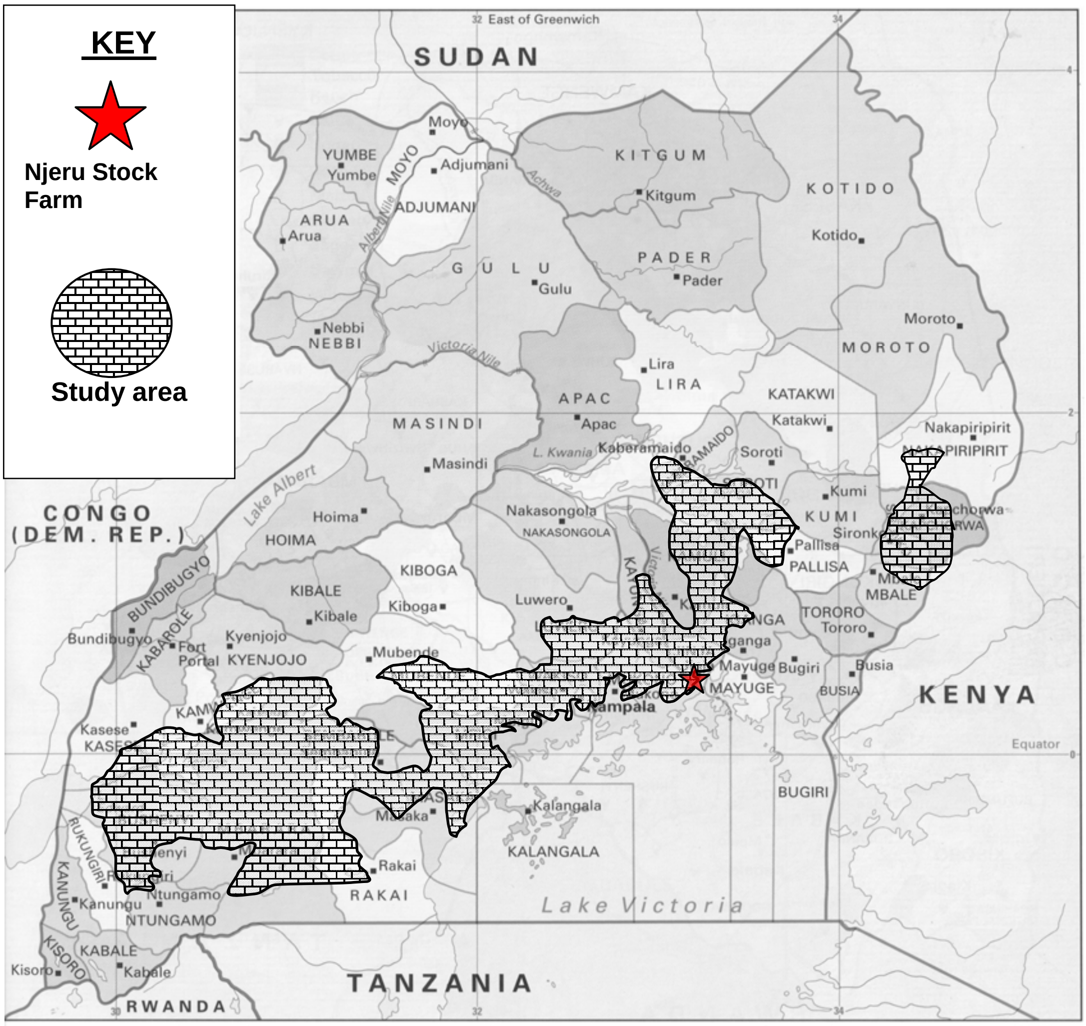
3 MATERIALS AND METHODS

3.1 Study area

The area of study covered the Lake Victoria crescent region found in the southern part of Uganda.

Figure 3.1: Map of Uganda showing the area of study



The area was selected for the following reasons:

i) An operational Herd/Milk Recording Scheme (HRS) that is under the management of NAGRC, and targets farmers with exotic dairy cattle and their crosses is found in this region. About 200 farmers with approximately 600 milk recorded animals are on this scheme. Record keeping promoting independent bodies such as NGOs (e.g. Send-a-Cow, Heifer Project International) and breeding firms (e.g., World Wide Sires), which also promote record keeping, are very active in this area. This is an attribute which brought in more data for the study.

ii) The rather high population density in the region varying from 126 to 176 persons per km^2 (UBS, 2002) leaves farmers with hardly any other option of increasing milk production other than through improved genetics. This has prompted farmers to highly appreciate programmes aimed at improving livestock genetics.

iii) The LSRP diagnostic survey was carried out in six districts which are found in this region. Therefore, farmers in this area would highly appreciate the outcome of this study because they were part of the team that identified this research area as a means of intervention to low livestock production.

3.1.1 Production systems

The targeted production systems for the Holstein-Friesian breed are zero grazing and fenced dairying systems.

3.1.1.1 Zero grazing

Zero-grazing is an intensive system of “cut and carry” stall feeding with recycling of manure. It is prevalent in and around urban areas that are characterized by scarcity of land but with a good market for milk. Most farmers in this system, mostly women, have one to three exotic or crossbred cows, and they rely entirely on artificial insemination (AI) for breeding their animals.

Plate 3.1: A farmer with her family and cow

Elephant grass *(Pennisetum purpureum)* is the main cultivated forage grass. Cultivated legumes include *Leucaena leucocephala, Calliandra calothyrsus, Lablab purpureus*, and *Sesbania sesban*. Feeding of crop residues and agro-industrial products is not uncommon especially during the dry season. The most popular concentrate is dairy meal and is usually fed to only lactating cows during milking. Although the source of water for the majority of the farms is around one kilometre away from the grazing unit, water is provided *ad libitum.* Hired labour is rarely used despite the system being labour intensive.

