of Artificial Insemination (AI) services, a majority of small scale farmers have started having direct access to imported semen through cooperative and private AI services (CAIS, 1999; Inyangala, 1999). This new breeding strategy will generate an expected annual genetic improvement of 38 kg of milk yield.

Feeding and management in the large-scale commercial dairy farms can be expected to change correspondingly to match the imported genetic progress. However, this is not likely to happen in the majority of small-scale farms. This is due to the fact that demographic and economic trends to-date indicate that the existence of sub-optimal environment on such farms might continue in the future (Yates, 1988).

Beyond feeding and management factors there is the issue of

adaptability of the improved genotype to the high diversity in the existing ecological zones where the small-scale herds are located (Hopcraft et al., 1976). Therefore, it is largely unknown which dairy cattle genotype and breeding policy would be suited to those environments.

The question then is about how the expected benefit from high yielding dairy germplasm in the smallholder farms will be achieved when the feed resource base will have hardly improved.

This environmental constraint, about which very little can be done in future, will be reflected in the low mean milk yield per cow (Kiwuwa, 1988).

The high yielding dairy cattle strains can only partially, if at all, realise their genetic potential on small-scale farms. The resulting wide gap between the available and the required level of feeding and management can be expected to lead to an increased rate of fitness loss and low production (Velzen, 1988).

Fitness traits in this study are defined as a set of traits, which include calving interval, age at first calving, survival rates by age and sex expected without voluntary culling and the rate of involuntary culling due to poor health and infertility in the breeding stock. The fitness loss at herd level will be manifested by frequent occurrence of poor health and reproductive problems causing higher levels of animal losses or forced culls (Wakhungu and Baptist, 1992b). These animals are so expensive to the farmer that they have had to purchase them

through credit.

The magnitude of a milk yield increment and an associated fitness loss is difficult to predict in small-scale dairy herds, because there is hardly any data reported on this phenomenon. Despite this, what can be quantified is the trade-off between expected (tentative) yield increments and fitness losses based on their impact on the overall productivity of the smallholder dairy cattle population.

If marginal fitness losses in dairy cattle balance what looks like impressive milk yield increments, then the high yield dairy germplasm and the current breeding policy, which ensures its propagation, are unlikely to be beneficial on small-scale farms in the long run. This could imply the need for design of alternative breeding policy option(s) to suit the small-scale farm environment. If, on the other hand, the small-scale dairy cattle population can tolerate fitness losses within a range, which will not render it unsustainable, then the current breeding policy can be accepted as safe.

1.5 Objectives and Hypotheses

The overall objective of this study is to evaluate two breeding policy options in the national smallholder dairy herd sub-sector by use of a demographic stationary state productivity model. The first option is the current policy where there is breeding of dairy cattle herds on small scale farms by AI based on imported semen or semen extracted from locally progeny tested bulls. The second option, which is hypothetical, is the

breeding of dairy cattle herds on small scale farms by AI based on semen extracted from bulls progeny tested under the small scale farm environment in Kenya.

To achieve the stated objective, this study was based on the following three hypotheses:-

- (a) Although the future changes in milk yield and fitness losses cannot be predicted for dairy cattle breed groups resulting from the current breeding policy, sensitivity analyses can narrow down the range of possible outcomes.
- (b) Stationary state productivity model can quantify, in terms of overall efficiency, the trade-off between potential lactational milk yield increments and fitness losses in the dairy cattle breed.
- (c) The results of (a) and (b) can give indications on the safety of the current dairy cattle breeding policy, or conversely the necessity of an alternative breeding policy option for smallholder dairy cattle herds.

2.0 LITERATURE REVIEW

2.1 Dairy Development Policies and Strategies in Sub-Saharan Africa

Sub-Saharan Africa is essentially a region of smallholders and its environments are sensitive to changes in land use. Communal or uncertain land tenure over most of the region only makes the dairy development task harder (Saleem, 1995).

Report by Winrock (1992) has indicated that the human population in sub-Saharan Africa will increase from about 500 million in 1990 to 1294 million by the year 2025. This will raise the demand for milk to a projected 43 million tonnes annually.

Most of the milk will come from ruminants, particularly cattle. To attain this level of output, a 4% annual increase in milk will be required to stem the falling trends in per capita milk consumption per annum (FAO, 1995; CARNET, 1996). This will be met from the estimated 196.4 million cattle population distributed throughout the region's two major cattle production systems:- traditional and improved production systems (Olaloku et al., 1990).

Growth in livestock sector in the region has been inadequate even to sustain self sufficiency. Policy analysts suspect that a major reason for this situation has been the prevalence of inappropriate government policies (von Massow, 1989).

There are, however, many technical, institutional and socio-economic difficulties to be overcome in the development of the dairy sub-sector. Despite the problems there are major opportunities to increase dairy production in Africa. These take different forms according to ecological zones and region (ILCA, 1987).

Most African governments are motivated by one or more of the following considerations when choosing policy options in the dairy sub-sector as summarised from von Massow (1989):- (i) to provide the urban consumers with dairy products at affordable prices; (ii) to stimulate dairy development, thereby generating income for producers and moving towards self-sufficiency in dairy products; (iii) to control and possibly reduce the amount of foreign exchange that is spent on dairy imports; and (iv) to generate revenue from dairy imports for the national budget.

In countries such as Kenya and Zimbabwe, which have developed commercial infrastructure able to meet speedily an increased demand for production inputs, increased milk price may be the most effective way of stimulating increase of milk supply. In countries without such infrastructure, policies that directly promote milk supply may attract a higher priority (ILCA, 1992).

Left on their own, experience has shown that most sub-Saharan Africa countries' strategies in dairy development, based on imported technology often with exotic dairy cows in large units, controlled either as cooperatives or government organisations, have failed (Yates, 1988).

2.2 Constraints in Smallholder Dairy Sector in the Developing Economies

Improvement of dairy production in the smallholder farms requires being in a position to define the constraints that impede high productivity. The major cause of failure has been the lack of knowledge of the interrelationships between the biotechnical and socio-economic components of the production system (FAO, 1991). Central to this is the human population pressure on arable land. This is reflected in the fact that a self-sustaining small scale herd will not be attainable (Voccaro, 1995), unless there is a high proportion of absolute grazing.

Highlands within the tropics provide a suitable agro-ecological zone for the introduction of high yielding cattle from temperate countries. However, actual levels of milk yield on smallholdings in the region are not generally higher than in other zones due to the long history of dense human settlement and intensive exploitation of the soils (FAO, 1991).

The high population pressure on arable land in the tropical countries has reduced fallow periods and land for fodder production resulting in feed availability being virtually equated to crop residues, stubble or road side grazing and agro-industrial by-products (Brumby and Gryseels, 1984; Abate, 1992). These feeds provide a level of nutrients equivalent to those of unimproved tropical natural pasture.

Currently, developing countries have less than 1.0 hectare of

arable land per head of agricultural population (Voccaro, 1990). Trends in international trade suggest that their agricultural sector has often realised negative growth (Mukhebi, 1990). The resultant effect has been the lowering of export earnings which have endangered economic growth and food security.

Despite the oversupply of cheap cereals from the developed world, developing countries cannot finance the cereal import bills. At the same time, shrinking capital resources are responsible for the low income in the households (Mbogoh, 1984). Thus the need for low-priced milk is ever greater at the expense of the dairy farmers' profit.

Rural development policies often call on small scale farms to make contributions to increasing yields without guarantee of a fair share in the benefits (Ruthenburg, 1980). Thus socio-economic and political forces run counter to their interests. Few exercise any control over the marketing and distribution of their farm products. This explains why small scale farmers have been unable to take advantage of the resulting high prices from increased urbanisation because they cannot purchase high quality inputs (Yates, 1988).

In most of the developing countries, there is a weaker link between smallholders and researchers. Lacking the strength to compete with large-scale dairy farms, most of them have been left out of the mainstream of the national agricultural research services (FAO, 1991). Thus research priorities are

always incompatible with the needs of the smallholder dairy farming. This is one of the major causes of the smallscale farm environment being inherently unstable and prone to deterioration.

Some developing countries have done dairy cattle genetic improvement trials on research stations. The results were such that substantial productivity was observed when such animals were compared with indigenous cattle stock (Cunningham and Syrstad, 1987). With few exceptions, there has hardly been any successful maintenance of high yielding levels of the dairy cattle genotypes on smallholdings (Kiwuwa, 1988; Yates, 1988).

The genetic improvement in the dairy cattle germplasm imported from the developed countries has been so enormous that it has resulted in small scale farmers being unable to provide a matching improvement in the environment leading to their wastage of this germplasm (Gombe and O'Hara, 1986; Karanja, 1991; Mukhebi, 1990; Woolliams, 1990). Thus, it is apparent that resources allocated to genetic improvement have had little impact on the yield levels of smallholder herds at aggregate level.

The situation alluded to above is what has been overlooked in dairy development economic studies (Vocarro, 1990; Muinga, 1992). Most economic assessments, e.g gross margin calculations, ignore sustainability (e.g Karanja, 1991; Muriithi, 1990). They do not include the cost of making

particular genotypes to survive, yet survival is important since it determines herd replacement rate and the animal health costs.

Hodges (1990) notes that the nutritional condition of dairy stock in the tropics is at least as important a factor as animal diseases in explaining the low animal productivity. However, the technology promoted in ruminant nutrition did not overcome many of the constraints faced by the small scale dairy farmers (Voccaro, 1990). Ruminant nutrition technologies have continuously come up against the reality that they had little advantage over the traditional methods.

The inability to feed animals adequately throughout the year is the most widespread technical constraint on small scale farms (McIntyre *et al.*, 1992). In medium potential areas, dry season feed supply is the paramount problem, while, in wetter regions, forage supplies in the rainy season have low dry matter content (Voccaro, 1990).

The use of crop residues as feed on smallholdings has been assessed to reduce profits (Muriithi, 1990). Their low nutritive quality leads to negative nitrogen and mineral retention as well as low or negative metabolisable energy balance (Langholtz, 1990). Although these poorly nutritive forages are recommended for use as basal diets with concentrate supplements, the reality is such that most of the smallholders cannot afford concentrate feed (Mbugua, 1985; Bondoc *et al.*, 1989; Karanja, 1991).

Napier grass varieties are the most widely studied fodder crops in the tropical region (Ibrahim, 1986), because they grow in a wide range of climatic conditions from sea level to over 2000 metres altitude. Where there has been a shift towards more intensive grazing systems, napier has proved to be outstanding fodder (Karanja, 1985). Though napier grass can be conserved in form of silage, hay or as standing forage, such conservation processes have severe limitations such as labour and capital shortage on smallscale farms (Zenestra and Njenga, 1976).

Potter and Anindo (1989) observed that napier grass fed alone to Friesian cattle was capable of producing approximately 10 litres of milk per day, at a very high level of forage intake. This observation was in agreement with the results from earlier studies (Otim and Mugerwa, 1976; Karanja, 1984). Nevertheless, t'Mannetje (1978) suggested that the effective availability of nutrients in tropical forages may be less than for temperate forages of apparently similar chemical composition.

Dual purpose leguminous fodder shrubs are drought tolerant and rich in protein, e.g. Calliandra, Sesbania and Leucaenia. They are grown on hedge rows, river banks, bench terraces and contour strips. However, they are rare on smallholdings (Semenye et al., 1989). Residues of dual purpose crops, e.g. sweet potato vines, maize and sorghum stover, cow peas stubble and banana stems and leaves are largely used as supplementary

forage (Abate, 1992; Muinga, 1992). In spite of the agronomic attention they receive as food crops, their herbage yields and quality are largely unpredictable.

The small scale dairy sector has been more successful in India because of the well organised milk marketing system (Brumby and Gryseels, 1984). Provision of a ready outlet for milk in areas far removed from urban centres was the plank on which that success was built. There have been several attempts to repeat the Indian dairy development model in Eastern Africa, but with little and/or variable success (Yates, 1988). The main reason was that, to some extent, there was a development aid syndrome whereby there was direct transfer of technology from regions of developed countries to the tropical countries during implementation of donor funded projects.

2.3 Breeding Programmes in Smallholder Dairy Sector in the Developing Economies

The greatest constraint to breeding programmes in tropical countries is the multi-functional role cattle play in the smallholder sector (Harris et al., 1984). In addition, lack of the infrastructure led to inefficient recording systems and poor data processing procedures (Franklin, 1986; Kunzi and Kropf, 1986; Cunningham and Syrstad, 1987).

Detailed economic assessment of costs and returns to production are rarely available. The resultant effect is the limiting of the definition of breeding objectives to purely biological terms. In addition, the breeding objectives in small farm dairy

sector are not so clearly defined as in large scale sector (Hickman, 1986; Bondoc et al., 1989). This is due to the fact that performance is difficult to measure in such systems. Hence these small herds are not recognised by more advanced official livestock breeding programmes. Besides, may be the farmers' objectives differ from what national governments would want them to be. For instance, a farmer may be interested in an dairy animal that will survive yet the government livestock extension departments will be pushing farmers to select high yielding animals so as to supply milk to urban centres.

Use of AI is essential for genetic improvement of a dairy cattle population distributed over a large number of smallholder herds (Hickman, 1981; Yates, 1988). Nevertheless, AI, oestrus detection and other breeding activities are too costly and sophisticated for the environment on smallholdings (Bane and Hultnas, 1974; Gombe and O'Hara, 1986). Thus the use of natural mating is more common.

The major limitation in smallholder herd productivity is not so much the genetic potential but the little improvement in the feeding and management (husbandry) of the cattle. Therefore, within such an environment, natural selection takes precedence over the cattle keeper's selection for high production (Kiwuwa, 1988).

This is confirmed by the fact that cattle genotypes with low

potential for production compensate by having better fertility rates and longevity than those with high genetic potential (Voccaro, 1990; Msanga and Nduye, 1991). Thus the inclusion of fertility and viability traits as well as health costs in the evaluation of breeding policies and breed groups may help to accurately identify breeding strategies which improve productivity.

There is evidence that profitability of milk production in the smallholder herds depends on choice of breed groups and breeding policy (Cunningham and Syrstad, 1987; Kiwuwa, 1988; Yates, 1988). Thus the problem of genetic improvement is largely one of choice of suitable genotypes and breeding policy for their sustained genetic improvement in the smallholder environment.

In the recent decades, the effect of the proportion of genes of European dairy breeds in crossbreds has been widely studied on large scale farms in the tropical regions (Bondoc *et al.*, 1989; Voccaro, 1990). Thus far the optimal proportion has been estimated at 62.5% under average management (Brumby and Gryseels, 1984; Cunningham and Syrstad, 1987). On the other hand, the optimal proportion has been estimated at 50% on smallholdings as reported in some studies (Kiwuwa *et al.*, 1983; Agyemang and Nkhonjera, 1986; Kidane, 1987; Thorpe and Trail, 1988; Yates, 1988).

Maintenance and improvement of European breeds for a crossbreeding scheme can be costly (Trail, 1986; Syrstad,

1986); and besides, it is too expensive to rely on importation of semen (Mukhebi, 1990). Nevertheless, the breeding strategy to achieve the optimum genotype at farm level may involve use of crossbred bulls or creation of stabilised F_1 populations (Mehla *et al.*, 1988).

Top crossing of indigenous tropical cattle with European dairy breeds is done without a defined breeding policy in the smallholder herds (Voccaro, 1990). The resultant animals are highly susceptible to endemic diseases, prone to climatic stress and consequently have low productivity if this was continued for at least three generations.

A large effective population size is important to maintain a high level of genetic variation. Breeding programmes in smallholder farms are handicapped by small population size and most herds are single sire groups. Critical values of effective population size are in the range of 10-50 where loss of genetic variation is 1% per generation (Maijala, 1976). In practice, these critical values are not achieved in single sire smallholder herds.

To maintain a low inbreeding rate, Franklin (1986) and Brem (1986) have suggested the use of cooperative or group breeding schemes, with open nucleus test herd for the smallholder herds.

These schemes' integrate farmers' resources, leading to economies of scale at the industry and herd level, and generally enable appropriate selection objectives.

There is little evidence from literature to suggest that there are particular strains within breeds of dairy cattle which are more efficient converters of certain nutrients into milk (Jasiorowski et al., 1988). However, potential may exist for selecting animals for dairy traits depending upon the composition of the nutrients available to those animals (Burton, 1986). Rather, cattle can be selected to suit a particular system of farming and can thus alter the economics of milk production under that system.

The breeding strategy, such as that described above, was successfully demonstrated by the New Zealand dairy industry (Jasiorowski et al., 1988). This is where, though cattle were bred using imported semen from Europe and North America, they have been selected to make the best use of grass with concentrate feed supplement provided for short periods during extreme feed shortages. As a result, New Zealand has a low cost system of milk production.

Efforts to improve dairy cattle productivity on smallholdings have been frustrated for decades by the adverse environmental conditions and the attitude of the national dairy cattle breeding policy makers, implementers and funding agencies. The New Zealand example came about because of their positive attitudinal leverage at policy making and funding level without the constraint of the developing countries' donor aid syndrome.

Furthermore, to find a way round this problem has not been successful due to the fact that the smallscale dairy enterprises are often too weak to support high-input production systems necessary for sustenance of suitable environment for the genetically improved animals. Hence breed adaptation to environmental stresses has been increasingly recognised as an essential part of breeding programmes (Alberro, 1981). This implies that selection for dairy traits in smallholder herds would be equated to selection for resistance to environmental stresses which limit cattle's production potential.

Milk yields of the Friesian and their crossbreds have generally been higher than those from other breeds, but the genotype's life time performance, disease tolerance and adaptability to the tropical environment has been lower (Kiwuwa *et al.*, 1983).

It is, therefore, evident that no one dairy breed group has superior aggregate performance in all environments in which milk will be produced.

The implications of the findings alluded to above are that genotype-environment interactions, though difficult to determine, are important (Peters and Thorpe, 1989). Hence matching of specific breed groups and production environments will be optimal strategy to improve the efficiency of utilization of available resources.

Many workers indicate that the heterosis-environment interaction is common (Cunningham 1981; Bondoc *et al.*, 1989; Madalena, 1990). A low yielding breed and a high yielding

breed may not differ greatly in poor conditions. However, heterotic effects are most marked in dairy cattle crossbreds with zebu for most traits under the smallholder environment (Kiwuwa, 1988). Therefore, the genotype-environment interactions arise due to the substantial heterosis and the additive genetic component contributed by the two parents to the crossbred.

2.4 Production performance

2.4.1 Survival versus Production

Survival, reduced to its basic concept, is the protection and continuance of the organism's DNA, constituting its genetic coding. The primary keys to survival are a ready availability of feed and a healthy reproductive rate (Casey and Maree, 1993).

In any naturally occurring animal population, animals clustered around the mean of a normal distribution curve, with respect to their performance traits, have a higher survival than those clustered at the extremes. In natural selection, excessive values of performance traits will eventually be eliminated (Falconer, 1995).

In natural state, all traits and instincts are in harmony, resulting from evolutionary history, to facilitate survival. These include migration, feeding habits, re-conception rate, breeding season, ease of parturition, milk production and many other attributes taken for granted under domestication (Hammond, 1947). As any of these instincts deviate from the

norm, where the chances of survival are the highest, the risk to survival begins to increase.

Whereas survival is the key drive in wild animals, production is the major objective in domesticated livestock. Artificial selection is pursued to increase productivity, e.g. higher quality of product, increased milk yield per animal, higher growth rate, earlier maturity, etc. The emphasis on these economically important traits has increased their significance as potential causes of disturbance of the homeostasis between the animal and its environment and by upsetting the animal's physiological functioning (Hammond, 1947; Langholtz, 1990).

Biological manifestations of animals are all sensitively related to an environmental optimum. Shifts in the environmental conditions in terms of feed, disease, continuous handling, unnatural grouping, confinement, intensification, etc, constitute a biological stress. These are manifested in different stress symptoms and syndromes that have a limiting influence on animal production (Casey and Maree, 1993). In cows, the stress syndromes include milk fever, acidosis, ketosis, infertility, mastitis, metritis, laminitis, arthritis, dystocia, peritonitis, liver abscesses and pleurisy.

2.4.2 Genetic Potential and Commercial Optimum

At conception, the full genetic potential of the organism is fixed in its genes (Falconer, 1995). The objective of artificial selection by livestock breeders is to concentrate desirable genes in animals and thereby to obtain improved

performance. For this prime purpose, breeding schemes have been developed to identify superior individuals by way of own performance or progeny testing (Hickman, 1986).

The genetic potential of all animals, and especially the superior animals, can only be expressed in a favourable environment (Hammond, 1947). The favourable environment includes the physical comfort and the nutritional requirements for maintenance, growth and productivity.

In commercial production systems (like in large scale commercial dairy herds) the environmental impact on productivity is far greater than the genetic impact (Casey and Maree, 1993). Nevertheless the provision of a favourable environment for full genetic expression is so costly to provide that superior genetic material is wasted in unfavourable environments, as the case with smallholder dairy herds in the tropics (Yates, 1988).

Alternatively, the pursuit of superior genetic performance and maximum levels of productivity are usually conducted at uneconomical levels. This precipitates a conflict between stud breeders and commercial production systems.

2.4.3 Genetic Correlation Among Milk Yield, Reproductive and Survival Traits

Several studies have reported underlying antagonism between milk yield and reproductive performance (Matsoukas and Fairchild, 1975; Berger et al., 1981; Rege et al., 1992). This

implies that selection of sires on the basis of proofs for milk production would cause decline in fertility arising from correlated response in the long-term period.

The fact that most of the reported genetic correlation estimates are not significantly different from zero does not completely rule out the possibility of an underlying antagonism (Langholtz, 1990). This emphasizes the need to formulate breeding programmes which do not ignore reproductive performance.

Negative relationships of health and fitness traits with production resulting from pleiotropic genes will tend to be more constant across management regimes (Pearson et al., 1990). The correlations between reproductive traits and measures of production indicate that higher yield is associated phenotypically and genetically with poorer reproductive performance in lactating cows.

The strongest limitation to increased genetic improvement for milk yield is associated with meeting the nutrient requirements of the increased production (Seirsen and Lovendhal, 1986). Therefore, much of the negative relationship between production and reproduction appears to be explained by the extended negative energy balance with higher producing cows. It is important in the long term to ensure a balanced improvement in biological components limiting milk yield and to consider the biological consequences for other important traits.

Age at first calving ($h^2 = 0.29$) and calving interval ($h^2 = 0.08$) are among the most important determinants of herd-life and life-time productivity (Rege and Mosi, 1989; Njubi et al., 1992; Rege et al., 1992). Indications are that the age at first calving has medium heritability and favourable genetic correlations with other reproductive traits (Njubi et al., 1992; Rege et al., 1992). This tends to strongly suggest that this trait be incorporated in dam and sire selection.

2.4.4 Economic Weights in Dairy Cattle Improvement

The goal of dairy cattle breeding programmes is to improve economic merit of cows. When several traits contribute to economic merit, a selection index can be used. The index combines the available information to maximize the expected genetic progress in economic merit (Falconer, 1995).

Economic merit in this case is a linear function of the additive genetic values of the component traits, with the weighting factors being the partial regression coefficients of economic merit on genetic values of the trait. The weighting factors are often referred to as economic weights (Arendonk and Brascamp, 1990). These weights are used to calculate revenues of a breeding programme and to combine estimated breeding value components of a trait into an estimated breeding value for economic merit of animals for selection purposes.

In literature (Smith et al., 1986) economic weights have also been estimated from changes in economic efficiency defined as

cost per unit of output. In a one product situation this is equivalent to profit per unit of product. The latter definition can be used in a multiple product situation.

Baptist (1990a) used a productivity index to derive within breed economic weights as the percentage change in the feed energy efficiency index (output in Kenya Shilling per Kilogramme of dry matter requirement per animal-year) caused by a specified change (in measurement units used) in milk yield and a number of fitness traits. The specified change in each of these traits is standardized by dividing the magnitude of change in trait by the standard error of the estimated mean for the trait. This is equivalent to the probability of 33% of the trait varying under the environment on small scale farms.

2.5 Livestock Productivity Models

2.5.1 The Role of Models

Productivity, when applied to livestock, is defined as the efficiency of a production system; and as such would be a ratio of units of output per unit of input to the system (James and Carles, 1996). Although the units used for outputs may differ from those used for inputs, it is necessary that all outputs be measured in the same units of scale as for the inputs. This is done in order to find a single number for each component of the ratio. If this ratio applies to a particular input factor of production in a livestock production system, then it is termed as a livestock productivity index.

Economic values or units of scale could be assigned to all

outputs and inputs of a production system. Basing on this treatment of the ratio, then the economic efficiency of a livestock production system would be defined as the quotient derived by the division of total value of outputs by the total value of inputs over a defined period of time.

Productivity indices which relate input to output of one animal or a population of animals have become widespread (Wilson, 1982; Hofs *et al.*, 1985; Bayer, 1986). They are similar to the widely used ILCA index where parturition rate, weaning rate, survival rate and output mass (milk and liveweight gain) are combined multiplicatively; and besides, the product of those traits are related to the (metabolic) body weight of dams. Thus these indices are commonly expressed in the form of cow, ewe or doe indices (Hofs *et al.*, 1985; Tawonezvi *et al.*, 1988; Wilson and Murayi, 1988).

ILCA-type indices draw attention to the fact that animal productivity cannot be perceived as mere liveweight gains or lactation yields but, crucially depends on fitness (survival and reproductive) traits. These indices are easy to compute on pocket calculators. Nevertheless, inconsistencies occur in their applications due to the fact that only some of the life-cycle stages are included. In spite of their inconsistencies, they provide a first step towards more complex analyses.

The life cycle ratio of input-output is a useful criterion of livestock production efficiency. This is so because it relates closely to cost per unit of valued output and to the profit

margin under any given production system (Smith *et al.*, 1986). Thus the net result in production efficiency would depend on the relative magnitude of changes in input and output.

Metabolisable energy for maintenance is the largest component of the total fixed costs of dairy production (Koong *et al.*, 1985; Taylor *et al.*, 1986), yet it is positively associated with production levels. Due to these relationships, reductions in the fixed costs in terms of metabolisable energy for maintenance reduces output. This is because energy restriction for improved efficiency in the enterprise may be antagonised by a corresponding deterioration in fitness traits. For this reason, there is need to evaluate the bio-economic importance of changes in performance traits on the efficiency of production.

The lack of information from studies designed to evaluate biological interrelationships between output-input characteristics restricts the evaluation of livestock production systems (Brumby and Trail, 1986). Notwithstanding the above, experiments to compare mixed production systems, such as the smallholder dairy cattle sectors of the developing countries, are likely to be cost prohibitive and time consuming.

Developments in systems science and availability of modern computers provide a method of organising disciplinary research findings into a simulation model so that they can realistically be related to application (Khan and Spedding, 1983). Thus a

simulation model may be a medium for conducting necessary and sufficient experiments to address specific hypotheses. Such an approach cuts down costs and compresses the time scale relative to field experiments.

An overview of livestock productivity models has been reported by Baptist (1990b). It reveals the fact that an increasing number of computer based livestock productivity models at different levels of aggregation have been developed and published in the recent decade (MacNeil and Harris, 1988; Korver and van Arendonk, 1988; Brockington et al., 1986; Blackburn et al., 1987; Baptist 1990a; Kauffmann et al., 1990).

These models can be put to different uses, such as evaluation of culling policies in herds/flocks of livestock, and assessment of the impact of extension, new technologies and breeding schemes/policies.

2.5.2 Models Computer Package Application Capabilities

A cross-section of models at herd or flock level comprises the five models described below. They were selected on the basis of their availability as interactive micro-computer applications and were sufficiently documented for direct use without the user making changes to programme source codes:-

(a) The Texas A&M University Sheep and Goat model was, among the first computer based systems models developed in animal science (Blackburn et al. 1987).

The sheep and goat model differs from other models because it does not set yield levels and fitness traits to derive feed requirements. It sets seasonal availability and quality of

feed, worm burden and evaluates their effect on survival, yields and reproductive performance of a genotype defined on the basis of its potential feed intake, body growth, conception rate, lactation yield and fibre production. This feature is central to its being a mechanistic rather than a black box model (i.e defined as a model in biology or agriculture which uses mechanisms or algorithmic functions, unknown to the user, to relate outputs of a system to its inputs).

(b) Herd-Econ is a product of wildlife and rangelands division of CSIRO of Australia (Stafford Smith *et al.*, 1988). It is a ranch model for beef cattle and wool sheep. It gives a complete financial assessment of the property on an iterative process where annual input and output flows are discounted over the years. Involuntary and voluntary culls, and in-transfers can be specified on an annual or monthly time scale for good, average and bad years as either rates or in terms of animal numbers culled, sold or purchased at arbitrary time intervals.

It is basically a discounted cash-flow and financial assessment model applied on ranches. However, it does not attempt to model stationary state (steady state) population dynamics and energy flow or optimise culling strategy (i.e a stationary state model is defined as a model which derives expected numeric offtake and population structure for an infinitely large equilibrium population- which does not grow). Hence it is a black box model for ranch management and extension, but less suited to the more general purposes of productivity indexing or

comparison between production systems, species, and breeds or strains.

(c) The ILCA Bio-Economic Model was developed by the Livestock Economics Unit of ILCA (Kauffmann et al., 1990) as a menu-driven spreadsheet application. It is a cost-benefit analysis model, extended to cattle herds, which calculates the net present value for a fixed project duration of 10 years.

It does not optimise the culling strategy nor set the population to a stationary state of population dynamics. Hence, it has the limitations alluded to above which make it both a restrictive and black box model.

(d) The Livestock Production Efficiency Calculator (LPEC), composed of three separate modules for cattle, sheep and goats, was developed at University of Reading (Villamil, 1987, PAN Livestock Services, 1991. It has been reviewed by James and Carles (1996).

In this model, liveweight and milk off-take are driven for a stationary state herd or flock and aggregated in terms of monetary or other unit values, while input costs are considered (James and Carles, 1996). The physical level of feed energy requirements is calculated based on population structure, liveweight development and lactation yield.

The production efficiency index is expressed as the annual aggregate off-take per unit of feed intake or carrying capacity (100 MJ of ME requirement per day). LPEC is probably the more user-friendly computer-model package available and the first

known to have made use of the concept of stationary-state population dynamics.

A stationary state population dynamics model eliminates the drawbacks arising from the omission of some of the animal's life cycle stages. Such model's micro-computerized programme uses age- and sex-specific rates for mortality, culling and parturition, respectively, to estimate population structure and the frequency of voluntary and involuntary disposals in different animal categories.

The stationary state breeding policy keeps population size constant by fattening surplus females which then do not reproduce. Hence the culling strategy is characterized by the voluntary disposal of fattening males and females at a sex-specific age. Offtake in the breeding animal categories is only for involuntary reasons. This model when used provides results which are valid for comparative studies/assessments of flocks/herds across different production systems.

(e) PRY (Prying livestock productivity) model was developed by Baptist (1990b). It comprises both a deterministic model of stationary-state demography and a stochastic model of herd or flock dynamics. It is species-independent and allows for greater detail with regard to culling patterns.

The first model automatically varies the cull-for-age threshold of breeding females and the disposal age of surplus female and male young stock to identify the optimal culling strategy for a

stationary-state population. It calculates gross return on dry matter intake for a stationary-state population of defined demographic properties under-optimal culling.

The deterministic module derives expected numeric off-take and population structure for an infinitely large equilibrium population. This method of derivation is based on the actuarial approach, which is a standard method in wildlife biology (Coughley, 1977).

The second model is basically a simulation model. It stochastically develops a closed seed population with inherent fitness characteristics and subjected to a specific offtake pattern. In simulated stockbreeding, an equivalent number of breeding animals are replaced, either at death, or when they reached the optimal cull for age threshold, or when they were recognized to be sterile females. The simulation experiments are designed to yield productivity component estimates with a standard error considered to be sufficiently small.

The demographic (fitness) parameters on which PRY model is based are age at first parturition, parturition interval, litter size, survival rates (by age and sex), and rate of involuntary culling (by age), cull for age threshold for breeding females and for disposal of surplus female and male young stock.

PRY has been used to contribute to methodology of defining breeding objectives (Baptist, 1990a), productivity indexing

(Baptist and Badamana, 1990), the determination of impact of reproductive wastage in smallholder dairying in Kenya (Wakhungu and Baptist, 1992a) and the evaluation of cropping strategies in game-ranches (Baptist and Sommerlatte, 1991). A detailed manual of the computer programme is available (Baptist, 1990b).

2.5.3 Efficiency and Sufficiency of Model Options

The design of improved technology or livestock production policies depends upon evaluation of alternative productivity model options in terms of their efficiency (Upton, 1986). Each alternative policy is evaluated assuming a constant steady-state herd/flock structure. The steady-state herd structure allows estimation of the net output after allowing for herd replacement or depreciation (Upton, 1985).

Upton (1985) has advocated the use of deterministic stationary-state (steady-state) models in productivity assessment since they remove biases arising from changes in population sizes within different herds or flocks. This reasoning is deterministic and implies a large population at the scale of a region, sector or breed/species. In order to use the deterministic module for productivity assessments on any population such as the Kenyan smallholder dairy herd, the population should be checked to be certain that it is in a stationary state.

PRY like LPEC produces an index which allows direct comparison of the productivity of different breeds or even species of livestock. PRY and LPEC, in the worst situation where some

parameters are unknown, allows the use of assumed (default) values and takes into account the interactions among the parameters.

At present, the LPEC (James and Carles, 1996) and PRY (Baptist, 1990b) are among the few model packages able to derive stationary state productivity deterministically. PRY model, due to its species independence and higher number of modules, is slightly more flexible than LPEC.

Other steady-state models as illustrated by several authors (Upton, 1985; Djikhuizen *et al.*, 1986; Abassa *et al.*, 1987; Putt *et al.*, 1987) also eliminate the drawbacks arising from omission of some of the animal's life cycle stages as do PRY and LPEC models. However, most of them have a major limitation because they apply parturition rates which cause inconsistencies in their results.

Walsh and Gram (1980) have noted that a good model is one that abstracts from all the details that are unnecessary for the purpose of solving a problem at hand. PRY requires fewer assumptions and gives more aggregate results than the variation of fitness traits to simulate seasonal or annual situations, which is the approach adopted in most of the mechanistic models.

2.5.4 Model Sensitivity Analysis

Sensitivity analysis is an extension of productivity model approach. It may be used to estimate the impact of shifts in

the values of key variables that drive the model on the efficiency of a livestock production system. Animal breeders need to evaluate the bio-economic effect of genetic changes in performance traits on the efficiency of livestock production. This may be achieved by assessing both the correlated responses or benefits and the input costs associated with genetic changes in component traits (Jenkins *et al.*, 1986).

Knowledge of the magnitude of relative economic values (or economic weights) of fitness (survival and reproductive) traits is of great importance in livestock utilisation. Estimates of age at first calving, calving interval and litter size are available from literature (Voccaro, 1990) but information about natural mortality rates is scanty.