Plate 3.2: A couple in Soroti district next to their grass-thatched zero grazing unit. (They are beneficiaries of Soroti Catholic Diocese Development Organisation cattle project).

3.1.1.2 Fenced dairying system

Fenced dairying is an intensive or semi-intensive system, whereby three or more exotic or crossbred animals are kept in fenced units because of the high susceptibility of animals to tick-borne diseases. These units, with mostly improved pastures, are grazed on a rotational basis. Farms with few animals depend on artificial insemination (AI) for breeding their cows while medium and large-scale farms may at times have their own bull. *Chloris gayana*, *Cynodon dactylon* (star grass), *Paspalum notatum* and *Brachiaria decumbens* make up the main forage grasses. Legumes include *Leucaena leucocephala, Lablab purpureus*, and *Stylosanthes guianensis.* Hired labour is not uncommon in this system.

Plate 3.3: Family Nuwagaba Farm in Bushenyi district

Plate 3.4: Njeru Stock Farm

3.1.2 Central Nucleus Farm – Njeru Stock Farm

An analysis of the status quo and historical development of the nucleus farm, Njeru Stock Farm, was done. The farm lies at an altitude of 1,250 metres above sea level on one of the short grass lush hills along the northern shores of Lake Victoria. It receives, on average and in a bi-modal pattern, 1,500 mm of rainfall per annum and has an average temperature of 26^{0}C.

Plate 3.5: Njeru Stock Farm overlooking Lake Victoria

The farm was established in 1969 with the aim of boosting the dairy industry through the use of high milk producing Friesian cattle; act as a model/demonstration farm; and to provide extension services to the local community. It occupies a total area of 302 ha capable of supporting 275 livestock units (LU)[1] at a stocking rate of 1.1 ha/LU. In 1971, after extensive preparatory work, 350 Friesian parent stock females from the Netherlands were introduced on the farm. This herd was of two different colour combinations: black and white Holstein-Friesians, and red and white (Menzy Rhine Ikje – MRI) Friesians. In 1975 much of this herd was sold off to create space for 250 Friesians imported from Kenya. The political upheavals in the years that followed saw a loss of much of this stock. In 1987/89 the last importation of live animals, 200 Friesians from Zimbabwe, was done. Further purchase of live animals for the farm, the last one so far, was in 1998/99. These animals were screened from the existing Friesian population in the country from farmers in the zero grazing and fenced dairying production systems that keep some form of records and use AI. Since then, all replacement

[1] **Livestock Unit** (LU) = It is a livestock conversion factor equivalent to 1 Friesian cow weighing 500 kg, producing 20 kg of milk per day with 4% buttterfat content.

stock is from calvings of the artificially inseminated farm herd. About 50% of the semen used on the farm is imported from outside the country. The farm belongs to the fenced dairy production system, and currently has about 167 LU of different grades of the Holstein-Friesian breed. The objectives of the farm have not changed much since its establishment except that it has set its course on developing a tropicalised Friesian instead of depending on imports as was characteristic in its early years of establishment. Its current objectives are as follow:

i) To improve on the adaptability of the local Holstein-Friesian population through the use of the open nucleus breeding schemes.
ii) To supply the different production systems with appropriate Friesian genotypes.
iii) To act as a model/demonstration farm.

3.2 Data collection and compilation

Data from the two aforementioned production systems was compiled from record forms used by farmers on the Herd/Milk Recording scheme (HRS), farmers under the supervision of NGOs and private breeding companies, University farms, and from independent progressive farms. Since HRS collaborates with NGOs such as Send-a-Cow and private breeding companies, for example, World Wide Sires to promote recording, the record formats used by these organizations to capture farm information are very similar. The three formats that are commonly used and from which most of the data was got are:

i) Cow Lifetime card: A six pages 19.8 cm x 30.3 cm foldable card on which all information pertaining to an individual female animal is recorded. It has the following sections: Identification section of the owner (e.g., name, location etc.) and the animal (e.g., date of birth, parentage etc.); breeding/reproduction details (e.g., number of inseminations per conception, date of calving down etc); milk production details for each parity (e.g., lactation length, total lactation milk yield etc.); offspring information (e.g., sex, weight, etc); and a health section (e.g., vaccinations, treatments etc).

ii) Daily Milk Record book: A one hundred fifty pages 22 cm x 31 cm book divided into three sections. First, a section with monthly forms where am/pm milk from a cow is recorded and then summed up at the end of the month to get the monthly total production, which total is then transferred to the Cow Lifetime record card. Second, a milk disposal section with details on how much milk is given to calves, sold off, wasted, or consumed by the family. Third, a section where transaction details pertaining to the dairy unit inputs are recorded (e.g., amount, type, and cost of concentrate purchased, date of purchase etc.). These record books are recommended for and mostly used by farmers with up to nine animals.

iii) Daily Milk record sheet: A 52 cm x 33.5 cm sheet on which a maximum of 25 cows can be recorded. It is recommended to farms with more than ten females. Am/pm milk for each cow is recorded everyday, summed up at the end of the month, and the monthly total for each animal is entered on their Cow Lifetime cards.