Nevertheless, where available, the fitness traits parameters have relatively high variation between than within breed.

The main purpose of the model sensitivity analyses is to provide an objective gauge for the comparison and relative evaluation of different policies rather than to propose specific policies. Upton (1989) notes that low variances of the variables are required to make it possible to detect differences in policies.

Baptist (1990c) recommends that with availability of modern computers, together with more refined animal evaluation statistical model procedures, it would be possible to solve the problem by using the expected values of the key variables from well structured data recording schemes. However, the expected

values may not exist for smallholder production sectors in subSahara Africa.

In sensitivity analyses, the estimates of the parameters of the key variables may be varied individually or simultaneously and may be changed in a direction likely to improve or reduce performance. However, Upton (1989) recommends that in order to limit the number of repeat analyses, and for simplicity, a case can be made for only varying the parameters individually and in an adverse direction only.

The question of how low or high the variations in the parameters should be has been reviewed by Upton (1989); Baptist(1990c) and Kauffmann *et al.*(1990). Ideally the choice should be based on objective measures of the range or variability of estimates of parameters of the key variables where standard errors have been estimated from data. The standard errors may be used to determine a lower (or upper) limit for the appropriate confidence interval.

Casey and Maree (1993) have examined the fact that normal distribution curves of the economic traits can be described mathematically with mean and standard deviations around the mean. Two standard deviations around the mean accommodate 95% of the variation in the particular trait. Animals with traits outside this range are regarded as outliers with an extremely low survival probability.

Nature does not preserve those individuals who are outliers

with regard to any trait unless the environment (husbandry inputs) can be modified in their favour. Those animals with the highest survival probability are within the range of 1 standard deviation. Thus, all other factors being held constant, the probability of any of the trait's mean performance varying (improving/deteriorating) by 1 standard error unidirectionally will be 34% all the time.

On the other hand, this approach may mislead if the data series on which the standard errors are based is too short to cover all the possible environmental variations (Wakhungu and Baptist, 1992a). Such a situation arises when dealing with populations like the smallholder dairy herds because most of them do not record and have herd sizes of 2-10 head of dairy cows.

3.0 MATERIALS AND METHODS

3.1 *The Study Area: Environment, Farming and Time Period*

Kenya is located on the east coast of Africa within latitudes 5°N and 5°S and longitudes 34°E and 34° 2'W. It is dominated by the Eastern Africa plateau through which cuts the eastern branch of the Great Rift Valley. The highland and plateau areas, at altitudes of over 1000 metres, have mean annual rainfall of over 600 mm and ambient temperatures of 13-35°C (Jaetzold and Schmidt, 1983).

Only about 20% of the land surface is suitable for rainfed agriculture. The principal belt of that land is found around a baseline running from north-west to south-east through Nairobi. The soils and climate of the belt are influenced by the relief features consisting of mountains Elgon and Kenya, mountain ranges of Cherangani, Mau, Aberdares and Taita as well as the lakes within and outside the Rift Valley and the Indian Ocean (Jaetzold and Schmidt, 1983).

The population density in this belt was estimated at over 80 persons per km² in 1989. This is partly attributable to the fact that 80% of that population lived on over 0.75 million smallholdings of 0.2-5 hectares per household (Jaetzold and Schmidt, 1983).

The main food crops grown are maize, beans, potatoes and sorghum, while the cash crops include tea, coffee, pyrethrum, cashew nuts, coconut, sugar cane and horticulture. Dairy

production, based on European dairy breeds and their crossbreds with zebu, is the major livestock enterprise. The upgrading of the zebu by the use of the European dairy breed bull semen via the Kenya National Artificial Insemination Services (KNAIS) has ensured a steadily increasing proportion of the grade dairy herd on smallholdings (MLD, 1992).

The study covered districts having smallholder mixed crop-dairy farms in medium to high potential arable areas at altitudes ranging from low to high. The 23 districts were, by provinces:

- i) Nyanza - Kisii, Siaya and Kisumu;
- ii) Western - Kakamega and Bungoma;
- iii) Rift Valley - Uasin Gishu, Trans Nzoia, Nakuru, Kajiado and Kericho;
- iv) Central - Kiambu, Kirinyaga, Nyandarua, Muranga and Nyeri;
- (v) Eastern - Meru, Tharaka Nithi, Embu, Machakos and Makueni;
- vi) Coast - Kwale, Kilifi and Taita Taveta.

The years' period covered was 1980-1992. There was drought throughout 1984 whose effects persisted into the first quarter of 1985 (MLD, 1985). During 1987 and 1992 there was no proper onset of short rains while the dry seasons were prolonged and severe (MLD, 1987; MLD, 1992). The rainfall pattern in these districts was bimodal with long rainy season (March-May), short rainy season (October-November) and the dry season (the rest of year).

Infrastructural problems persistently affected the efficiency of milk marketing, veterinary and artificial insemination services in the districts (KNAIS, 1991). In addition, the general trend of inflation rate caused most of the credit

facilities to be scarce to the smallholder dairy farmer. The price of milk was dependent on the marketing channels, locality as well as transport costs involved (MLD, 1992).

Most of the smallholder sector milk was mainly collected and channelled through local dairy societies to Kenya Co-operative Creameries (KCC). The KCC remained a monopoly outlet market for milk, apart from the Kitinda (Bungoma District) and Meru (Meru District) Co-operative Union milk plants (MLD, 1989). Government throughout the period while that of meat and commercial feeds was deregulated starting from 1989 regulated the price of milk. However, marketing of cattle was unorganised as it varied from region to region (MLD, 1992).

3.2 Breeding and Management of Smallholder Grade Dairy Herds

3.2.1 Breed Groups

The herd size per farm household ranged from 2 to 5 mature head of cattle of various breed groups. The 10 major breed groups covered in the study identifiable from their genotypes based on their pedigree records were:

- i) the four pure dairy breeds- Friesian (F), Ayrshire (A), Guernsey (G) and Jersey (J);
- ii) the F_1 crossbreds of either A or F with Zebu denoted as (F_L);
- iii) the first backcrosses to either A or F denoted as (R_L);
- iv) F_1 crossbreds of either G or J with Zebu denoted as (F_S);
- v) first backcrosses to either G or J denoted as (R_S);
- vi) the Kilifi Synthetic (K) consisting of approximately equal proportions of Sahiwal, Jersey and Brown Swiss.
- vii) the smallholder "High grade" Nondescript (ND) which had

arisen from the parentage of either F_L or F_S and other unspecified grade cattle breed groups. It was raised on the farms where there were no proper mating plan.

According to Graevart (1996), the Jersey and Guernsey are small sized breeds and the Ayrshire and Friesian are large-sized breeds. This classification was based on body weight and frame.

3.2.2 Herd Management

The management of smallholder herds was classified according to the three grazing systems namely: - extensive open grazing, semi-zero grazing and zero grazing.

3.2.2.1 Extensive Open Grazing System:

The number of herds/farms covered under this system was 132. This category of herds represents or occupies the lowest strata in the national grade dairy cattle breeding organizational structure (hierarchy). This system was the commonest where dairy cattle were kept on little amounts of purchased inputs, such as concentrate feed, veterinary drugs and services. Family household subsistence was the main dairy production objective.

The main features in this system were that the households used mainly communal grazing land as some were often landless or most of the family land was under food and cash crops. Cattle were often tethered or herded in communal open lands, which included roadsides, forest edges and river valleys. After food crop harvest they were grazed in fields, emphasizing use of

crop residues and weeds. The daily operations were geared towards providing milk for subsistence and surplus for sale. These types of herd were distributed variably in the 23 districts.

Calves were bucket fed on milk or suckled and weaned at 3-4 months of age. Male calves were kept for breeding (natural service), fattening as well as for oxen draught power. There was no fodder or forage conservation. Cattle were often kept in a boma (cattle shed) at night without supplemental feed. Cows were bred by AI, natural (bull) or both services depending on the locality and infrastructure. There was hardly any record keeping, except milk sales receipts and the AI record card where AI service existed.

3.2.2.2 Semi-Zero Grazing System:

The number of herds/farms covered in this system was 134. Limited capital and land area constrained the ability of the farmers to keep more cows. Cattle were grazed on natural or improved pastures during the day but at night were kept in boma or paddocks where they were fed on feedstuffs such as Napier grass, maize or bean thinning, crop residues and weeds.

In some herds in the maize growing areas maize cobs, sunflower heads and hay or stover were crushed, mixed with molasses or salt and used as supplemental feed. Crop residues on harvested food crop fields were the main source of feed in the dry season.

The use of AI was emphasized to meet the breeding objective of upgrading the zebu to European dairy breeds to increase milk yield per head. Farmers kept or hired bulls to supplement AI services. Calves were bucket fed on milk and weaned at 3-4 months of age. The male calves were kept for breeding or fattening as steers for beef or bullocks for draught power. Farmers kept records to some extent and maintained the use of purchased inputs, especially for animal health and concentrate feed.

3.2.2.3 Zero-Grazing System

The number of herds/farms covered in this system was 188.

This system was popular in densely populated areas where pure dairy breeds and their crossbreds with the zebu were stall fed on harvested fodder and crop-residues. Thus it was highly intensive, requiring high inputs of capital, drugs and labour.

The number of herds under the system has been on the increase due to the National Dairy Development Project (NDDP) and where milk marketing channels provide for high milk price.

The NDDP emphasized use of napier grass (*P. puerperium*) as the main fodder throughout the year. In addition, farmers fed crop residues, such as cereal straws and stover, banana leaves and stems, and sweet potato vines. A little of cereal bran, dairy meal concentrate and molasses were fed, depending on the proximity of the source and the level of infrastructural development in the vicinity.

Record keeping was done to facilitate better management.

Breeding was often effected through AI, though natural service was used in the event of failure of AI. The breeding objective was the same as for the semi-zero grazing system.

With the failure of the KNAIS, these herds are increasingly depending on private or cooperative AI providers or natural service from quality bulls purchased from large-scale pedigree herds. Few of these herds bred their own replacements as they relied heavily on purchasing heifers from large-scale dairy farms; and they hardly participated in the National Dairy Cattle Breeding Programme.

Calves were bucket fed on milk and weaned at 3-4 months of age. However, male calves were disposed of more often at one month of age, with the exception of some herds where entire bull calves were kept to weaning age and sold for breeding purposes, mostly to semi-zero or open grazing systems herds in remote areas of the districts.

3.3 Data Collection and Processing

3.3.1 Questionnaire

A questionnaire was prepared, tested and used in the collection of data on the farms in the period January, 1991- December 1992, (Appendix 1). Records of animals born and reared on the farms in the period 1980-1992 were entered in the questionnaire. Checking with databases at Kenya Milk Records Organisation, Kenya National Artificial Insemination Services, the National Dairy Development Project and the Rural Dairy

Development Project authenticated the records.

The breed group identity for each individual animal in the herd was determined by its pedigree as traced in record copies kept in AI set file at the farm or at the District AI offices. Where AI had been replaced by bull service, the farmers' records or answers to questionnaire with regard to the entry or exit of the animal in the herd assisted in the determination of breed group identity.

The AI set files kept at the farm were used mainly to check reproductive, pedigree, and mortality and disposal data entered in the questionnaire. The AI set files had record copies entered by the inseminator at the time of first insemination of the cow which included the information on the locality, farm and animal identification; date of birth, insemination, bull service (if any) and previous service. Also other details of cow calving and disposal were entered. Calf record details were in a table attached to the register card in the file.

The farmers who recorded milk yield regularly had the lactation performance data of their dairy herds entered in the survey questionnaire. The other condition was that the lactation records were from cows not dried for health reasons. However, there were hardly any records of butterfat content.

The total acreage of the farm and portions devoted to fodder or pasture were got from the farmers' records and extension assistants. This was commonly done for herds under open

extensive grazing system while the same data was readily available in herds under zero grazing or semi-zero grazing. Farm gate price data were extracted and derived from revenue receipts at farm level, Kenya Co-operative Creameries and Dairy Societies records.

The Nairobi Consumer Price Indices (Middle Class) (Table 1) were used to adjust all price values in the period 1980-1992 to the level of those in year 1992. This was done according to the following derivation:

$$\{(PCI_{1992}/PCI_x)\}(Price_x)$$

where PCI_{1992} = Consumer Price Index value for year-1992

$Price_x$ = Actual farm-gate price value for any

TABLE 1: Nairobi Middle Class Consumer Price Indices in the
Period 1980-1992

Year	Consumer Index
1980	173
1981	216
1982	256
1983	282
1984	312
1985	342
1986	375
1987	405
1988	453
1989	506
1990	597
1991	690
1992	850

Source: Oscarsson et al. (1987) and Israelsson and
Oscarsson (1994)

3.3.2 Coding

The collected data were extracted, entered and coded by use of the PANACEA (1987) database computer programme package. The procedures were:-

3.3.2.1 Base Record

This included records of all young female non-lactating stock and males comprising:- identification of the animal, breed group, herd, acreage and geographical location of the farm, identity of sire and dam (if any), sex, date of birth, date of and reason for disposal from the herd.

The individual animal birth/entry and disposal records in the herd were considered for purposes of statistical analyses of survival rates and selective culling rate for cows and heifers. Data for survival of different age groups (0-4, 5-30, and 31-144 months) and sex, were coded as:

1 = alive or retained in the herd, and 0 = dead or culled involuntarily. Data for selective culling among cows and heifers were coded as: 1=culled on basis of own health or fertility, and 0= alive and retained in the herd.

The proportion of animals in the herd still present at the end of the chosen interval of time was defined as survival rate.

This was only possible if no living animal were disposed of by voluntary culling. Thus the survival rates defined in this manner were assumed to be inherent and were specified by sex and age. This measurement of survival traits represented the probability of an animal not to be lost on voluntary culling

grounds.

In each parity class, a proportion of breeding females were expected to fail to conceive or pose health problems for which they were culled involuntarily. The frequency of such forced culls (selective culling rate per parity - SCRAP rate) was age dependent. This was equivalent to the probability of a breeding heifer or cow to be culled before the calving was due.

3.3.2.2 Lactation Record

This was built up and coded for each cow's parturition. This included identification of the cow and its herd, date of birth, breed group; calving date, identity and sex of calf, grazing system and mating method. Also included were lactation milk yield and length.

The parity groups for female breeding stock were coded as lactation numbers completed 1 to 6, while lactations numbers completed beyond the 7th were lumped together and coded as the 7th lactation number. The combination of 7th with subsequent lactations was based on preliminary analyses which showed no significant pairwise differences among the 305-day milk yield records in these lactations. This was taken as a classification to adjust animal performance records for age.

3.3.2.3 Climatic Record

Based on climatic information described in Section 3.1, it was considered appropriate to derive season by dividing the year into three seasons of calving/birth using the classification procedure described by Rege and Mosi (1989). The seasons were

coded as: 1 = Long rainy season which included the months of
2 = Short rainy season included the months of October - November;
3 = Dry season, including the months of December - February and
June-September.

3.3.2.4 Herd

A total of 454 herds were included in the field data collection. However, 56 herds had to be excluded because there was only one animal with record for the traits to be analyzed. When checked by cross-tabulations, most of the herds whose data were retained for further analyses had at least 2 animals per herd. This was to ensure such herd structures could not cause confoundment of herd effect with individual animal effects.

3.4 The Structure of Data for Statistical Analyses

The acreage of the farms surveyed ranged from 0.5 to 8.9 acres and the respective mean and modal acreage were 2.35 and 3 acres. The main structure of the data used in the statistical analyses is presented in Table 2. However, the detailed structure of the final data varied with the factors (classes and subclasses) fitted in the statistical model for the analysis of each of the animal performance characters.

TABLE 2: Structure of the data

Classes	Number
Provinces	6
Districts	23
Locations (localities)	68
Herds	398
Years (1980-1992)	13
Seasons	3
Grazing Systems	3
Mating Methods	3
Breed Groups	10
Lactation Numbers (parity groups)	7
Male calves (0-4 months)	1079
Female Calves (0-4 months)	976
Young heifers (5-30 months)	701
Young bulls (5-30 months)	786
Cows (31-144 months)	1789
Mature bulls (31-144 months)	810

3.4.1 Statistical Analyses of Data

3.4.1.1 Production and Reproductive Traits and Produce Prices

The main object of the analyses carried out was to obtain less biased estimates of parameters of production and reproductive traits and produce prices. These estimates were used as input variables in the PRY productivity model computer package (see section 3.5).

Some systematic factors were measured for further study in their own right; some to account for variation attributable to them, in order that less biased estimates of the parameters required in this study could be obtained. Unequal and disproportionate subclass numbers gave unbalanced factorial designs, for which conventional analyses of variance techniques were not applicable.

The basis used for analyses of those data having unequal and disproportionate subclass numbers was the method of fitting constants (Harvey, 1990). Application of this method to the different data layouts required that appropriate statistical models be formulated in each case.

The residual mean square was used to test the significance of all differences between subclasses of the independent variables, which had shown significant effect in the analyses of variance of any specific dependent variable. Linear contrasts of subclass least squares means were computed for some of the independent variables, which showed significant effect in the analyses of variance. Tests of significance

associated with the linear contrast were done to gauge whether the observed values could have occurred due to chance.

The models used provided for estimation of the effects of several levels of different factors on the variables being studied. The general statistical model (in matrix notation) used in the analyses of variables in this study was:

$$\underline{Y} = X b + e$$

Where \underline{Y} = the vector of observations

X = the (known) incidence or design matrix for fixed effects

b = the (unknown) vector of the (fixed) effects

e = the vector of residual terms

However, specific models were fitted depending on the dependent variable.

The following model was fitted for lactational milk yield:

$$Y_{ijklmnop} = U + P_i + H_j + L_k + b_1 (A_{ijklmnop} - A) + B_1 + G_m + M_n + S_o + b_2 (D_{ijklmnop} - D) + X_p + e_{ijklmnop}$$

Where

$Y_{ijklmnop}$ = the $ijklmnop$ -th animal's record

U = the underlying constant common to all observations.

P_j = fixed effect due to i -th parity (lactation numbers: $i=(1,2,\dots,7)$)

H_j = fixed effect due to j -th herd ($j = 1, 2', \dots, 398$)

L_k = fixed effect due to k -th locality of the herd ($k=1, 2, \dots, 68$).

$A_{ijklmnop}$ = the $ijklmnop$ -th lactation length, an

independent variable

A = the mean lactation length.

b_1 = partial regression coefficient of lactational milk yield on lactation length.

B_l = fixed effects due to the l -th breed group ($l=1,2,\dots,10$).

G_m = fixed effect due to m -th grazing system ($m=1,2,3$).

M_n = fixed due to n -th mating method in the herd ($n=1,2,3$).

S_o = fixed effect due to o -th calving season ($o=1,2,3$)

$D_{ijklmnop}$ = the $ijklmnop$ -th stock density, an independent variable.

D = the mean stock density.

b_2 = partial regression coefficient of lactation yield stock density.

X_p = fixed effect due to p -th year of calving ($p=1,2,\dots,10$)

$e_{ijklmnop}$ = a random error effect associated with each observation.

The following model was fitted for calving interval:

$$Y_{ijklmnop} = U + P_i + H_j + L_k + b_1 (A_{ijklmnop} - A) + B_l + G_m + (BG)_{lm} + b_3 (I_{ijklmnop} - I) + M_n + S_o + b_2 (D_{ijklmnop} - D) + X_p + e_{ijklmnop}$$

Where

$Y_{ijklmnop}$ = the $ijklmnop$ -th animals record

U = the underlying constant common to all

Observation.

P_i = the lactation (parity) of the cow ($i=1,2\dots7$)

H_j = the j -th herd ($j=1,2\dots398$)

L_k = the k -th locality of the farm ($k=1,2\dots67$)

$A_{ijklmnop}$ = the $ijklmnop$ -th farm acreage, an independent

Variable

A = the mean farm acreage

b_1 = partial regression coefficient of calving

B_l = the l -th breed group ($l=1,2,\dots,10$)

$I_{ijklmnop}$ = the $ijklmno$ -th lactational milk record, an

i = the mean lactational milk yield

b_3 = partial regression coefficient of calving

M_n = the n -th mating method ($n=1,2,3$)

S_o = the o -th calving season ($o=1,2,3$)

$D_{ijklmnop}$ = the $ijklmnop$ -th stock density, an independent

D = the mean stock density

b_2 = partial regression coefficient of stock

X_p = the p -th year of calving ($p=1,2,\dots,10$)

$e_{ijklmnop}$ = the random error effect associated with

The model for age at first calving was similar to that for calving interval, except parity as fixed effect and lactational milk yield as covariate were excluded but included grazing system and breeding X grazing system (see Appendix 3).

The following model was fitted for cow price:

$$Y_{ijklmnop} = u + P_i + H_j + L_k + b_1 (D_{ijklmnop} - D) + B_l + G_m + M_n + S_o + X_p + e_{ijklmnop}$$

Where

$Y_{ijklmnop}$ = the $ijklmnop$ -th animal's record with

u = the underlying constant common to all

P_i = the i -th parity ($i=1,2,\dots,7$)

H_j = the j -th herd ($j=1,2,\dots,398$)

L_k = the k -th locality of the farm ($k=1,2,\dots,67$)

B_l = the l -th breed group ($l=1,2,\dots,10$)

G_m = the m -th grazing system ($m=1,2,3$)

M_n = the n -th mating method ($n=1,2,3$)

S_o = the o -th calving season ($o=1,2,3$)

$D_{ijklmnop}$ = the $ijklmnop$ -th stock density, an independent

\bar{d} = the mean stock density

b_1 = partial regression coefficient of cow price

X_p = the p -th year of calving ($p=1,2,\dots,11$)

$e_{ijklmnop}$ = the random error effect associated with each

The models fitted for price of milk, heifer and bull calves were similar to that for cow price, except that parity and mating method were excluded. The models for bull calf price included farm acreage as a covariate.

3.4.1.2 Selective Culling Rate and Survival Traits

From the viewpoint of theory (Snedecor and Cochran, 1996), the analysis of binomially distributed data (0 or 1) measured on proportions or probability scale presents more difficulties than that of the normally distributed continuous variables. One approach is to transform proportions or probability units to logit units to provide an approximate method used in practice to enable analysis of binomial data.

A logit is a transformed form of a proportion or percentage, q ,

where q has a range of 0 to 1. The formula for the transformation is:

$$\text{Logit}(q) = \log(q/(1-q)),$$

where, \log is a natural logarithm (to base e).

The logit is a continuous variable with values ranging from negative infinity to positive infinity. The inversion from a logit, y , to a probability is:-

$$q = \exp(y) / (1 + \exp(y))$$

The assumptions involved in the logit approach introduce little error in the conclusions, if the number of animals that are coded dead and live in a given age group exceed 20 in every cell in the multiway tables. The advantage of this method is that the logit transformation pulls out the proportions or probability scale near 0 and 100% so that the logit scale extends from negative infinity to positive infinity.

The statistical analysis of data on logit scale results in row and column effects being additive, whereas in the original proportions or probability scale for the same data there may exist interactions that are entirely a consequence of that scale. Therefore, if the binomial data were analysed without being transformed to logit scale this would lead to erroneous conclusions from the results of the analysis.

Hypothesis testing assumes normality, and this assumption may not always hold with binomial (0 or 1) data. However, binomial variables approximate a normal distribution very well when the number of observations in each subclass is 20 or larger, unless the frequency of 0 or 1 is very large or very small.

To avoid any biases in the results analyses, of these traits were done using logit models utilising multi-way tables of proportions or probability. For each trait, a linear model was fitted to logits of the percentage mortality or of culled animals for the cells in a multi-way table. The number of animals (alive and dead or culled and retained) in the cells are used as weighting factors.

The model fitted for analysis of selective culling rate for cows was:

$$Y_{ijklmn} = u + P_i + B_j + S_k + X_l + e_{ijklmn}$$

Where

Y_{ijklmn} = the $ijklmn$ -th animal's record

u = the logit of percent culled common to all

P_i = the logit for i -th lactation number

B_j = the logit for j -th breed group ($j=1,2,\dots,10$)

X_l = the logit for l -th year of calving

($l=1,2,\dots,9$)

S_k = the logit for k -th calving season ($k=1,2,3$)

e_{ijklmn} = the random error term associated with each

The model was fitted with an iterative maximum likelihood technique, using the SAS procedure CATMOD (SAS,1987). Other fixed factors were not included in the model because the resultant multiway table was too big, with many empty cells. However, only variables which generated a multi-way table with fewer numbers of empty cells were retained in the model.

The model fitted for analysis of selective culling rate of

heifers was similar to that for cows, except that parity was not included and both season and year of birth of the heifer replaced the year and season of calving. In addition, the models for survival rates had the same factors fitted as for the model fitted for the selective culling rate of heifers, except that grazing system was added as a fixed effect.

3.5 Calculation of Productivity Index

The overall productivity index was defined as Feed Energy Efficiency (FEE) and derived as the aggregate valued offtake per unit of feed energy requirement. This was measured by a combined run of the demographic stationary-state constants (DIC) and produce-related constants (PIC) modules of the PRY computer package (Baptist, 1990b). The least squares estimates of parameters of the animal performance traits and prices of products (see Section 3.4) were used as driving variables in the two modules of PRY.

The driving variables of the DIC module were:

- (i) calving interval;
- (ii) age at first calving;
- (iii) selective culling rate of heifers and cows;
- (iv) survival rates for males and females:
 - preweaning calves (0-4 months),

The driving variables of the PIC module were:

- (i) lactational milk yield;
- (ii) prices of milk, calves (male and female) bulls and cows.
- (iii) litter size- although twinning was negligible in the calvings of the small scale dairy cattle covered in this study.

(iv) In addition, liveweight-for-age of each breed the module.

Unit offtake (milk and liveweight) values on a monetary scale (Kenya Shillings) were applied to obtain total output in economic terms. The physical input was the feed energy requirement.

The productivity index not only depended on performance (fitness and yield) traits and product price variables, but also on the management imposed culling and replacement regime (policy) on the breed groups. By use of PRY package, it was possible to identify the optimal culling strategy (culling and replacement policy maximizing FEE) to enable unbiased comparison among the breed groups.

The reference farming situation was a sustainable dairy cattle population on small-scale farms located in the low, medium and high altitudes areas. The farms were within the high arable potential belt of the country. Therefore, any hypothetical situation or option requiring calculation or re-calculation of the productivity index had to be tested to determine whether it made the breed group's population sustainable with regard to the DIC variables using the PRY SAM module. If the population was not sustainable, the PRY programme crashed on any attempt to find the optimal culling strategy. Thus the FEE index could not be calculated nor were any further PRY analyses were possible.

The PRY PIC module could take into account different body growth patterns. However, in order to keep control over the number of parameters that were to be used, it was assumed after Thiessen (1976); Thiessen and Taylor (1986); and Casey and Maree (1993) that there was no difference in body growth and composition as well as energy contents and efficiencies of liveweight gain between the breed groups. In addition, the metabolic constants required by the module for the maintenance energy requirements, milk yield, butter fat content and gestation products were set to default values according to Baptist (1990d).

3.6 Sensitivity Analyses

The simultaneous future changes in milk yield and fitness traits in the pure dairy breeds and their crossbreds could not be predicted for certain in the smallholder herds. This was because the different yield and fitness traits could vary in different directions (opposite, unidirectional or synergistic) under practical situations.

It was known that environmental regimes in smallholder herds tend to be stressful. Hence most of the traits considered would be adversely affected. The sensitivity analysis, therefore, provide the basic means of deriving the economic weights of the possible breeding objectives among the breed groups. It also helps to narrow down the range of possible outcomes arising from future fluctuations (negative or positive improvements) in milk yield, reproduction and fitness traits in smallholder herds by use of the PRY package.

The measurement of sensitivity was made possible by the magnitude of change in the FEE index of the breed group, at optimal culling level, as the driving variable (milk yield, reproductive and fitness traits) within each breed group was improved marginally by 1 standard error corresponding to its respective least squares mean. The FEE index was re-calculated for each hypothetical change caused by each of the driving variables within each breed group.

The mathematical description of the normal distribution curves of economic traits, in terms of mean and standard deviation, is given by Casey and Maree (1993). Nonetheless, the decision to vary the least squares mean of the trait by 1 standard error in this study is empirical rather than stochastic as reviewed from Upton (1989), Baptist (1990c) and Kauffmann et al. (1990).

The impact of change in the driving variable on the FEE index was expressed as percentage change of the FEE index compared to the initial FEE index value before the change. Therefore, the FEE index was used as a basis upon which the likely future direction of improvements in milk yield and fitness traits were assessed by sensitivity analysis. The sensitivity analysis value (as percentage change in FEE index) was used as the gauge for economic weight of the trait in the overall selection objective (economic merit) of the breed group.

3.7 Milk Yield Trade-offs and Fitness Losses Evaluation

The purpose here was to provide an objective gauge for the evaluation of the pure breeding policy options in smallholder

dairy cattle herds rather than to propose specific policies. This was done to provide an outline of potentials, constraints and requirements, which were to be expected for either of the stated breeding policy options (Section 1.5).

The policy options differed mainly with regard to the change in the dairy breed groups' inherent milk yield potential and the corresponding fitness loss. The effect of each policy option on each pure dairy cattle breed productivity on small scale farms was gauged by the magnitude of trade-off values of the milk yield (expressed in kilograms) for the deterioration of fitness traits to levels of magnitude when the driving variables were altered adversely by 1 standard error around the corresponding least squares mean.

The expected annual genetic improvement in milk yield caused by the current breeding policy provides the maximum value of the milk yield (in Kilograms) available for the trade-off with the defined fitness loss as described in the paragraph above. In the trade-off calculations, it was necessary to determine how much of the increase in the inherent milk yield potential, due to the current breeding policy, would be required to counterbalance the effect of the deterioration in fitness traits so that the FEE index would be maintained.

The current breeding policy has, in the past, led to an expected annual milk yield increment of 6.29 kg in the genetic potential in a highly selected Holstein-Friesian cattle in

Kenya (Rege and Mosi, 1989). On the other hand, the alternative policy option was also expected to lead to change but whose magnitude and direction, in terms of the genetic potential and fitness loss, were favourable in the small-scale herd environment.

For instance, the current policy option could be rejected if the trade-off values of milk yield for fitness loss was at least 6.29 kg (i.e the annual genetic gain in milk yield made possible by that policy in the past) based on the results of Rege and Mosi (1989). The rejection of that option could imply that the alternative policy was acceptable for the improvement of that particular pure breed population on smallholdings.

A transition or drastic modification in the practice of the current breeding policy is taking place in the national dairy cattle herd as the Kenya government is promoting privatization of AI services (KNAIS, 1991; Inyangala, 1999). In the near future small scale farmers will predominantly have direct access to imported semen through cooperatives or private AI commercial service companies (KNAIS, 1991; Wakhungu and Baptist, 1992b; Inyangala, 1999). This will be virtually a new accelerated programme of genetic lift, avoiding the local progeny test scheme which is prone to long generation intervals or which has virtually collapsed. The expected annual genetic progress generated by this transition or modification will be much higher (Wakhungu and Baptist, 1992b) than that reported by Rege and Mosi (1989).

The following is a derivation of the estimate of the expected annual genetic gain in milk yield generated by the transition in the current breeding policy, based on facts and figures reported in literature (CAIS, 1999; Colleau, 1991; van Vleck, 1976; Woolliams, 1990; Wakhungu and Baptist, 1992b):-

$$\text{Annual Genetic Gain} = \{2\% \} \{76\% \} \{0.5\} \{5000 \text{ kg}\} = 38 \text{ kg}$$

Where,

2%= gain due to maximum genetic progress per year

76%= gain due to expected contribution of progeny tested sire to Genetic progress per year in the source herds of imported semen;

0.5= due to negligible selection differential among cows

inseminated on small scale-farms in Kenya, only imported semen cause expected genetic progress;

5000 kg= minimum level of herd average in herds at imported Semen source; and

38 kg= the expected genetic gain per year in milk

The time lag for the imported semen genetic impact in smallholder herds is estimated at 5 years (Wakhungu and Baptist, 1992b).

Basing on the above calculation, if the trade-off value of milk yield for the deterioration in any fitness trait was more than 38 kg per year for any pure dairy breed then the alternative option of the breeding policy would be a reasonable proposition for that breed on small scale farms.

4.0 RESULTS

4.1 Lactational Milk Yield

The mean, standard deviation and coefficient of variation of lactational milk yield were 2430.71 kg, 477.74 kg and 19.65%, respectively. Herd, breed group, lactation length, parity, year and season of calving had highly significant ($P < .01$) effect (Appendix 2).

The Friesian had the lowest milk yield but did not differ significantly ($P < .05$) from that of the Ayrshire, while the Guernsey had a significantly ($P < .05$) higher milk yield than both the Friesian and the Ayrshire (Table 3). The R_s , Kilifi, Jersey, F_L and F_s did not differ significantly ($P > .05$), although they produced significantly ($P < .05$) more milk than the rest of the breed groups. The milk yields of the Nondescript and the Kilifi did differ significantly ($P < .05$), but they were significantly ($P < .05$) higher than those for pure breeds, except the Jersey.

The milk yield significantly ($P < .01$) increased with lactation length at the rate of 16.14 kg/day. Cows calving in the long rainy season produced significantly ($P < .01$) more milk. On the other hand, there were significantly ($P < .01$) higher milk yields in the 3rd, 4th and 5th lactations than in the first two lactations. In spite of that, there were no significant ($P > .05$) differences among the rest of the lactations.

TABLE 3: Estimated least Squares means (LSM) and standard errors (SE) for Lactational Milk Yield (kg) by breed groups.

	N	LSM \pm SE
Overall Mean	2055	2438.61 \pm 23.78
Friesian	477	2142.63 \pm 39.43 ^a
Ayrshire	363	2170.28 \pm 34.14 ^a
Guernsey	226	2345.97 \pm 41.52 ^b
Jersey	132	2613.90 \pm 53.60 ^c
Nondescript	186	2460.54 \pm 51.98 ^d
F ¹	165	2744.71 \pm 50.84 ^c
R ¹	159	2465.15 \pm 58.15 ^d
F ⁵	147	2798.46 \pm 52.51 ^c
R ⁵	164	2821.64 \pm 57.76 ^c
Kilifi	36	2953.66 \pm 117.71 ^c

^a Means followed by different superscript in the same column differ significantly (P<.05).

N = Number of observations

4.2 Age at First Calving

The mean, standard deviation and coefficient of variation for age at first calving were 39.48, 8.10 months and 20.52%, respectively. Locality, herd, grazing system, breed group and grazing system X breed group interaction affected the age at first calving significantly (see Appendix 3).

Jersey heifers calved at the earliest, but did not differ significantly ($P < .05$) from the Guernsey and F_s heifers (Table 4). The Friesian heifers were the oldest at calving, though their age at calving did not significantly ($P > .05$) differ from those of the Ayrshire, R_L and the Nondescript heifers (Table 4). Besides, the age at calving for the R_s differed significantly ($P > .05$) from those of the heifers of the other breed groups, except for the F_L and Kilifi.