Samples of these three formats can be found in appendinces I, II and III

The two University farms whose records were used, Kabanyolo of Makerere University, and Equator Valley Farm Ltd of Nkozi University had slightly different formats for capturing the same type of information. An MS Access database was created in which data from the different sources and formats was entered. Records from animals with information thought to be insufficient for the analysis were discarded, thus ending up with 414 animal records in this database. Use was also made of 121 animal records from a Panacea database created between April 1990 and March 1993 during a study undertaken by the German Development/Technical Cooperation (GTZ) and the Ugandan Directorate of Animal Resources in the western part of Masaka district. This region, situated in the Lake Victoria basin and renown for dairy farming, has a favourable climate suitable for keeping of temperate cattle breeds (AH&PM, 1993). The defunct Panacea programme was developed by the Pan Livestock Services of the University of Reading, England. A further 178 records were got from the AIDA (Artificial Insemination Database Application) database. AIDA, which was developed by the International Atomic Energy Agency (IAEA), is used by NAGRC in compiling AI data, and it is exclusively a breeding/reproduction database. Data analysed from these 3 databases covered a period of 25 years and 4 months from November 1975 till February 2002.

Farms under the fenced dairying system were divided into three sub-groups according to the number of reproductive capable animals on the farm. Since the number of animals in this system range from three to hundreds, such a division would enable us to have a picture of the herd sizes involved. For example, most of the animal records in this system came from herds with more than 30 animals, and these were from only 4 farms (see table 3.1)

For the economical aspects of the study, data was got from Njeru stock farm and NAGRC's bull stud, AI and Herd/Milk Recording units.

Table 3.1: Data structure

	Number of animals in Database				Number of farms in Database			
	MS Access	Panacea	AIDA*	Total	MS Access	Panacea	AIDA	Total
Fenced dairying								
(1-15 animals)	68	51	0	119	5	5	0	10
(16-30 animals)	83	58	0	141	4	3	0	7
(30+ animals)	152	0	0	152	4	0	0	4
Sub-total	303	109	0	412	13	8	146	21
Zero grazing								
(1-5 animals)	111	12	178	301	40	4	146	190
TOTAL	414	121	178	**713**	53	12	146	**211**

*AIDA database has no milk production records

3.3 Data analysis

Records from 713 animals on 211 farms were compiled from the three databases. An estimation of the biological coefficients and population parameters using this data was done using SAS - Statistical Analysis Systems (SAS Inst. Inc., Cary, NC). Restrictions or bounds of inclusion for the analysis were put on the dataset in order to eliminate unrealistic data and/or outliers.

i. For calving interval (CI), basing on the gestation period, a lower limit of 300 days was set. Studies carried out by, for example, Osei et al. (2005) and Ageeb et al. (2000) show that the gestation length of Friesian cattle in the tropics is 278 $\pm$ 12 days. Such a restriction would help in eliminating cows which may have aborted, but then, recorded as having calved down. The upper acceptable limit for CI was set at three standard deviations above the unadjusted mean (mean 444, SD 107), that is, 765 days. This excluded animals with extreme values due to, especially, poor management.

ii. Lactation length (LL) limits were between 161- 499 days. The figures were taken from Ojango (2001) whose dataset for analysis as regards this trait covered this length. Ojango's work, a study conducted on the Kenyan Holstein-Friesian, is to be used for making comparison of paramaters got in this study.

iii. Age at first calving (AFC): bounds of inclusion ranged from greater than 540 days (1½ years) to a maximum limit of 1,460 days (4 years).

3.4 Genetic plan modelling

A deterministic computer simulator programme, ZPLAN (KARRAS et al., 1997), was used to model the breeding programme. Compared to stochastic simulation, it is fast and flexible, uses multi-modelling, and considers returns and costs over a given time horizon (NITTER and GRASER, 1994).

WILLAM (2004) mentions the lack of accounting for reduced genetic variance (Bulmer effect) due to selection and inbreeding as a drawback of this programme. With the use of biological, technical and economic parameters, ZPLAN calculates the annual monetary gain for the aggregate genotype, annual genetic gain for single traits, and discounted return and discounted profit for a given investment period (WILLAM et al., 2001). It is assumed that parameters and selection strategies are unchanged during the investment period and considers only one round of selection. Since the selection index procedure and gene flow method (HILL, 1974; MCCLINTOCK and CUNNINGHAM, 1974) constitute the core of the programme, requirements for these features had to be derived or determined.

3.4.1 Selection Index

VALLE ZÁRATE (1996) points out that the basic requirements for the selection criteria must be that the breeding aim is quantifiably representative, and that the characteristics can be easily and accurately recorded, are sufficiently heritable and are limited in number. MATHUR et al. (1991) and PÄRNA (2003) further recommend that the traits to be included in the selection index should be economically important.

Total lactation milk yield (MY) and calving interval (CI) are the only two traits, which were included in the selection index. Lactation length (LL) was excluded because breeds of temperate origin, unlike local breeds, do not have this problem. This trait, in Holstein-Friesian, is influenced more by environment/management factors. Besides, LL is indirectly covered in MY and CI whose correlation to both traits is positive ($r_{LL\ MY}$ = 0.51; $r_{LL\ CI}$ = 0.26) and significantly different ($P < 0.0001$) from zero.

Age at first calving (AFC) is antagonistic to longevity hence, breeding early decreases longevity. ESSL (1997) points out that there is some evidence from selection experiments of a significant antagonism between early maturity and longevity. Farmers in Uganda need animals which would stay as long as possible in their herds, thus making the inclusion of such a trait dispensable. Moreover, studies like that of NILFOROOSHAN et al. (2004) on Iranian Holsteins show that it has a low heritability.

The parameters needed for the selection index were either calculated from the data or sought from literature. They included the following: genetic and phenotypic correlations of the traits (r_G, r_P); phenotypic standard deviations (σ_P), heritabilities (h^2), and the relative economic weights (v). In order to be able to calculate the required index coefficient or weights, sources of information (i.e., from family members, own performance, or progeny performance for the selection groups) were identified. The CORRELATION and MEAN procedures in SAS were used to estimate the phenotypic correlations and standard deviations, respectively. Genetic correlations and heritabilities were got from studies conducted in Kenya (OJANGO, 2001; REGE, 1991).