Those heifers kept under semi-zero and extensive grazing systems calved at significantly ($P > .05$) earlier ages. Breed group by grazing system interaction was observed in the fact that the ranking of breed groups was not maintained in the different grazing systems. For instance, whereas F_s heifers calved at a significantly ($P < .05$) later age under extensive grazing, they calved at significantly ($P < .05$) earlier age under semi-zero grazing.

TABLE 4: Estimates of Least squares means and standard error for age at first calving (AFC) (months) and calving interval (CI)(months) by breed groups.

	N	CI	N	AFC
Overall mean	1560	13.70 ±.10	4.95	38.40±.47c
Friesian	348	14.00±.17 ^a	129	44.18 ±.75 ^c
Ayrshire	286	14.12 ±.11 ^a	77	40.36 ±.90 ^c
Guernsey	176	13.91±.15 ^c	50	34.30 ±1.10 ^a
Jersey	100	13.53±.13 ^b	32	31.62 ±1.32 ^a
Nondescript	142	13.62 ±.16 ^a	44	38.56 ±1.16 ^c
F ^L	122	14.13 ±.12 ^c	37	45.34 ± 1.22 ^b
R ^L	127	13.64 ±.17 ^a	38	37.04 ±1.16 ^b
F ^S	111	13.53 ±.14 ^b	36	35.68 ±1.24 ^a
R ^S	123	13.38 ±.13 ^b	41	37.04 ±1.16 ^b
Kilifi	25	12.98 ±.37 ^b	11	36.51 ± 2.21 ^b

Within variable groups, means in the same column without a common superscript differ significantly (P<.05).

N = number of observations.

The R_L had a significantly ($P < .05$) earlier calving age under semi-zero grazing, while it had significantly ($P < .05$) later age at calving under zero-grazing. However, the general observation was that all breeds had more advanced age at first calving under the extensive grazing system than those under the semi-zero grazing, except for the Ayrshire, Friesian and Kilifi.

4.3 Calving Interval

The mean, standard deviation and coefficient of variation for calving interval were 13.88, 1.64 months, and 12.0%, respectively. Locality, herd and breed group had significant effect ($P < .05$) on calving interval.

The calving interval of F_L was the longest, though it did not significantly ($P > .05$) differ from that of the Guernsey. On the other hand, whereas the Kilifi had the shortest calving interval, it was not significantly ($P > .05$) different from those of Jersey, F_S and R_S . However, the calving interval of F_L was significantly ($P < .05$) longer than that of the Kilifi, F_S and R_S .

4.4 Selective Culling Rate of Heifers and Cows

The mean and standard deviation for selective culling rate of heifers were 9.20% and 5.0%, respectively. Selective culling rate of heifers did not significantly ($P > .05$) vary with breed groups (Appendix 4 and Table 5). Year of birth and grazing system had significant effect on selective culling rate of heifers (Appendix 4).

The respective lowest and highest selective culling rates occurred in heifers born in 1982 and 1987, with the difference between these two years being significant ($P < .05$). On the other hand, heifers under zero-grazing had a significantly ($P < .05$) lower selective culling rate.

The mean and standard deviation for selective culling rate for cows were 23.40% and 6.03%, respectively. Breed group and parity had significant ($P < .01$) effect (Table 5). The highest and lowest selective culling rates occurred in 3rd and 7th lactations, respectively. There were significant ($P < .05$) differences among lactations; except for lactations 2 and 4.

The Friesian, Guernsey and the Nondescript cows had a significantly ($P < .05$) lower selective culling rate while the Kilifi, Jersey and the R_L had significantly ($P < .05$) higher rate than the cows in the rest of the other breed groups.

TABLE 5: Maximum likelihood estimates and standard errors of selective culling rate (percentage units) in heifers and cows by breed groups (from logit model)

	Heifers	Cows
Interception	.09 ± .01	.23 ± .01
Friesian	.10 ± .02	.20 ± .01 ^a
Ayrshire	.10 ± .01	.23 ± .02 ^b
Guernsey	.13 ± .02	.21 ± .02 ^a
Jersey	.13 ± .03	.24 ± .03 ^c
Nondescript	.09 ± .04	.20 ± .02 ^a
F ^l	.13 ± .03	.23 ± .03 ^b
R ^l	.11 ± .02	.24 ± .02 ^c
F ^s	.09 ± .03	.23 ± .03 ^b
R ^s	.10 ± .02	.22 ± .03 ^c
Kilifi	.09 ± .05	.27 ± .05 ^c

* Means followed by different superscript in the same column differ significantly (P<.05).

4.5 Survival Rates by Age Groups

4.5.1 Calves (0-4 months)

4.5.1.1 Males

The male calves had mean, standard deviation and coefficient of variation of 83.20, 21.31 and 29.01%, respectively for survival rates. Year of birth and breed group significantly ($P < .01$) affected the survival rate (see Appendix 5).

The Ayrshire and Friesian had the lowest survival rate while the Rs had the highest rate compared to the rest of the breed groups (Table 6). Generally, crossbreds of the small-sized dairy breeds had a significantly ($P < .05$) higher survival rate than those of the large-sized dairy breeds.

The calves born in 1986 and 1992 had the highest and lowest survival rates, respectively. The survival rate of calves born in 1986 was significantly ($P < 0.05$) higher, whereas those born in 1992 had lower survival rates than for those born in 1987-1990.

4.5.1.2 Females

The mean, standard deviation and coefficient of variation were 83.80%, 30.90% and 36.87%, respectively. The survival rate was significantly affected by the breed group and grazing system (Appendix 5). Female calves born in zero-grazing system had the highest survival rate.

The Jersey and Friesian had the highest and lowest survival rates, respectively (Table 6). The differences among the

TABLE 6: Maximum likelihood estimates and standard errors of survival rate (percentage units) of calves (0-4 months) by breed groups (from logit model)

	Males	Females
Interception	.82 ± .01	.84 ± .01
Friesian	.73 ± .02 ^a	.77 ± .02 ^a
Ayrshire	.72 ± .02 ^a	.86 ± .02 ^b
Guernsey	.89 ± .03 ^c	.80 ± .04 ^a
Jersey	.80 ± .04 ^b	.92 ± .03 ^c
Nondescript	.81 ± .03 ^b	.81 ± .03 ^c
F ^l	.83 ± .04 ^b	.86 ± .04 ^b
R ^l	.78 ± .03 ^b	.83 ± .04 ^b
F ^s	.86 ± .02 ^c	.84 ± .02 ^b
R ^s	.94 ± .03 ^c	.81 ± .04 ^c
Kilifi	.82 ± .07 ^a	.88 ± .06 ^a

* Means followed by different superscript in the same column differ significantly (P < .05).

Ayrshire, FL, RL, and Fs were not significant ($P > .05$), though they differed significantly ($P > 0.05$) from those of the Guernsey, Jersey, Nondescript, Friesian, Kilifi and Rs.4.5.2 Young Stock (5-30 months)

4.5.2.1 Heifers

The mean, standard deviation and coefficient of variation for heifers were estimated at 84.30%, 32.66% and 38.74%, respectively. Breed group and season of birth had significant effect on survival rate (see Appendix 6).

RL and Fs had significantly ($P < .05$) the lowest and highest survival rates compared to the other breed groups (Table 7). The Jersey had significantly ($P < .05$) the highest survival rate among the pure dairy breeds.

The crossbreds of the small-sized breeds had significantly ($P < .05$) higher survival rates compared to the crossbreds of the large-sized breeds. Nevertheless, there was a significant ($P < .05$) decline in survival rate as the proportion of the purebred dairy genotype increased in the crossbreds.

Heifers born in the short rainy season had significantly ($P < 0.05$) higher survival rate. However, there was no difference between survival rates of heifers born in the long rainy season and the dry season.

TABLE 7: Maximum likelihood estimates and standard errors of survival rates (percentage units) of young stock (5-30 months) by breed groups (from logit model).

	Heifers	Bulls
Intercept	.84 ± 0.02	.87 ± 0.03
Friesian	.84 ± 0.03 ^b	.83 ± 0.04 ^a
Ayrshire	.86 ± 0.03 ^c	.84 ± 0.04 ^a
Guernsey	.86 ± 0.04 ^c	.87 ± 0.05 ^d
Jersey	.88 ± 0.06 ^d	.84 ± 0.05 ^d
Nondescript	.85 ± 0.04 ^b	.87 ± 0.05 ^c
F ^l	.83 ± 0.04 ^b	.85 ± 0.05 ^a
R ^l	.77 ± 0.05 ^a	.89 ± 0.05 ^c
F ^s	.91 ± 0.05 ^c	.96 ± 0.05 ^c
R ^s	.85 ± 0.04 ^c	.92 ± 0.05 ^f
Kilifi	.81 ± 0.07 ^f	.79 ± 0.07 ^e

* Means followed by different superscript in the same column differ significantly (P<.05).

4.5.2.2 Bulls

The mean, standard deviation and coefficient of variation of survival rate for bulls were estimated at 88.02%, 28.38% and 32.10%, respectively. Year of birth, grazing system and breed group had significant effect on the survival rates (Appendix 6).

The Kilifi and the F_5 bulls had significantly ($P < .05$) the lowest and highest survival rate compared to the other breed groups (Table 7). The differences among the survival rate of the Guernsey, the Nondescript and the R_L were not significant ($P > .05$).

Among the pure breeds, the Guernsey had significantly ($P < .05$) the highest survival rate. The crossbreds of the small-sized breeds had a significantly ($P < .05$) higher survival rate compared to those of the large-sized pure dairy breeds and their crossbreds.

The bulls born in 1988 and 1990 had the lowest and highest survival rate, respectively. Those born in 1988 had significantly ($P < .05$) lower survival rates than those born in the rest of the years.

Bulls born under semi-zero grazing system had a significantly ($P < .05$) higher survival rate. However, there was no significant ($P > .05$) difference between those born in the zero- and extensive- grazing system.

4.5.3 Adult Stock (31-144 months)

4.5.3.1 Cows

The mean, standard deviation and coefficient of variation for survival rates of cows were estimated at 80.01%, 30.21% and 37.76%, respectively. Year and season of calving, grazing system and breed group had significant effect on survival rate (see Appendix 7).

The F_L and Jersey had significantly ($P < .05$) the lowest and highest survival rates, respectively (Table 8). However, the survival rates of Friesian, Ayrshire and F_s were not significantly different. The small sized pure dairy breeds and their crossbreds had significantly ($P < .05$) higher survival rates than those of the large sized pure dairy breeds and their crossbreds.

The Nondescript had a significantly ($P < .05$) higher survival rate than the Kilifi. The trend observed in the crossbreeding was such that as the proportion of small sized pure dairy breed inheritance in the crossbred increased there was significant increase in survival rate. Nonetheless, this trend was not observed in the crossbreds of large sized pure dairy breeds.

Those calving in 1987 and 1990 had significantly ($P < .01$) the lowest and the highest survival rates, respectively. However, there was no significant ($P > .05$) difference between the survival rates of those that calved in 1986 and 1989. In addition, there were no significant differences among the survival rates of those calving in 1991 and 1992.

Cows under zero grazing system had a significantly ($P < .05$) higher survival rate. However, there was no significant ($P > .05$) difference between those kept in the semi-zero and extensive grazing systems.

Similarly, the differences among the survival rates of those calving in the rest of the year (dry season) and the rainy seasons were significant. Nevertheless, those calving in the long and short rainy season had the highest and lowest survival rates, respectively.

4.5.3.2 Bulls

The mean, standard deviation and coefficient of variation of survival rate for mature bulls were estimated at 84.36%, 31.02% and 36.77%, respectively. The grazing system and season of birth had significant effect on survival rate (Appendix 7). Breed group did not significantly affect survival rate of bulls and their survival rates are shown in Table 8.

Those born in herds under semi-zero grazing had significantly ($P < .05$) the highest survival rates while those under the extensive grazing had the lowest. Also, the difference between the survival rates of those born in herds under extensive and zero-grazing systems was significant ($P < .05$).

The bulls born in 1984 and 1988 had significantly ($P < .01$) the lowest and highest survival rates, respectively. The trend was such that those born in the period 1980-1985 had significantly ($P < .05$) lower survival rates than those born in 1988.

However, the survival rates of those born in 1986-1987 were comparable to those of 1988.

The survival rate of those born in the short rainy season and long rainy season were significantly ($P < .01$) highest and lowest, respectively. There was no significant ($P > .05$) difference between the survival rates of bulls born in the long rainy season and in the dry season.

TABLE 8: Maximum likelihood estimates and standard errors of survival rates (percentage units) of adult stock (31-144 months) by breed groups (from logit model).

	Bulls	Cows
Intercept	.84 ± 0.03	.79 ± 0.02
Friesian	.83 ± 0.04	.80 ± 0.03 ^a
Ayrshire	.84 ± 0.04	.81 ± 0.03 ^a
Guernsey	.83 ± 0.05	.89 ± 0.04 ^b
Jersey	.82 ± 0.06	.96 ± 0.05 ^c
Nondescript	.84 ± 0.05	.84 ± 0.04 ^d
F ^L	.85 ± 0.05	.73 ± 0.04 ^c
R ^L	.86 ± 0.05	.74 ± 0.04 ^c
F ^S	.83 ± 0.05	.80 ± 0.04 ^a
R ^S	.82 ± 0.05	.89 ± 0.04 ^b
Kilifi	.77 ± 0.08	.76 ± 0.05 ^f

* Means followed by different superscript in the same column differ significantly ($P < .05$).

4.6 Prices of Products and Stock

4.6.1 Milk

The mean and standard deviation of milk price were estimated at Kshs 3.90 and 1.82 per kg, respectively. Locality, year of calving, grazing system and stocking density significantly affected the price (see Appendix 8). Breed group did not significantly affect milk price (Table 9).

Cows kept under zero-grazing fetched significantly ($P < .05$) higher milk price than those kept under the other two grazing systems. The price of milk significantly ($P < .05$) varied inversely with the stocking density. Over the period 1984-1992, the price of milk rose consistently but varied with year significantly ($P < .05$).

4.6.2 Cows

The mean and standard deviation of cow price were estimated at Ksh 5786.63 and 1803.00 per cow, respectively. Locality, herd, breed group and grazing system affected the price significantly (Appendix 8). The cow price significantly ($P < .05$) varied inversely with stocking density.

The Jersey and the Kilifi had significantly ($P < .01$) the lowest and highest cow price, respectively (Table 9). Nevertheless, the differences among the Friesian, Ayrshire, Jersey, R_L and R_S were not significant ($P > .05$). The F_L and F_S had significantly higher prices than those of R_L and R_S .

TABLE 9: Estimates of least squares means and standard errors for the prices (Kenya shillings per litre or per head) of milk, cow, female and bull calves by breed group.

	N	Milk	Cow	Bull Calf	N	Female Calf
Overall	2031	3.75± .01	5786.63± 64.08	416.53 ± 15.09	976	415.60 ± 13.08 ^a
Friesian	468	3.86± .03	5682.03± 090.15a	557.50 ± 36.08a	237	547.60 ± 13.08 ^b
Ayrshire	359	3.72 ± .04	5670.77± 101.30a	375.63 ± 16.00b	162	362.80 ± 16.14 ^b
Guernsey	226	3.65± .05	5811.91 ± 116.00b	420.17 ± 19.20b	106	370.26 ± 22.18 ^b
Jersey	132	3.78 ± .04	5513.15 ± 140.90a	426.09 ± 16.30b	64	421.60 ± 27.06 ^c
Nondescript	186	3.83 ± .07	5843.80 ± 140.00b	372.30 ± 32.60b	91	347.42 ± 34.52 ^b
F ^L	153	3.81± .05	5901.00 ± 140.05b	417.02± 27.14b	75	401.80± 28.68 ^b
R ^L	165	3.76 ± .05	5631.20± 143.90a	338.10± 29.40b	74	426.10 ± 32.24 ^c
F ^S	147	3.78± .06	5910.00± 141.42b	461.07 ± 28.06b	68	474.63 ± 33.32 ^c
R ^S	159	3.63 ± .06	5564.40 ± 142.06a	441.06± 29.02b	81	400.82± 29.18 ^b
Kilifi	36	3.58 .14	6316.08 ± 250.10c	366.46 ± 49.42c	18	398.60 ± 52.09 ^b

Within variable groups, means in the same column without a common superscript differ significantly ($P < .05$).

The cow price was significantly ($P < .01$) higher in most of the high producing herds which frequently participated in agricultural shows. Cows under zero grazing had significantly ($P < .01$) the highest price, while those under semi-zero grazing had the lowest. The price of cows under the extensive grazing was significantly ($P < .05$) lower than that for those under semi-zero grazing.

4.6.3 Calf Prices

4.6.3.1 Bull Calves

The mean and standard deviation of the price of bull calves were estimated at Ksh 416.53 and 98.34 per calf, respectively. Locality, herd, year of birth, breed group, grazing system, mating method and farm acreage had significant effect on the bull calf price (Appendix 8). Friesian attracted significantly ($P < .01$) the highest price (Table 9). The differences among the rest of the breed groups, with the exception of the Kilifi, were significant.

The price trend was such that they increased over the period 1984-1992. The prices in the year 1991 and 1992 were significantly ($P < .05$) higher than those in the period 1984-1988.

The price of the calves significantly ($P < .01$) varied directly with the farm acreage at the rate of Ksh $18.15 \pm .05$ per acre. Those born in semi-zero grazing herds attracted significantly ($P < .01$) higher price compared to those in zero and extensive grazing herds. However, those in extensive grazing herds had significantly

($P < .05$) a higher price than those in zero-grazing herds.