Restricted index

A number of studies (e.g., HANSEN et al., 1983; OJANGO, 2001) have found that the genetic correlation between milk production and cow fertility is negative. Thus, selection for production would, in the long-term, produce undesirable genetic reduction in fertility. In the restricted selection approach, it is assumed *a priori* that any reduction in fertility is unacceptable (WELLER, 1994). Under the restriction of zero genetic change in CI, the selection index that maximizes genetic increase in milk production was computed and used in the model.

Table 3.2: Phenotypic (upper triangle), genetic (lower triangle) correlations and heritabilities (diagonal) of traits used in the index

	Trait	1	2
1	Total Lactation Milk Yield (MY)	0.25	0.25
2	Calving Interval (CI)	0.17	0.047

3.4.1.1 Deriving economic weights

The economic weight of a trait (v) in the breeding objective is defined as the marginal profit obtained through a unit change of the trait considered above the population mean when all other traits are held constant (BARWICK, 1993). In this study, profit (P) was derived as the difference between revenue (R) and costs (C), and the marginal profit was expressed on a per cow per year basis. Using the partial budgeting method, profit equations/functions were used to derive the economic weights of MY and CI. The equation used was:

$$v = \frac{\Delta R - \Delta C}{\Delta T} = \frac{\Delta P}{\Delta T} \qquad (3.1)$$

Where ΔR and ΔC are the changes in revenue and costs, respectively, after a 1% improvement in the trait of interest, that is, an increase in MY and a decrease in CI. ΔT is the 1% change in the trait of interest.

Calculations were based on a fixed herd size of 100 breeding cows (N) under a management system similar to that at Njeru stock farm, and are done in Ugandan Shillings - UGS (1€ ~ 2,000 UGS). However, values for use in ZPLAN were in Ugandan currency points (Ugcp). Use of currency points instead of real monetary units gives a realistic picture of the monetary value at any given time and as such counteracts the loss in value of the currency due to inflation. The equivalent of UGS in currency points is defined by law; consequently, it can be redefined or amended as and when it is deemed necessary. A currency point is equivalent to twenty thousand Ugandan Shillings (ANIMAL BREEDING ACT, 2001).

Calculations of revenues and costs

Revenue is got from the sale of milk, male calves, excess heifers than as needed for replacement stock and culled cows. The costs centres fall into two groups: the variable and fixed costs. The former include feed, veterinary, casual wages, and reproduction costs and the latter costs as used in this study are listed in table 3.8. For the herd composition (see figure 3.2), a fixed herd-size of 100 breeding cows (N) was used. It acted as a basis for deriving numbers for other types of stock e.g., heifers and calves in relationship to the biological parameters on which they depend (see table 3.3). Calculations were made without rounding up; however, the figures presented in the formulas are rounded up. This might lead to slightly different results than what is presented.