It was notable that calves born in high producing herds attracted a significantly ($P < .05$) higher prices. Localities with a low density of dairying herds, particularly in Western, Nyanza, Coast and Eastern (lower parts) provinces had significantly ($P < .05$) higher bull calf prices.

Calves born through AI had significantly ($P < .05$) a higher price. The price was not high for those born through natural service and those from herds where the records showed doubt as to whether they were from AI or natural service breeding method.

4.6.3.2 Female Calves

The mean and standard deviation of prices of calves were estimated at Ksh 415.96 and 53.14 per calf, respectively. However, the prices differed with locality, herd, mating method, year of birth, grazing system, and farm acreage and breed group significantly (Appendix 8). The calf price significantly ($P < .01$) varied inversely at the rate of Ksh 15.05 ± 0.1 per calf for every unit increase in total farm acreage.

The calves of Friesian and Nondescript had significantly ($P < .01$) the highest and lowest prices, respectively (Table 9). The prices of Friesian and Jersey calves were significantly higher among the pure dairy breeds. The prices among the Jersey, F_s , and R_L did

not differ significantly.

Those born in zero grazing herds attracted significantly ($P < .01$) the highest price compared to those in semi-zero and extensive grazing herds. However, those in extensive grazing herds had significantly ($P < .01$) a lower price than those in semi-grazing herds.

The price increased consistently over the years in the period 1984-1992. Price of those born in 1984 was significantly lower than for those born in 1992. However, there were no significant differences among the prices of heifers born in the periods 1986-1989 and 1990-1992.

Calves born in high producing herds attracted highest price. Localities with a high density of dairying herds, particularly in Central, Rift Valley, Coast, Nyanza, and Eastern provinces had significantly ($P < .05$) higher female calf prices.

Calves born through AI had significantly ($P < .01$) a higher price than those born through natural service. Also, calves born in herds where the records showed doubt as to whether they were from AI or natural service breeding method attracted lower prices.

4.7 *Breed Group Productivity*

4.7.1 *Optimal Culling Strategies*

The R_L breed group was not sustainable as it had demographic trait values which did not favour sustainability of the breed group under smallholder environment. There was between breed groups variation in terms of their optimum culling ages, which ranged from 8 to 11 months for young stock and 117 to 143 months for breeding females.

The cull-for-age thresholds varied directly with the expected mature-size of the breed group. In addition, the culling ages for breeding females were higher for the pure breeds than for their corresponding crossbreds with zebu cattle (Table 10). The F_S and the Friesian had the lowest and highest cull-for-age threshold of breeding females, respectively.

4.7.2 *Feed Energy Efficiency (FEE) Index*

The FEE index values were such that Friesian and Jersey had the lowest and highest, respectively (Table 10). The overall trend observed was that the small-sized pure breeds and their crossbreds (F_S and R_S) as well as the Kilifi were superior to the large-sized pure breeds and the F_L . The Nondescript was slightly superior to Guernsey, F_L and the large-sized pure breeds. The F_S and R_S FEE index values were close to each other whereas the Jersey was superior to both breed groups. But within small-sized pure breeds the Jersey was superior to Guernsey. The Ayrshire was superior to the Friesian.

The correlation between the ranking by breed group lactational milk yield in Table 2, and FEE values in Table 10 was estimated at 0.73; and was not significantly ($P > .05$) different from zero due to high standard error. On the other hand, if the ranking by breed group changed to potential lactational milk yield, as realized in large scale commercial herds (Graevart, 1996; Njubi et al., 1992), then its correlation with the rank of corresponding breed group FEE values was estimated at -0.0417.

TABLE 10 Fee Index, rank and cull-for-age threshold of breeding female (BF), surplus female (SF) and male (SM) by breed groups.

Breed group	Fee Index (Ksh/kg DM)	Rank by Cull-for-age threshold (months)			
		FEE	BF	SF	SM
Friesian	1.322	9	143	11	11
Ayrshire	1.501	8	140	10	10
Guernsey	1.896	7	132	8	8
Jersey	2.369	1	141	8	8
Nondescript	1.967	5	134	10	10
F ^L	1.950	6	131	11	11
F ^S	2.257	2	117	9	9
R ^S	2.218	3	118	9	9
Kilifi	2.176	4	141	9	9

Kshs. = Kenya Shilling; Kg DM = Kilogramms of dairy matter

4.7.3 Sensitivity of Breed Groups

An increase of magnitude of 1 standard error in the least squares mean of each trait within each breed group caused change in the FEE index which ranged from 0% to 2.30% (Table 11). The traits arranged according to their magnitude of impact on the FEE index, in a descending order was as follows: the lactational milk yield, the age at first calving, calving interval, selective culling rate among heifers and cows, survival rate among females and males.

Notwithstanding the above trends, the relative importance of each of the traits within the breeds varied from breed to breed following their magnitude of contribution to the breed group FEE (Table 10). The FEE was most sensitive to changes in milk yield.

TABLE 11 sensitivity of the FEE index to change in the productivity components of Friesian (F), Ayrshire (A), Guernsey (G), Jersey (J), Nondescript ((ND), F^L, F^S, R^S and kilifi breed groups.

Yield/fitness trait	Change in FEE (%)								
	F	A	G	J	ND	F ^L	F ^S	R ^S	Kilifi
a) Milk offtake/lactation	1.06	1.27	0.74	1.35	1.53	0.95	1.28	1.44	1.05
b) Survival rate:									
i) Female (age in months):-									
0-4	0.00	0.35	0.00	0.54	1.51	0.00	0.15	0.66	0.46
5-30	0.28	0.00	0.22	0.98	0.76	0.29	0.55	0.97	0.72
31-144	0.47	0.77	0.25	0.54	0.88	0.10	0.54	0.98	0.85
ii) Male (age in months):-									
0-4	0.00	0.35	0.00	0.51	0.38	0.00	1.04	0.62	0.32
5-30	0.30	0.42	0.05	0.58	0.51	0.05	0.15	0.60	0.50
31-144	0.47	0.77	0.25	0.54	0.88	0.10	0.54	0.98	0.85
d) Selective culling rate (per age group):-									
i) Heifer	0.30	0.60	0.05	0.76	0.81	0.47	0.40	0.81	0.71
ii) Cow	0.30	1.07	0.11	0.80	0.76	0.74	0.71	1.22	0.94
e) Reproductive traits:-									
i) Age at first calving	0.76	0.87	0.63	1.69	2.4	0.68	2.30	0.99	0.87
ii) Calving interval	0.38	0.35	0.32	0.55	0.46	0.32	0.85	0.32	0.41

4.7.4 Trade-offs: Milk Yield and Fitness Losses

On both single-trait and combined trait basis, all the pure dairy breeds considered had higher milk yield trade-off values than 6.29 kg/year, which can be attained by the current national dairy cattle breeding policy (Table 12). The milk yield trade-off value for age at first calving was much higher than 38 kg (which is expected annual genetic progress under the projected future transition to heavy reliance on imported semen) for all breeds, except the Jersey. The other traits could only cause trade-offs of less than 38 kg live weight.

From the trade-off values observed above, there is a probability of 34% that the present breeding policies (both original and modified) are likely to lose more milk from deterioration of fitness traits than it is likely to gain from potential increase in yield. The biological and probabilistic argument for this observation is described in detail in Section 2.5.4.

The survival rates of young female stock were the second outstanding set of traits after the age at first calving, in terms of milk yield trade-offs, among all the breeds. The trend of milk yield trade-off values for female stock survival rate was such that they increased with age of the animals; and tended to decrease with body size of the dairy breed. These were followed by the selective culling rate. On the other hand, the survival rate among males of Friesian and Ayrshire had higher sensitivity values

than those for Jersey and Guernsey.

When the marginal change in female survival rates were combined for all age groups the Friesian breed was not sustainable under the smallholder environment. This was the same case where the selective culling rate (of heifer and cow combined) resulted in the Friesian being unsustainable. This is why there were no corresponding entries in Table 12 for the combined variation in the female survival rates in the Friesian.

It is interesting that the milk yield trade-offs for most of the traits were greater than 6.29 kg (the annual genetic progress realised in the current dairy cattle breeding policy) with few exceptions between breeds and within breeds. The overall trend is that for all breeds covered in this study, the current breeding policy is inappropriate on basis of milk yield trade-off values being greater than 6.29 kg (Table 12).

On the basis of the projected future transition to heavy use of imported dairy germplasm where milk yield trade-off values should be less than 38 kg, it is only the Jersey, which fits the criterion for all traits. The major constraint to the rest of the breeds is associated with the higher milk yield trade-off values of age at first calving. However, for the Friesian, the age at first calving and the combined effects of female survival rates and selective culling rates are the constraint to improvement in FEE (Table 12).

TABLE 12: Lactational milk yields trade-off for marginal loss (of 1 standard error) in fitness traits of breed groups.

Fitness trait		Trade-off in milk yield (kg)			
		F	A	G	J
Survival rates (annualized)					
a)	Females (Age in months):-				
i)	0-4	0.50	9.00	2.00	0.00
ii)	5-30	20.00	15.00	20.00	9.00
iii)	31-144	28.00	22.00	23.00	11.00
b)	Males (Age in months):-				
i)	0-4	5.00	15.00	1.00	0.00
ii)	5-30	8.00	7.00	3.00	0.00
iii)	31-144	8.00	4.00	1.00	1.00
c)	Combined survival rates:				
i)	Female	UPS	32.00	35.00	35.00
ii)	Male	0.00	8.00	4.00	0.50
Reproductive traits:					
a)	Calving interval	15.00	9.00	23.00	5.00
b)	Age at first calving	44.00	50.00	53.00	10.00
Selective culling of females (per age group)					
i)	Heifer	10.00	15.00	12.00	2.00
b)	Cow	13.00	17.00	14.00	0.25
c)	Heifer and cow combined	UPS	20.00	20.00	15.00

F = Friesian, A = Ayrshire, G = Guernsey, J = Jersey,

UPS = breed group attains unsustainable population state

5.0 DISCUSSION

5.1 Milk Production

The mean milk yield was within the range of the yields reported on smallholdings in sub-Saharan Africa (Kiwuwa et al. 1983; Agyemang and Nkhonjera, 1986; Thorpe and Trail, 1988), but lower than those reported in large-scale commercial herds in Kenya (Lusweti and Mpofu, 1989). This was partly attributable to the low nutritional quality of the roughage diets with little concentrate supplemental feeding on smallholdings. This is because of the fact that typical smallholder farms have less capital and land (Abate et al., 1987). These two major factors make smallholder farms to be unable to provide quality feed and other inputs to the dairy cattle.

The mean stocking density estimated at 2.5 cows per acre was twice that recommended by the National Dairy Development Project (MLD, 1990). This implied limited availability of fodder on the small-scale farms.

The high coefficient of variation of milk yield was consistent with the fact that some herds attained milk yields twice as high as the mean observed in this study. Thus there is substantial scope for improvement in milk yield through improved feeding and management.

The lactational milk yield varied highly with the lactation length. This concurred with the findings of Njubi et al. (1992). This is an indication that the correction of the milk yield for

lactational length was essential for the accuracy of ranking of cows on basis of milk production.

The superiority of Jersey and Guernsey over the Friesian and Ayrshire, in terms of milk yield, was contrary to those reported on large scale commercial dairy farms in Kenya and Zimbabwe (Luswetian and Mpofu, 1989). This could

However, the smallholders cannot guarantee quality inputs in the future, given the rising demographic trends in the human population in the rural areas (Wakhungu and Baptist, 1992b). Thus a broad front (holistic) approach to development is required in attempts to remove the genotype-environment interaction observed in this study.

It was not surprising that the milk yield varied significantly between herds. This was a good indication of the necessity to include herd effect to account for herd differences in animal evaluation models on the small scale farms. Therefore, this was within the expectation that herds had different levels of management and feeding which caused between herd variation in milk production.

The effect of parity on milk yield could have been partly a reflection of the age of the cows. Generally, young cows have higher feed requirements than mature cows due to their

physiological state (Rege and Mosi, 1989; Kiuwa et al.1983). Hence, there was a likelihood that they had a high frequency of negative energy balance incidences leading to lower milk yield (Short et al., 1990b). This was, therefore, viewed as a reasonable classification to be used to adjust milk records for age of cows.

Season of calving caused important variation in milk yield. Cows which calved in long rainy season might have had higher quantity and quality feed during the early lactation and reached the peak during or immediately after the long rainy season. This concurred with findings of Kiuwa (1983), Rege and Mosi (1989) and Njubi et al., (1992). This was expected because smallholder farmers were unable to produce milk profitably even when there were milk price incentives to supplement cows with concentrate feed during the dry season.

The implication here is that the lack of supplementation in most herds on smallholdings makes it easy to define calving seasons. Thus, if the economic conditions allowed, milk yield could be improved if cows were bred to calve during the long rainy season.

The annual trend of production was such that milk yield improved with the years covered in this study. The declining trend in the earlier half of the period was due to the impact of the 1983 drought which persisted into the subsequent years (MLD, 1985).

There was inversion of the trend mainly due to the fact that the rains in the period 1988-1992 were heavy and well distributed (MLD, 1992). This tends to suggest that husbandry improved over the years due to gain in knowledge of farmers through extension efforts (MLD, 1990).

The observations in this study were yet another confirmation of the findings by Potter and Anindo (1989), who observed that rainfall was a critical factor in the dairy cattle industry as it affected indirectly the feed quality and availability. Thus mean annual rainfall and seasonal distribution could be used as proxy to availability of fodder.

5.2 Reproductive Traits

5.2.1 Age at First Calving

The mean age at first calving was within the range of those reported in grade dairy herds in the tropics (Kiwuwa et al. 1983; Rege and Mosi, 1989; Njubi et al., 1992). The high coefficient of variation was expected because some herds attained a much lower age at first calving than the mean ($36.78 \pm .64$ months) observed in this study. These results confirmed that there was considerable scope for improvement through better feeding and management.

The existence of the breed group-grazing system interaction on age at first calving implied the differential response of breed groups to the three grazing systems. Lower age at first calving under the extensive and semi-zero grazing systems could be attributable

to the opportunity of constant exposure of heifers to bulls or other cows in the herd which could aid heat detection. This could not have been possible under zero-grazing (Valk, 1992).

The Jersey had the lowest age at first calving, although it was similar to the Guernsey and F_5 . However, the F_L had the highest age at first calving. These observations were contradictory to those reported in the Malawian (Agyemang and Nkhonjera, 1986) and Ethiopian (Kiwuwa *et al.*, 1983) herds. The difference could be partly attributable to the management systems' objectives in the herds reported earlier.

There was a decline in performance as the upgrading of the zebu to the small-sized pure breeds progressed to 75%. This could be partly due to the corresponding decrease in heterosis or genotypes not suited to that environment.

The better performance of the Jersey and Guernsey than the Friesian and Ayrshire indicated that the small-sized dairy breeds and their crossbreds could form the superior alternative to the Friesian and Ayrshire in the Kenyan smallholdings with regard to age at first calving. Nevertheless, as indicated by Langholtz (1990), Njubi *et al.*, (1992) and Seirsen and Lovendahl (1986) age at first calving in all breeds, regardless of their mature size, can be shortened considerably by improved feeding and management.

The effect of locality and herd on age at first calving was expected because these two factors affected the smallholder herds in terms of availability of fodder and capital to purchase inputs. Some herds were located in mixed crop-livestock systems where there was more emphasis on crop production rather than fodder throughout the year, particularly in the low altitude areas.

5.2.2 Calving Interval

The mean calving interval observed was within the range of those reported on smallholdings in sub-Saharan Africa (Kiwuwa et al. 1983; Agyemang and Nkhonjera, 1986; Thorpe and Trail, 1988). The shorter calving interval of Jersey and Guernsey over the Friesian and Ayrshire was contrary to those reported on large-scale commercial dairy farms (Lusweti and Mpofu, 1989; Njubi et al., 1992). This could be attributable to frequent negative energy balance in the large-sized pure breeds caused by the poor feed situation on the Kenyan smallholdings.

The Kilifi had the shortest calving interval, although it was similar to that of the Jersey, F_3 and the R_3 . This was expected because of the small body frame of these breed groups leading to lower energy requirements for maintenance over and above those for milk production.

The F_L had the lowest performance among the crossbreeds. On the other hand, the F_L was superior to the Friesian and Ayrshire.

These observations were contradictory to those reported in the Malawian (Agyemang and Nkhonjera, 1986) and Ethiopian (Kiwuwa et al., 1983) herds. Thus the superiority of F_1 to the large-sized dairy breeds could be partly due to heterosis.

The existence of the genotype-environment interaction phenomenon, with regard to feeding and management, in the Kenyan smallholdings could be a reality. This was implied by the shorter calving intervals of the Jersey and Guernsey and their crossbreds than the Friesian and Ayrshire and their crossbreds. This was contradictory to what was observed in large scale commercial dairy herds (Lusweti and Mpofu, 1989; Njubi et al., 1992).

The effect of locality and herd on calving interval was expected because these two factors affected the smallholder herds in terms of infrastructure for delivery of AI service and capital to purchase supplemental feeds. Some herds were located in remote areas where there were no all-weather roads and others were in mixed crop-livestock systems where there was more emphasis on crop production during the cropping seasons, particularly in the high altitude areas.

5.3 Selective Culling Rate of Breeding Females

The lack of significant breed group effect cannot be explained easily. However, it is known that heifers have a better physiological balance than the older cows and can withstand the

stressors in the commercial environment (Short et al., 1990a)

The superiority of cows of the Friesian, Nondescript as well as the Guernsey over the other breed groups arises from the fact that these breed groups had preferential treatment in the herds where they were located. Thus the popularity of these breed groups was high leading to their relaxed culling on the smallholdings. The Kilifi breed groups had significantly higher culling rate and this was attributable to the high prevalence of tsetse fly and tick borne diseases in the coastal strip where they were mainly kept.

Heifer selective culling rate on zero-grazing units was surprisingly lower than on the semi-zero grazing units. The observation could be partly due to the strict culling on the semi-zero grazing units. This was because of the high efficiency of heat detection by use of bulls. Besides, the constant contact of heifers with other cows facilitated the detection of heat. These observations are similar to those reported by Gombe and O'Hara (1986).

The availability of extra pasture enabled the keeping of uncastrated bulls for natural service and facilitated heat detection in semi-zero grazing herds. Thus reproductive management level made possible by the zero-grazing system was partially the cause, since heat detection is generally difficult in herds under

this system. This merits a further investigation for the cause and effect relationships with regard to dairy cattle husbandry practices and reproductive behaviour of breeding females under zero-grazing management.

Older cows had higher selective culling rate because of their age having a predominant negative physiological influence on their lactational and reproductive performance. This observation was also made by other investigators (Seirsen and Lovendahl, 1986; Short et al., 1990b). Their failing physiological state due to aging made them prone to diseases which could not be treated or prevented due to lack of capital on smallholder farms.

5.4 Survival Rates

The general trend was such that large-sized pure breeds and their crossbreeds had unacceptably low survival rates compared to the small-sized pure breeds and their crossbreeds. This was a manifestation of the fact that the small-sized pure breeds and their crossbreeds were more adaptable to the smallholder environment in Kenya.

The majority of smallscale farmers keep the large-sized dairy breeds and their crossbreeds (Hopcraft et al., 1976). This observation confirms the results of Stotz (1979) where he found that replacement rates of these breeds and their zebu crossbreeds on smallholdings was 25% compared to 16% on large scale farms. The

replacements on smallholdings were got through the continuous purchase from large-scale commercial dairy herds.

The Kilifi is mainly kept in the coastal sub-humid zone of Kenya. This area has frequent cases of tick borne diseases and trypanosomiasis (ILCA, 1992). This partly explains why the Kilifi has substantially low survival rates. Control of the tsetsefly and ticks infestation would remove this constraint.

Season of birth in heifers and mature bulls and season of calving in cows caused important variation survival rates. Thus the short rainy seasons may have provided good environment in terms of availability of fodder, low incidence of diseases and ease of purchase and delivery of inputs during and immediately after the period. However, the small-scale herd size does not allow seasonal breeding management due to the need for a fair level of dairy cash flow on small-scale farms throughout the year.

The year of birth effect reflects the genetic or environmental trends over time. The traits affected by the year of birth/calving were male calf survival rate and post-weaning survival rates in young bulls and cows. However, the nature of these traits is that they have generally low heritability estimates. Hence the annual trends observed could have been largely due to environmental factors. This is confirmed by the fact that lower survival rates were associated with years which

had prolonged dry period and no proper on-set of short rains (MLD, 1984; MLD, 1987; MLD, 1992).

The grazing systems influenced the survival rates of the animals as these systems had varied objectives and resources for dairy production. Female calves and cows were well cared for under zero-grazing system since they are raised as replacement and breeding stock, respectively. This was not done for the male calves. On the other hand, young bulls and mature bulls were raised under semi-zero grazing units for sale as beef, breeding bulls and for animal draught power. Hence this preferential treatment enhanced higher survival rates in semi-zero grazing herds.

5.5 Prices of Products and Stock

Differentials by breed group were substantial on all the prices, except for milk. This could have occurred because certain breed groups were preferred to others and, therefore, were kept depending on their availability as breeding stock. For instance, the demand of the Kilifi heifers by small-scale farmers in the Coast Province was very high. Since the only source for export and sale to farmers in coastal zone of the Kilifi breed was Kilifi Plantations, the prices for heifers were very high.

On most of the smallholdings in the highlands and medium altitude zones, the large-sized exotic dairy breeds were popular, which caused high demand for their female stocks. These breed groups have high disposal rate on smallholdings due to poor adaptability

(Karanja, 1991). On the other hand, all the FIs known to be highly adaptable, rather than back crosses to exotic dairy breeds, attracted higher prices. This generated high demand-driven prices at the major source, large-scale commercial dairy farms, where replacement heifer prices were high.

Cows in dairying zones do not usually attract high prices from smallholder farmers unless they are suitable as replacement stock. When offered for sale for beef processing the price criterion by butchers for cows in the rural areas highly depends on the body size. Since breed groups have different body sizes, breed group affects the disposal price. This was also reflected in the fact that the male young stock of the large-sized breed groups attracted higher prices than those from the small-sized breed groups. This was, therefore, reflected in the substantial effect of breed group on cow and bull calf prices.

Milk prices did not vary with breed group over the period 1981-1992 because Kenya Cooperative Creameries (KCC) operated in a monopolistic market of dairy produce and did not pay for butterfat content in milk, which varies with the dairy cattle breed group. Prices in the informal market were set in close relation to those offered by the KCC.

The rising trend in milk prices over the period 1981-1992 was due to the fact that the government regulation on milk prices was in

force. Prices of milk were increased annually by the government to cover the inflationary trends (KNAIS, 1990). This applied to formal milk markets, which in turn affected informal markets.

The prices of cows, bull and heifer calves were low during 1984-1985 as these years were affected by the drought in 1983 and 1984. However, in the period 1985-1992, the prices rose in direct relation with inflationary trends and better climatic conditions for fodder availability.

The price of milk partly reflected the cost of production and this was passed on to the consumer in regions of high demand, especially in urban and peri-urban areas. Thus the zero-grazing herds had higher prices for milk. The breeding females attracted higher prices. This was because a good number of them were sold on basis of surplus to farms' need for replacement female stock or financial needs attracted buyers who were practicing zero grazing.

Most of the zero grazing was common in high population density areas far from beef production areas. Thus disposals of cows from zero-grazing herds attracted higher butcher prices. Nevertheless, the heifer prices were not linked to the grazing system of the herd as there was a high demand for heifers in the dairying districts. Hence the prices were fixed at higher levels with little bargaining.

The herd as a factor affected prices of milk and cows. This could have been a reflection of the cost and level of production. Thus herds with higher input costs of grazing (i.e., zero-grazing) offered milk at higher prices in the markets where government price regulation was not effective. The breeding females in these herds had higher price values because their replacement stock were always in high demand. This caused their higher valuation on the farms.

Stocking density on farms substantially affect cost of production either positively or negatively depending on the overhead costs. If overhead costs are high, they need to be reduced by increasing the units of production to gain economies of scale. This explains the observation that the price of milk in the informal markets varied inversely with stocking density in this study.

The price of bull calves or young stock varied directly with the total farm acreage. This was linked to the fact that under sustainable smallholder dairy production systems the male young stocks were treated as surplus stock. Hence herds on smallholdings with extra land, especially under semi-zero grazing system, attracted higher price values for male young stock. But the low demand for the same young stock on farms with lower acreage would cause low price values. This is seen in practice where the male young stock from zero-grazing units is disposed of within one week of age.

Localities with a low density of dairying herds, particularly in Western, Nyanza, Coast and Eastern (lower parts) provinces had significantly higher bull calf prices. This arises because most of these areas have poor infrastructural network that cannot support delivery of AI services. Hence the bull calves have value because they are raised for natural service.

Calves born through AI had significantly a higher price. This is because they are valuable alternatives to AI service. The farmers perceive, and rightly so, that calves born through AI breeding services have high probability of carrying genes favouring the selection objective high milk production.

5.6 Breed Group Performance

5.6.1 Factors Affecting Breed Group Productivity

The magnitudes of the parameters for fitness traits of the R_L caused it to be unsustainable on small scale farms. This observation was obtained basing on the model assumption of not allowing replacements of breeding stock from outside the herd.

On smallholdings where the R_L was kept, the farmers subjected it to lower feeding and management regime as for the F_L and zebu. In most cases, F_L was recommended to farmers who had little experience in raising of pure exotic dairy breeds (MLD, 1983). The Kilifi, which are located in the sub-humid coastal zone of Kenya

where they are subjected to the challenge of East coast fever and trypanosomiasis with little prophylactic treatment, were judged to be sustainable in smallholder environment.

As expected, the optimal threshold culling and disposal ages varied with breed group. The breeding animals were disposed of later in life when they came to the end of their productive stage while the young surplus stock were disposed of at ages which ensure optimum feed energy efficiency. However, all these ages were dependent on the expected mature size of the breed group.

Generally, young stock in breed groups with large mature size reach maturity at a later age than those individuals in breed groups with small mature size. This is a well known biological phenomenon occurring between breed groups. Thus it was not surprising that the respective ages of disposal varied directly with corresponding mature size of the breed group.

The culling strategy observed in this study confirms the current practice where smallholder dairy farmers dispose of male calves at two weeks of age (Wakhungu and Baptist, 1992a). In addition, they sell off surplus female calves just after weaning to avoid overstocking.

Under stationary state conditions of the model, all surplus young stock were managed under same regimes irrespective of their sex.

With lack of voluntary culling assumption non-existence of sexual dimorphism at early age, the sex of individual young stock did not cause any difference in their ages at disposal. These could be explained by the fact that they both contributed, almost equally, to live weight off take although their market prices per unit live weight were low and slightly different.

5.6.2 Breed Group Choice

On the basis of the magnitude of the FEE index, crossbreds were superior to their corresponding purebred parental breeds, except for the Jersey. These observations were a reflection of the magnitudes of the fitness and production traits parameters which were attained by the breed groups on the small scale farms. It is well recognized that crossbreds are superior to their purebred parental breeds as a result of the expression of a high proportion of expected heterosis under stressful condition as those prevalent on the smallholdings (Bondoc *et al.*, 1989).

As the F₁ crossbreds were backcrossed to pure bred exotic dairy breeds the heterotic advantage decreased and was reflected in the deterioration of fitness traits. This was confirmed in the observed decrease in the magnitude of FEE index values as the upgrading of zebu to dairy breeds approached 75% in the crossbreds.

These results were contrary to those reported by Kiwuwa *et al.*

(1983) on the Ethiopian holdings. Nevertheless, this could be due the differences in the productivity indices used, the management regimes and the genotypes of dairy cattle included in this study and that of Kiuwa's *et al.* (1983). The implications are that in the Kenyan smallholdings, F_1 crossbreds had outstanding adaptability compared to their corresponding parental dairy purebreds.

It is generally known that smallholdings provide low quality feeds, which barely suffice the maintenance and production requirements of the large-sized dairy breeds (Karanja, 1991). Therefore, the increase in FEE index values with the decrease in mature body size of the dairy breed groups could be partially attributable to the better adaptability of the small-sized pure breeds and their crossbreds to the stressful environment on the smallholdings.

The observation, alluded to above, concurs with those reported by Kiuwa (1988) and Bondoc *et al.* (1989). Hence this study confirms the long held view in the dairy cattle industry: that the small-size dairy breeds and their crossbreds as well as the F_1 crossbred of the large sized dairy breeds with zebu have high productivity and are highly adaptable to the smallholder environment. Therefore, Jersey, F_s , R_s , Kilifi, F_L , Nondescript and Guernsey, in the order of descending FEE index values, were found to be suitable breed groups for high productivity on the Kenyan

smallholdings.

These breed groups had the extra advantage in that they had higher fertility rates, lower age at first calving and higher milk yield which ensured a higher offtake rate in terms of young stock and milk yield. These factors enhanced the FEE index and sustainability of these breed groups, thus ensuring higher profits at minimum costs.

The offtake values of the above mentioned high ranking breed groups, in terms of FEE index, had lower proportions of culls than for the rest of the breed groups. The culls confirm the well-known fact that there is a higher turnover rate of large-sized breeding stock on small-scale farms (Wakhungu and Baptist, 1992b). The turnover rate will continue to increase if the current popular large-sized dairy breeds and their upgrades beyond 75% are not abandoned in favour of the F_L , F_S , R_S and small-sized dairy breeds.

Friesian and Ayrshire are the most popular and their AI semen is readily available in Kenya and by importation from developed countries (CAIS, 1999). Small-scale farmers are attracted to the large-sized breed due to their high milk yield as demonstrated on large-scale commercial dairy farms. This is also enhanced by the strong promotion of these breeds by their respective Breeders' Societies and the government and non-government extension agencies.

The popularity of the large-sized dairy cattle breed groups on smallholder farms is not based on their overall productivity. This is borne out by the fact that, if the ranking of breed groups was based on the potential lactational milk yield, as realized in large scale commercial herds, then its correlation with the rank of breed groups based on FEE index values obtained in this study was estimated at -0.0417 . These correlations show that the choice criteria of breed groups on smallholder farms has been contradictory to the objective of increasing productivity in smallholder herds.

The correlation between the ranking by breed group lactational milk yield on smallholder farms and FEE index values was estimated at 0.73 . This correlation was not significantly ($P > .05$) different from zero, due to high standard error associated with this correlation estimate. This result confirms that, other factors held constant, the lactational milk yield realized on smallholder farms should not be used as a sole criterion for choice of breed groups that will improve productivity in the small-scale farm dairy enterprise.

It should be noted that the FEE index does not include other costs for instance, drugs, mineral supplements etc, apart from feed as an energy source. Production strategy of many dairy producers is to maximize profit (Short et al., 1990a). If health costs are

significant in overall profitability of dairy cattle, omitting them gives inaccurate measure of profit.

Notwithstanding the above, including fitness traits such as fertility and survival rates, in economic comparisons of dairy cattle may more accurately identify selection policies that improve profit, especially when comparisons involve animals with diverse genetic ability for milk yield. This has been accomplished by the use of the FEE index in this study.

Evaluation of correlated responses to selection for milk yield is important. If intense selection is based on milk yield as a single trait, detrimental effects may be incurred on traits such as reproduction and survival rates (Casey and Maree, 1993)

The overall breed group productivity in this study confirms the long held view in the dairy cattle sub-sector that some breed groups are suitable choice for raising in small scale farms. The productivity values realised in this study help to establish a suitability rank, in descending order, as follows:- Jersey, F_s, R_s, Kilifi, Nondescript, F_L, Guernsey, Ayrshire and Friesian. The best four in the ranking were also reported in this study to have outstanding lactational milk yield, reproductive performance, survival rates and overall productivity.

5.7.1 Economic Weights in Breeding Objectives

Change in milk yield and age at first calving had substantial impact on FEE indices of all breed groups. These two traits affect directly the lifetime off take in terms of milk and fattening stock in the dairy herds.

On the whole, marginal change in milk yield had higher impact (sensitivity) on FEE indices of all breeds. This shows that the milk yield trait should have a higher economic weight than the other traits in the overall selection objective of dairy cattle breed groups in smallholder herds. This was in accordance with the definitions of economic weights by Smith et al. (1986); Baptist (1990a) and Arendonk and Brascamp (1990).

Age at first calving and calving interval are among the most important determinants of herd-life and lifetime productivity (Rege and Mosi, 1989; Njubi et al., 1992; Rege et al., 1992). Fortunately, the age at first calving has medium heritability and favourable genetic correlations with other reproductive traits (Njubi et al., 1992; Rege et al., 1992).

Age at first calving has been found in this study to have a high economic weight (FEE index sensitivity) in the overall selection objective of dairy cattle breed groups on small-scale farms. This tends to strongly suggest that this trait should be incorporated in dam and sire selection of breed groups on small-scale farms.

In Kenya, the current sire selection procedure involves pre-

screening on basis of the lactation milk yield of dam and half sisters, followed by evaluation for first lactation milk yield using progeny test information by contemporary comparison (Rege and Mosi, 1989). The former is specific to the farm and breeders society and the latter being used nationally for all dairy breeds. However, on the dam selection culling difficult breeders in subsequent parities does side the reproductive trait in practice.

All the above described Kenya dairy cattle breeding programme is done on large scale commercial dairy farms and yet the majority of users of the germplasm so selected are small scale dairy herds. The process should be included too in selection programs aimed at improving dairy cattle on small-scale farms.

It was established that the changes in males' survival rate and the female pre-weaning survival rate did not have substantial effect on FEE index, except in the Friesian, Guernsey, Kilifi and FL. This was due to their low contribution to the live weight off take in the rest of the breed groups. This shows that rearing of males and pre-weaning female calves in smallholder dairy herds, except for the four mentioned breed groups, for live weight off take did not improve productivity substantially.

This study, therefore, confirms that survival rates in males and pre-weaning calves have low economic weight in the overall selection objective of dairy cattle, except for Friesian, Guernsey, Kilifi and FL, on small scale farms. However, female

survival rates at post-weaning period have a high economic weight and this criterion should be included in the overall selection objective in small-scale dairy herds.

The heifer had generally lower sensitivity than the cow to reduction in selective culling rate. This could be explained by the fact that higher retention rate of breeding cows would lead to an increase in off take of young stock and milk, while higher retention rate of the heifers would only increase the heifer value in the off take.

Selective culling rate is a function of sterility rate, which reflects age at first calving in the herds. Fortunately, the age at first calving has medium heritability and favourable genetic correlations with other reproductive traits (Njubi et al., 1992; Rege et al., 1992). Therefore, genetic improvement in the age at first calving will cause to some degree a correlated genetic improvement in the fertility rate.

The overall observation for all the breed groups was that milk production contributed the most to the FEE index and sensitivity while the fitness traits could not be ignored in the smallholder herds. Thus fitness traits, except for males' survival rates and females preweaning survival rate, apart from milk yield were important economic traits in the productivity of breed groups on small-scale farms.