Figure 3.2: The fixed herd composition used in deriving economic weights

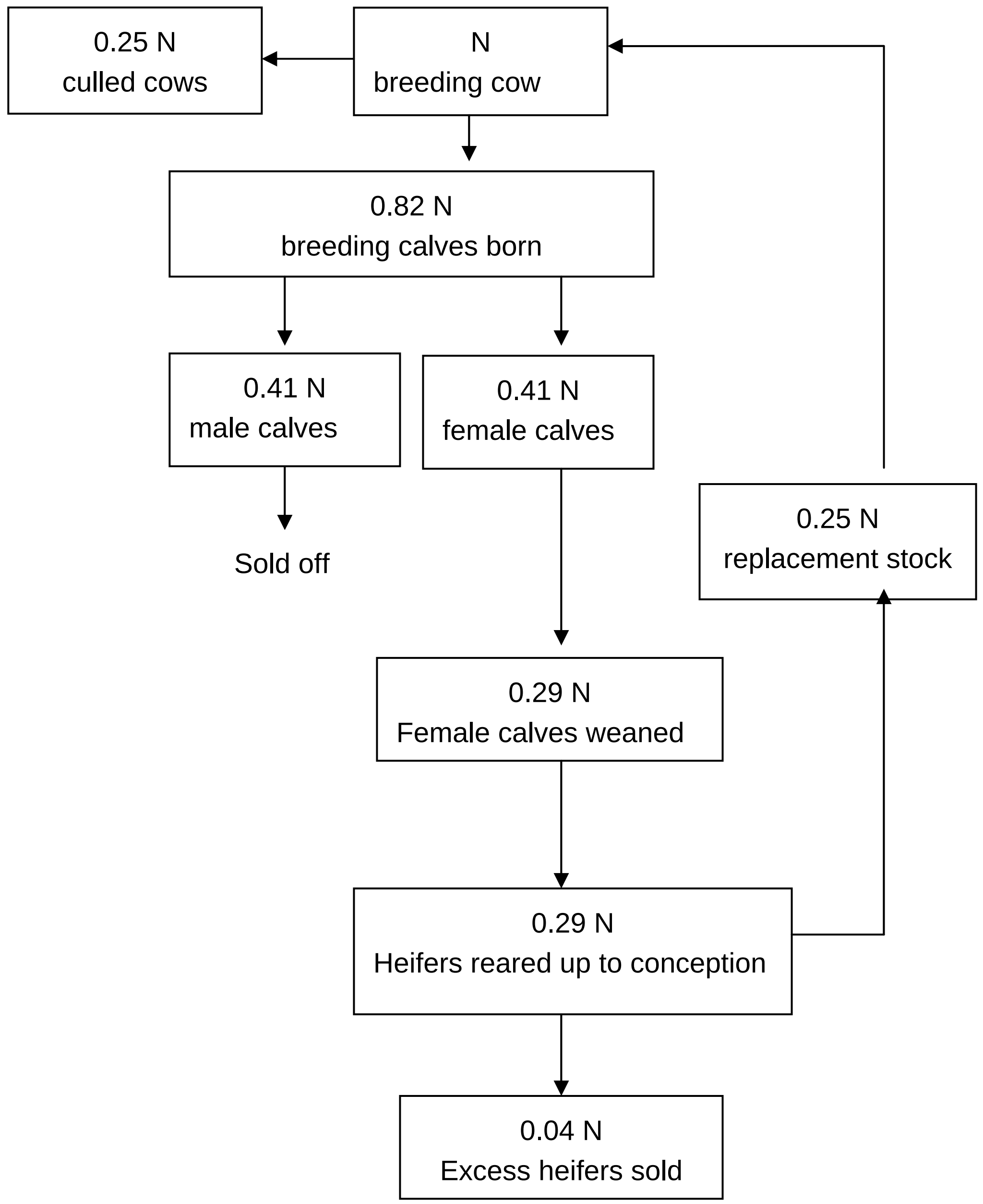


Table 3.3: Biological parameters used in deriving economic values

	Production variable	Unit	Level
LL	Lactation length[1]	days	322
AFC	Age at first calving [1]	days	968
	Birth weight female calves[2]	kg	29.99
	Pre-weaning daily gain[2]	kg	0.44
	Post-weaning daily gain up to puberty[4]	kg	0.443
	Weight of heifers at conception	kg	320
	Age at conception	days	587
LW	Mature live weight	kg	500
INS	Number of inseminations per conception		2.4
cr	Calving rate[3]	%	80
S_{24hrs}	Survival rate to 24hrs after birth[3]	%	98
$S_{m\ -30\ days}$	Survival rate of male calves up to 30 days when they are sold[3]	%	92
$S_{f\text{-}weaning}$	Survival rate pre-weaning[3]	%	92
	Period from birth to weaning[3]	days	90
	Period from weaning to first service	days	497
	Weight at weaning[2]	kg	69.59
	Weight at puberty[4]	kg	290
CC	Proportion of culled cows per year [3]		0.25
	Total dry matter intake (DMI) per cow per day		11
	DMI from concentrates per cow per day	kg	2
	DMI from forage per cow per day	kg	9

Source: [1]Uganda Herd/Milk Recording scheme; [2]Osei et al.(2005)
[3] Njeru Stock Farm; [4]Urgate (2005)

Table 3.4: Prices and costs used in deriving economic values

		Ugandan Shillings (UGS)
	Prices	
P_{milk}	Milk price per kg	450
P_{MC}	Price per male calf	40,000
P_{SH}	Price in-calf surplus heifer	250,000
P_{CC}	Price per culled cow	300,000
	Costs	
P_{conc}	Concentrate cost per kg DM	294
P_{forage}	Natural pasture cost per kg DM	14.7
	Casual labour costs per mature cow/year	181,895
	Veterinary costs per head of animal per day	39
P_{ins}	Insemination costs	10,000

Table 3.5: Biological coefficients used in the initial situation and after 1% improvement in MY and CI

		Initial situation	after 1% improvement	
			Increase in MY	Decrease in CI
CI	Calving Interval	444	444	439.56 (444 - 4.44)
MY	Total lactation milk yield/cow	3266	3298.66 (3266 + 32.66)	3266
AMY	Annual milk yield/cow [(365/LL) x MY]	3702.14	3739.16	3702.14
NCY	Number of calvings/year (365/CI)	0.8221	0.8221	0.8304
MC	Male calves/cow/year (Sex ratio x NCY x cr x S_{24} x $S_{m\text{-}30\ days}$)	0.2965 (0.5 x 0.822 x 0.8 x 0.98 x 0.92)	0.2965	0.2995 (0.5 x 0.830 x 0.8 x 0.98 x 0.92)
FC	Female calves/cow/year (sex ratio x NCY x cr x S_{24hrs} x $S_{f\text{-}weaning}$)	0.2965 (0.5 x 0.8221 x 0.8 x 0.98 x 0.92)	0.2965	0.2995 (0.5 x 0.8304 x 0.8 x 0.98 x 0.92)
N	Breeding cows (Basis for calculations)	100	100	100
H	Proportion of Heifer to N	0.2965	0.2965	0.2995
N_H	Number of heifers	29.65	29.65	29.95
N_{MC}	Number of male calves	29.65	29.65	29.95
N_{FC}	Number of female calves*	29.65	29.65	29.95
	Total heads of animals	188.95	188.95	189.85

*Female calves (N_{FC}) mature into heifers (N_H)

Sources of Revenue

I - Sale of milk (R_{milk})

Only improvement in MY has an effect on this revenue source

	R_{milk}	=	MY	x	N	x	P_{MY}	(3.2)
Initial situation	166,590,000		3702.00		100		450	
1% improvement MY	168,262,200		3739.16		100		450	

II - Sale of male calves (R_{MC})

Only improvement in CI has an effect on this revenue source

	R_{MC}	=	MC	x	N	x	P_{MC}	(3.3)
Initial situation	1,185,888		0.2965		100		40,000	
1% improvement CI	1,196,000		0.2995		100		40,000	

III - Sale of surplus heifers (R_{SH})

Only improvement in CI has an effect on this revenue source

	R_{SH}	=	(H	– 0.25)	x	N	x	P_{SH}	(3.4)
Initial situation	1,161,802		(0.2965	– 0.25)		100		250,000	
1% improvement CI	1,236,668		(0.2995	– 0.25)		100		250,000	

IV - Sale of culled cows (R_{CC})

Improvement in MY and CI do not change revenue got from the sale of culled cows

	R_{CC}	=	CC	x	N	x	P_{CC}	(3.5)
Initial situation	7,500,000		0.25		100		300,000	

Total revenue (R)

(3.6)

	R	=	R_{milk}	+	R_{MC}	+	R_{CC}	+	R_{SH}
Initial situation	176,437,690		166,590,000		1,185,888		7,500,000		1,161,802
improvement MY	178,109,890		168,262,200		1,185,888		7,500,000		1,161,802
improvement CI	176,524,535		166,590,000		1,196,000		7,500,000		1,236,668

Cost Centres

I - Feed Costs (C_F)

According to CHAMBERLAIN (1993) cows feeding on tropical pastures of 50% to 70% digestibility will eat a maximum quantity of dry matter (DM) ranging from 1.5 to 3.0 per cent of their body weight. The same was assumed in calculating feed costs. Costs are in Ugandan shillings (UGS).

i) Feeding of calves

In a study conducted by OSEI et al. (2005) on the reproductive performance of Friesian cattle in the hot humid forest zone of Ghana, calves were found to consume, on average, 0.5% DM of their body weight while birth weight and preweaning daily gain was found to be 29.99 kg and 0.44 kg, respectively. These findings were used as a basis for calculating the costs incurred in feeding of calves.

Whole milk contains approximately 13% DM and 5.37 Mcal of metabolisable energy (ME) per kg of DM. In order to feed a 30 kg calf to gain 0.4 kg body weight per day, the ME requirement is 2.22 Mcal/day. We therefore, need to feed 2.22 ÷ 5.37 = 0.413 kg of milk DM per day, or 0.413 ÷ 0.13 = 3.17 kg of whole milk per day (QUIGLEY, 2001). Because of its colostral state in the first 10 days after calving down, milk cannot be sold off. So it is assumed that no costs are incurred as a result of feeding this milk to the calves during this period.

a. Feeding of male calves till day 30 (F_{MC})

Calves receive 4 kg of milk everyday and are sold off at the age of 30 days. The cost of feeding milk to this stock is incurred for a period of 20 days.

Cost of milk fed to male calves: (3.7)

	F_{MC}	=	MC	x	N	x	P_{MY}	x	milk	x	days
Initial situation	1,056,732		0.2965		100		450		4		20
1% decrease CI	1,078,080		0.2995		100		450		4		20

b. Feeding of female calves up to weaning (F_{FC})

Female calves are weaned after 90 days. They receive 4 kg and 2 kg of milk per day for the first 60 days and the last 30 days respectively.

Cost of milk fed to female calves up to day 60 (F_{FC-1})

It is assumed that all DM requirements of the calf during this time is got from milk. The amount got from forage is negligible. Preweaning pasture intake by calves is assumed to begin actively at 60 days after birth (ILCA, 1978). Thus, dry matter intake (DMI) of a calf per day within this period up to day 60 is assumed to come solely from milk (i.e., 0.52 kg).

DMI/day from milk (kg)	=	DM % in milk	x	Milk consumed (kg)	(3.8)
0.52		13		4	

Cost of milk up to day 60 days: (3.9)

	F_{FC-1}	=	FC	x	N	x	P_{MY}	x	milk	x	days
Initial situation	2,668,249	=	0.2965		100		450		4		50
1% decrease CI	2,695,201	=	0.2995		100		450		4		50

Cost of feeding female calves from day 60 till day 90 (F_{FC-2})

The average weight of female calves (W_{FC}) at day 60 is expected to be around 56.39 kg.

(3.10)

W_{FC}	=	Birth weight (kg)	+	pre-weaning daily gain (kg)	x	days feeding
56.39		29.99		0.44		60

From day 60 till weaning they receive only 2 litres of milk per day. Calves weighing 60 kg require, on average, daily DMI of 1 kg (JEROCH et al., 1999). Therefore, it is assumed that in these 30 days 0.26 and 0.74 kg of DM comes from milk and forage, respectively.

(3.11)

DMI from milk (kg)	=	DM % in milk	x	Milk consumed (kg)
0.26		13		2

Cost of milk from day 60 till day 90 ($F_{FC-2-milk}$): (3.12)

	$F_{FC-2-milk}$	=	FC	x	N	x	P_{MY}	x	milk	x	days
Initial situation	800,475	=	0.2965		100		450		2		30
1% decrease CI	808,560	=	0.2995		100		450		2		30

Cost of forage from day 60 till day 90 ($F_{FC-2-forage}$): (3.13)

	$F_{FC-2-forage}$	=	FC	x	N	x	P_{forage}	x	Forage	x	days
Initial situation	9,675	=	0.2965		100		14.7		0.74		30
1% decrease CI	9,773	=	0.2995		100		14.7		0.74		30

From day 60 till day 90 the addition calf weight is 13.2 kg; so the weaning weight (W_{FC}) is around 69.59 kg and was calculated as follow:

(3.14)

W_{FC}	=	Weight at 60 days (kg)	+	[pre-weaning daily gain (kg)	x	days feeding]
69.59		56.39		0.44		30

ii) Feeding of heifers (F_H)

Feeding of heifers is divided into two phases: weaning to conception and gestation period.

a. Feed costs of heifers from weaning to conception (F_{H-1})

Assumptions: 4.8 kg DMI per day (1.5% of body weight), which is solely got from natural pastures, and 0.1 as the proportion of culled heifers (H_{cull}). Other considerations are found in table 3.3 and 3.4.