On the basis of sensitivity analyses in all the breed groups, it was established that in the definition of dairy cattle breeding objective in smallholder herds the traits with higher economic impact were invariably the same and could be ranked, in order of descending importance, as follows:-lactational milk yield, age at first calving, selective culling rate of cows, calving interval and post weaning survival rate in females.

This study has confirmed that the Jersey has outstanding performance on small scale farms compared to the other exotic breeds. This is partially due to a unique physiological manifestation linked to its small body frame and lighter live weight (Casey and Maree, 1993) and a very high genetic variability during the early stages of foundation of the breed on the island of Jersey (Graevart, 1996).

The body size characteristics and initial genetic history of the Jersey are associated with its capability to withstand environmental stressors linked to low level of feeding and other management inputs on small scale farms. It tends to attain puberty at early age and this is followed by an early age at first calving. It has low maintenance requirements (Thiessen, 1976), which enables it to be less, stressed on small scale farms, resulting in high survival rates and higher lactational milk yield.

5.7.2 Breeding Policy Evaluation

The variation in sensitivity values, with regard to fitness traits, in the dairy breed groups may be due to polymorphic loci which affect adaptation to various stressors in the smallholder environment. This polymorphism mechanism prevails but has not been taken into consideration under the current breeding policy, which is purported to improve dairy traits for a heterogeneous environment in the Kenyan dairy sub-sector.

The situation, alluded to above, is in agreement with adoption of the first half of Hammond's (1947) thesis i.e. if optimal level of all environmental parameters is assured in smallholder dairy herds, then these conditions should be kept in the large scale commercial dairy herds which are the main sources of progeny tested AI sires and replacement stock. This study, however, has established that the Jersey and Guernsey and their crossbreds, which are known for lower performance in large-scale commercial dairy farm environment, were less affected by, or more able to compensate for sub-optimal environmental conditions in smallholder herds.

Apart from choice of the suitable breed, the choice of breeding policy to maintain or improve the pure dairy breed seed stock on the smallholder farms is far from resolved. With the overall production objective being defined in smallholder dairy herds as

the improvement of productivity, breeding policy options in smallholder dairy cattle population can be evaluated.

The issue of a separate breeding policy for small-scale farmers has a long history of debate. It becomes very crucial when it is thought that "better" genetic material is being turned down in favour of "more suitable" genetic material (Hopcraft *et al.*, 1976). Nevertheless, the results in this study have demonstrated (by use of crucial survival traits in smallholder herds) that what is better breeding policy for large-scale commercial dairy herds (Rege and Mosi, 1989) are not necessarily better for smallholder herds.

Under the present breeding policy, the smallholder herds are linked to the genetic improvement in imported semen source herds and the semen from bulls progeny tested in large-scale herds via the Kenya National Artificial Insemination Service (CAIS, 1999). However, this high-yielding dairy cattle germplasm, selected under high input-high output large-scale dairy farm conditions, has been observed to generally have lower fitness under the stressing low input smallholder dairy herd conditions.

This study has confirmed that large-sized dairy breeds are more affected than small-sized dairy breeds by the current breeding policy with regard to smallholder herds environment. This is because, unlike under large scale commercial dairy herd

environment, the fitness loss is perceptible, relevant and not outweighed by the expected superior milk yield of the large-sized dairy breeds on small scale farms.

The above scenario notwithstanding, it is difficult to predict the magnitude of fitness loss in smallholder environment, as there is lack of data and literature on these aspects of smallholder dairy herds. Nevertheless, PRY model calculations on the basis of FEE index, as done in this study, were used to determine the magnitude of fitness losses that could be supported by smallholder dairy production system without its overall productivity being markedly affected.

The magnitude of a milk yield increment and an associated fitness loss in a smallholder environment are, generally, not possible to predict quantitatively. Nevertheless, what could be quantified was the trade-off between tentative milk yield increment expected from the annual genetic progress arising from the current breeding policy and the fitness losses in the future.

On the large-scale commercial dairy farms the annual genetic progress in milk yield arising, in the past, from the national breeding programme in Friesian was estimated at about 6.29 kg in Kenya (Rege and Mosi, 1988). The Jersey herd in Mtwapa Research Station using AI semen arising from the national breeding programme had annual progress estimated at -0.03% (equivalent to -

0.15 kg) (Njubi *et al.*, 1992). This was as a result of institutional constraints; and the commercial Jersey herds using AI intensively could have been better.

It is expected that the Ayrshire and Guernsey under the national breeding programme would likely attain expected genetic progress within the range reported for Friesian (Rege and Mosi, 1989) and Jersey (Njubi *et al.*, 1992). Thus the expected annual genetic progress would be in the range -0.15 to 6.29 kg per year if the current breeding programme remains. These estimates show that the current breeding programme for pure dairy breeds does not have substantial impact on the dairy cattle populations on smallholdings in Kenya. Hence there is need for a separate or a modified breeding programme designed to take into account the environmental conditions in grade dairy herds on smallholdings.

The dairy herds in North America and Western Europe have been reported to achieve an expected annual genetic progress of at least 2% in well-structured progeny testing programs (Woolliams, 1990; Wakhungu and Baptist, 1992b). The progeny tested sires contribute 76% to this genetic progress.

The semen has always been imported into Kenya for contract mating scheme to produce young bulls for progeny testing in the current breeding policy. However, with the liberalized economy the large-scale farmers have tended to use the imported semen directly in

their herds rather than local progeny tested semen, to reduce the genetic lag period (CAIS, 1999).

The dairy cooperatives, which are predominantly smallholder based and private veterinary companies, have acquired the potential to go directly for the imported semen currently and in future (CAIS, 1999). That would translate to expected annual genetic progress of 38 kg of milk yield in the smallholder herds using the imported semen (see Section 3.7).

The estimate of 38 kg of milk yield annual genetic progress from the calculations (see Section 3.7) is within the range of 30-110 kg of milk yield annual genetic progress reported in the imported semen source herds in North America and Western Europe (Claudio *et al.*, 1990; Hansen *et al.*, 1990; Smith and Burnside, 1990; Woolliams, 1990; Wakhungu and Baptist, 1992b). Using arguments similar to the calculation procedure described (see Section 3.7), the range (30-110 kg) reported in semen source herds translates to expected genetic improvement range of 11.4-41.8 kg of milk yield per year. This will be solely due to the imported semen genetic impact alone in Kenyan small-scale farms under the described drastic transition in the current breeding policy.

Most of the milk yield trade-offs for marginal loss in the fitness traits, identified to have high economic merit in this study, far outstrip the upper range of the expected annual milk yield

increment (6.29 kg) due to the current breeding policy. This is an indication that this breeding policy should be abandoned and an alternative breeding policy appropriate for the Friesian, Ayrshire, Jersey and Guernsey in smallholder herds should be proposed for implementation.

The situation in the projected future shows that there would be high proportion of both the smallholder and large-scale dairy herds using imported semen with minimum use of locally progeny tested semen. The milk yield trade-off values in the Friesian, Guernsey and the Ayrshire for the increase in age at first calving will be higher than 38 kg.

The above observations imply that the Friesian, Ayrshire and Guernsey breeds will require an alternative national breeding policy for the smallholder herds. The results in this study imply strongly that the alternative breeding policy should lay emphasis on improvement of fertility through direct selection for age at first calving.

A simultaneous decline in the females' survival rate and selective culling rate caused the Friesian breed to be unsustainable in smallholder herds. But the simultaneous decline in the same traits resulted in milk yield trade-off values for Ayrshire and Guernsey being high and close to 38 kg. This observation establishes the fact that the current breeding policy should be abandoned with

regard to smallholder herds.

Fitness traits cannot be selected artificially, rather it is best done by natural selection. Natural selection for fitness is guaranteed if the bulls used were those that were bred and tested locally on smallholdings. The annual rate of genetic improvement in fitness traits in dairy cattle will be expected to be very small, but will be continuous and cumulative over the time-scale (in the long term) of the breeding programme.

Such genetic improvement is permanent; it is not used up, but yields its benefits continuously, and needs little further input to maintain it (Smith, 1984). It will be self-sustaining and a growing resource for the Kenyan smallholder sector (Wakhungu and Baptist, 1992b). This would lead to smallholder Friesian, Guernsey and Ayrshire strains which will be of high demand for dairy cattle development programmes in the country and internationally.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on context in which this study was carried out the following conclusions may be drawn:-

i) The trade-off between potential lactational milk yield increments and fitness losses can be quantified, in terms of overall productivity, by use of stationary-state livestock productivity model.

ii) Sensitivity analysis based on a stationary state demographic model is able to determine a realistic range of possible outcomes (confidence range) in an attempt to predict genetic improvement in lactational milk yield and the probable associated fitness loss which will be generated by the current breeding policy in the future dairy herds on small scale farms.

iii) The results indicated the rejection of the current breeding policy of importing genetic progress into smallholder dairy sector herds for all the pure dairy breeds. Furthermore, if the current breeding policy undergoes the projected transition whereby there is heavy reliance on direct import of semen in smallholder herds, then the alternative breeding policy option will be appropriate for the pure dairy breeds, except for the Jersey. The alternative breeding policy option proposes use of semen from bulls progeny tested within the smallholder dairy herd environment, with emphasis on fitness traits apart from milk yield.

iv) The economic weights for traits to be included in the overall breeding objective have been established by sensitivity analysis on the model in this study, in order of descending economic merit as:-lactational milk yield, age at first calving, selective culling rate of cows, calving interval and post weaning survival rate in females.

v) This study has established the existence of the genotype-environment interaction with respect to dairy breed groups kept on small scale farms. This confirms the long held view in the dairy cattle industry that the small-size dairy breeds, especially the Jersey, their crossbreds with Zebu and the Kilifi as well as the F_1 crossbred of the large sized dairy breeds with zebu show higher productivity and are, therefore, highly adaptable to the smallholder environment. In addition, the non-significant correlation between the lactational milk yield and productivity (FEE index) for the breed groups in this study strongly suggests that lactational milk yield cannot be the sole criterion for selecting a suitable dairy breed group for small scale farms in Kenya.

6.2 Recommendations

i) The national dairy cattle breeding programme administrators agree that genotype-environment interaction exist, but feel that this problem can be overcome by having smallholders adjust their

level of husbandry to that prevalent on large scale commercial dairy farms where testing of AI bulls takes place. Nonetheless, this Utopian approach will not be possible unless there are research breakthroughs in feeds, feeding and other husbandry practices.

ii) Since the small scale farms are unevenly spread in the country, there is need for a holistic approach in research on the constraints in the development of the smallholder dairy cattle sub sector. The research will need to include a broad range of issues, where apart from the technical issues, which to some extent have been tackled the cultural, institutional and economic aspects of the small scale farm sector will be addressed.

iii) The environmental differences on small scale and large scale farms makes it mandatory for the current breeding programme to take include the farm scale factor (large scale vs small scale) in animal evaluation models to correct for genotype-environment interaction effects. This will make it necessary to look for the best way of modifying the existing breeding programme or designing a separate breeding programme suitable for environmental conditions on small scale farms.

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8.0 APPENDIX

Appendix 1:KENYA SMALLHOLDER DAIRY HERD DATA FIELD QUESTIONNAIRE

A) Background Information:

Date of Visit Investigator(s).....
 Owner's / Farm name Location District

Farm acreage (acres/hectares(); price of milk Ksh [] at KCC [] or Grazing system: Tick [] if Yes
 Extensive [] semi-zero [] zero []

Main source of animal forage:.....
 Supplemental feeds

Breeding method:Tick [] if Yes

AI [] Bull [] Both []

B Herd structure: Enter stock numbers
 Calves not weaned (0-4)
 Female [] male []
 Young stock (5-30 months)
 Males [] females [];
 Adult (31 – 144)
 Cows [] bulls [];

c) breeding Female Information:

Cow ID/Name	Breed type	Lact No.	Milk Yield (kg)	Lact. Length (d)	Calve date

d) Progeny History Method:

i) All mature breeding female listed under C should be on site during the interview with the farm owner or herdsman. Offsprings are identified by location number, their sex, function. Disposal or loss etc.

ii) Interview questions about each cow

Cow No.	2	3	4	5	6	7	8	9	10
Entry into herd									
Inheritance	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Birth within									
Herd	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Purchase	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Other	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Other _____	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]

ii) Focus on calves for each cow

Calf No. 1	2	3	4	5	6	7	8	9	10
------------	---	---	---	---	---	---	---	---	----

Sex Male [] female []

Where is it?

Age-months in herd []for breeding in herd value Ksh. [] Date-----

Age-months sold [] for breeding price ksh. [] Date-----

Age-months at death [] cause----- [] Date -----

Age months at butcher[] for beef or veal price ksh. [] Date-----

Age-months other ---- [] reasons ----- [] Date -----

d) Mortality and off take of adults:

Animal ID/Name	Breed type	Died	Sold	Gift	Loss	Rasons and Date

Appendix 2: Analysis of variance of lactational milk yield

Source	d.f.	MSX10 ⁴
Locality	67	30.20
Herd	397	814.86**
Breed group	9	1209.61**
Season of calving	2	295.15**
Year of Calving	8	383.16**
Grazing system	2	1.05
Mating method	2	21.01
Parity	6	433.55**
Covariate	.	
Lactation length	1	916.14**
Stock density	1	.07
Residual	1589	24.98

** = $p < .01$

Appendix 3: Analyses of variance of calving interval (CI) and age at first calving (AFC).

Source	CI		AFC	
	d.f.	MSX10 ²	d.f.	MSx10 ²
Locality	67	3.46*	67	85.22**
Herd	397	1.81	397	46.93
Breed group	9	14.83**	9	772.95**
Season of calving/birth	2	1.17	2	11.98
Year of calving/birth	8	2.59	10	77.55
Grazing system	-	-	2	193.82*
Mating method	2	.27	2	5.08
Parity	6	7.15*	-	-
Breed x Grazing system	18	3.15	18	77.30*
Covariate				
305-day milk yield	1	.20	-	-
Farm acreage	1	.69	1	19.70
Stock density	1	9.29	1	23.27
Residual	1462	2.58	404	44.89

* = P<.05 **=P<.01

Appendix 4: Maximum likelihood analyses of variance of selective culling rate of heifers and cows (from logit model)

Source	Heifer		Cows	
	d.f.	Chi-Square	d.f.	Chi-Square
Intercept	1	301.37**	1	281.80**
Season of calving/birth	2	4.84	2	5.65
Year of calving/birth	10	21.56**	8	9.38
Breed group	9	10.96	9	18.62*
Grazing system	2	9.74**	2	4.87
Parity	-	-	6	13.19*
Likelihood ratio	38	42.20	79	49.66

* = $P < .01$

Appendix 5: Maximum likelihood analyses of variance of survival rates of calves (0-4 months) (from logit model).

Source	Females		Males	
	d.f.	Chi-Square	d.f.	Chi-Square
Intercept	1	203.78**	1	198.22**
Season of birth	2	5.51	2	5.76
Year of birth	12	10.44	12	17.02*
Grazing system	2	10.89**	2	5.31
Breed group	9	19.36*	9	17.64*
Parity of dam	6	4.30	6	.56
Likelihood ratio	87	32.16	91	40.27

* = $P < .05$; ** = $P < .01$

Appendix 6: Maximum likelihood analyses of variance of young stock survival rates (5-30 months) (from logit model).

Source	Heifer		Bulls	
	d.f.	Chi-square	d.f.	chi-square
Intercept	1	214.16**	1	168.90**
Breed group	9	16.95*	9	19.42*
Season of birth	2	10.14**	2	2.25
Year of birth	11	4.27	11	15.60*
Grazing system	2	5.45	2	6.18*
Parity of dam	6	7.38	6	3.90
Likelihood ratio	76	26.30	93	38.96

* = P<.05; ** = P<.01

Appendix 7: Maximum likelihood analyses of variance of survival rates of mature stock (31 – 144 months) from logit model)

Source	Bulls		Cows	
	d.f.	Chi-Square	d.f.	Chi- Square
Intercept	1	201.31**	1	256.40**
Breed group	9	1.36	9	21.37*
Year of calving/birth	9	16.08*	9	17.01**
Season of calving/birth	2	12.66**	2	6.32**
Grazing system	2	18.28**	2	8.95*
Parity	6	1.11	6	1.43
Likelihood ratio	97	42.22	83	39.25

* = P<.05; ** = P<.01

Appendix 8: Analyses of variance for prices of milk, cow, bull, calves and heifer calves.

Source	d.f.	MILK PRICE		COW PRICE		BULL CALF PRICE		HEIFER CALF PRICE	
		MSx10 ²	d.f.	MSx10 ⁵	d.f.	MSx10 ⁵	d.f.	MSx10 ⁵	
Locality	67	47.34**	67	2013.51**	67	8.61**	67	7.45**	
Herd	397	8.38**	397	141.84**	397	0.75	397	0.78	
Year of calv/birth	10	238.24**	8	1230.46**	12	4.25**	12	3.41**	
Season of calv/birth	2	.08	2	.77	2	.81	2	.20	
Breed group	9	1.47*	9	36.19	9	.97	9	2.00**	
Grazing system	2	4.64**	2	243.66**	2	.03	2	.42	
Parity of cow	-	-	6	3.97	-	-	-	-	
Mating method	-	-	-	-	2	.20	2	0.9	
<u>Covariate</u>									
Farm acreage	-	-	-	-	1	21.59**	1	27.28**	
Stock density	1	29.94**	1	184.96*	1	.03	1	.81	
Residual	1961	.69	1955	32.18	1005	.70	902	.74	