(3.15)

	F_{H-1}	= DMI	x P_{forage}	x [FC	x N	- (H_{cull}	x N_H)]	x days
Initial situation	687,191	= 4.8	14.7	[(0.2965	100	(0.1	29.65)]	365
1% decrease CI	694,133	= 4.8	14.7	[(0.2995	100	(0.1	29.95)]	365

b. Feed costs of heifers during gestation (F_{H-2})

It is not possible to analyze age and weight at first calving separately. ROY (1978) suggested different weights for Holstein heifers with different ages, according to the daily liveweight gain. He pointed out that liveweight before calving must be over 500 kg for 2 to 3 years old heifers. The assumptions used for calculating costs were as follow: live body weight of 500 kg, daily DMI of 11 kg (2.2 % of body weight), and a gestation period of 270 days.

(3.16)

	F_{H-1}	= DMI	x P_{forage}	x [FC	x N	- (H_{cull}	x N_H)]	x days
Initial situation	1,164,931	= 11	14.7	[(0.2965	100	(0.1	29.65)]	270
1% decrease CI	1,176,698	= 11	14.7	[(0.2995	100	(0.1	29.95)]	270

iii) Cost of feeding cows (lactating, dry, pregnant) F_{cows}

The mean DMI of cows in the fenced dairying system was estimated by NASSUNA (2001) to be 2.2% of their average body weight while their average live body weight on pasture based production systems was estimated by NICHOL (2005) to be 500 kg. Animals receive concentrates (conc.) in form of dairy meal, whose DM content was analysed at the Faculty of Veterinary Sciences, Makerere University and established to be 918 gm/kg (NASSUNA, 2001).

Table 3.6: . Variables used in calculating the cost of feeding cows (F_{cows})

Variable		
Average body weight (kg)	500 kg	
Total DMI[1] (kg)	11 (2.2 % of body weight)	
Type of feed	Dairy meal	Natural pastures
DMI from type of feed (kg)	2	9
DM content of type of feed (gm/kg)	918	-
Cost of type of feed/kg (UGS)	270	-
Cost of 1 kg DM of feed (UGS)	294 (P_{conc}) (270/0.918 x 1000)	14.7 (P_{forage})[2] (294/20)

[1] DMI – daily dry matter intake

[2] It is assumed that forage (nature pastures) is 20 times cheaper than concentrates

$$F_{cows} = (Conc. \times P_{conc}) + (Forage \times P_{forage}) \times N \times days \quad (3.17)$$

F_{cows}	Conc.	P_{conc}	Forage	P_{forage}	N	days
26,290,950	2	294	9	14.7	100	365

Total feed costs:

$$C_{Feed} = F_{MC} + F_{FC\text{-}1} + F_{FC\text{-}2\text{-}milk} + F_{FC\text{-}2\text{-}forage} + F_{H\text{-}1} + F_{H\text{-}2} + F_{cows} \quad (3.18)$$

II – Veterinary costs (C_{Vet})

The estimated cost per head of animal at Njeru stock farm is 39 UGS, and male calves are sold off at the age of 30 days.

Table 3.7: Details of veterinary cost (C_{Vet}) calculation

Stock type	Initial situation		After 1% decrease in CI	
Mature cows	1,423,500	(100 x 39 x 365)	1,423,500	(100 x 39 x 365)
Heifers	422,028	(29.65 x 39 x 365)	426,291	(29.95 x 39 x 365)
Female calves	422,028	(29.65 x 39 x 365)	426,291	(29.95 x 39 x 365)
Male calves	34,687	(29.65 x 39 x 30)	35,038	(29.95 x 39 x 30)
C_{Vet} (UGS)	2,302,243		2,311,119	

III – Wage costs (C_{wage})

The number of casual labourers is dependent on the number of cows present in the herd. For this study, herd size is fixed at 100 cows, hence a reduction in CI does not affect this cost centre. Presently, Njeru stock farm has 95 cows and 20 casual labourers, who are employed at a cost of 17,280,000 UGS per year. Thus, a herd of 100 cows costs 18,189,474.

IV – Reproduction costs (C_{reprod})

The estimated calving interval (CI) was 444 days with the number of inseminations needed per pregnancy (INS) being 2.4. A 1% reduction in CI means a change (ΔC) of - 4.44 days bringing CI down to 439.56 days. We assumed that inseminations are carried out each time a cow is on heat, that is, every other 21 days; therefore, the reduction in INS by reducing CI will be by $\Delta C/21$

$$\text{INS} - \Delta C/21 = \text{reduced INS} \quad (3.19)$$

$$2.4 - 4.44 / 21 = 2.19$$

$$C_{reprod} = [\ (\text{INS} \times P_{ins} \times N) / \text{CI}\ ] \times 365 \quad (3.20)$$

	C_{reprod}	INS	P_{ins}	N	CI
Initial situation	1,972,973	2.40	10,000	100	444.00
1% decrease CI	1,817,337	2.19	10,000	100	439.56

The reduction in INS can also be got by regressing INS on CI

(INS + ΔCI x Regression factor) x N x semen price

V – Fixed costs (C_{fixed})

The fixed costs were based on costs for Njeru stock farm

Table 3.8: Fixed costs (C_{fixed})

	ITEM	Expenditure (UGS)
1	Electricity	1,620,000
2	Servicing of milking machine	916,000
3	Salary of permanent workers involved in the dairy sector	42,022,976
4	Renovation of buildings related to the dairy sector e.g. dip, office building etc	1,232,000
5	Farm road maintenance	2,200,000
6	Motorcycles, tractor, lorry maintenance	3,923,200
7	Communication costs e.g airtime, faxes, internet use	680,000
8	Personnel allowances e.g. per diem	1,272,000
9	Training of staff	1,610,000
10	Provision of water	4,500,000
	Total	**59,976,176**

Table 3.9: Summary of sources of revenues

Source	Initial situation	after 1% improvement in trait	
		Increase in MY	Decrease in CI
Milk (R_{milk})	166,590,000	168,262,200	166,590,000
Male Calves (R_{MC})	1,185,888	1,185,888	1,197,867
Surplus Heifers (R_{SH})	1,161,802	1,161,802	1,236,668
Culled Cows (R_{CC})	7,500,000	7,500,000	7,500,000
Total Revenue (R)	176,437,690	178,109,890	176,524,535

Table 3.10: Summary of costs

Cost centres	Initial situation	after 1% improvement in trait
		Decrease in CI
Feed		
Male calves (F_{MC})	1,067,299	1,078,080
Female calves up to 60 days (F_{FC-1})	2,668,249	2,695,201
Female calves 60-90 days milk ($F_{FC-2-milk}$)	800,475	808,560
Female calves 60-90 days forage ($F_{FC-2-forage}$)	9,675	9,773
Heifers weaning – conception (F_{H-1})	687,191	694,133
Heifers gestation (F_{H-2})	1,164,931	1,176,698
Mature cow (F_{cows})	26,290,950	26,290,950
Total Feed costs (C_{feed})	32,688,770	32,753,394
Veterinary costs (C_{vet})	2,302,243	2,311,119
Wage costs (C_{wage})	18,189,474	18,189,474
Reproduction costs (C_{reprod})	1,972,973	1,817337
Fixed costs (C_{fixed})	59,976,176	59,976,176
Total Cost (C)	115,129,636	115,047,500

Feed costs make up 59% of all variable costs, just in line with WELLER's (1994) observation that the major production costs are feed-related.

Table 3.11: Milk Yield (MY) economic weight (marginal profit) derivation

	kg	UGS		
	MY	Revenue	Cost	Profit
Present situation	3,266.00	176,437,690	115,129,636	P_1 – 61,308,054
1% increase	3,298.66	178,109,890	115,129,636	P_2 – 62,980,254
ΔMY	32.66			
$\Delta P = P_2 - P_1$				1,672,200
Marginal profit	$\frac{\Delta P}{\Delta MY}$ = 1,672,200/32.66 =			51,200
Marginal profit/animal		51,200/100 =		512
		In Ugandan Currency points (Ugcp)*	512/20,000 =	**0.0256**

*1 Ugcp = 20,000 UGS

Table 3.12: Calving Interval (CI) economic weight (marginal profit) derivation

	days	UGS		
	CI	Revenue	Cost	Profit
Present situation	444.00	176,437,690	115,129,636	P_1 – 61,308,054
1% increase	439.56	176,524,535	115,047,500	P_2 – 61,477,035
ΔCI	4.44			
$\Delta P = P_2 - P_1$				168,981
Marginal profit	$\frac{\Delta P}{\Delta CI}$ = 168,981/4.44 =			38,058
Marginal profit/animal		38,058/100 =		380.58
		In Ugandan Currency points (Ugcp)	381/20,000 =	**0.019**

Standardizing economic weights

Economic weights of traits are expressed on a common basis in order to be able to make a comparison amongst them. In this study, they are expressed in terms of genetic standard deviation. BARWICK (1993) recommends the use genetic standard deviation instead of a phenotypic standard deviation of change in each trait. He is of the view that the measure on the genetic scale gives by far the better indication of what is important for breeding, since it combines economic value with a measure of what is achievable. Because of lack of a family structure in the data, the genetic standard deviation (S_a) could not be estimated directly. It was implicitly estimated from repeatability (r_e), variance due to animal effect (V_{animal}), and heritability (h^2). The restricted maximum likelihood (REML) procedure in SAS was used to estimate the variance components for MY and CI, and the equations in the analysis were solved iteratively. Below is the statistical model that was used:

$$Y_{ijk} = N_i + farm_j + anim_{kj} + \varepsilon_{ijk} \tag{3.21}$$

where

Y_{ijk}	=	record (MY or CI) of the cow
N_i	=	fixed effect of lactation/calving interval number
$farm_j$	=	random effect of farm j
$anim_{kj}$	=	random effect of animal k nested in farm j
ε_{ijk}	=	random residual effects

The summation of variance due to animal, farm, and residual effects make up the phenotypic variance (V_P)

$$V_P = V_{animal} + V_{farm} + V_{residual} \qquad \text{(Form. 3.22)}$$

Table 3.13: REML Variance Estimates

	Estimates	
Variance Components	MY	CI
Farm effect (V_{farm})	196319.9	532.47399
Animal effect (V_{animal})	407170.1	808.30854
Residual effect ($V_{residual}$)	803297.1	8270.4
Phenotypic variance (V_P)	1,406,787	9611

The phenotypic variation (V_p) in a herd for a particular trait is due to additive variance (V_a), dominance variance (V_d), epistatic variance (V_i), permanent environmental variance (V_{ep}), and temporary environmental variance (V_{et})

$$V_p = V_a + V_d + V_i + V_{ep} + V_{et} \tag{3.23}$$

The permanent effects on the animal (PE) are due to dominance (d), epistasis (i) and its permanent environment (ep).

$$V_{PE} = V_d + V_i + V_{ep} \tag{3.24}$$

In this study, we assumed that dominance (d) and epistasis (i) are zero, therefore

$$V_{PE} = V_{ep} \tag{3.25}$$

Variance due to animal effect (V_{animal}) is the sum of the animal's additive variance (V_a) and variance due to permanent effects on the animal (V_{PE})

$$V_{animal} = V_a + V_{PE} \tag{3.26}$$

From formula 3.25 it follows that

$$V_{animal} = V_a + V_{ep} \tag{3.27}$$

Basing on the aforementioned assumptions and facts, S_a for the traits was estimated. Details of the steps followed in deriving S_a are in table 3.14.

Table 3.14: Details of deriving genetic standard deviation (S_a) for MY and CI

Parameter		formula	results	
			MY	CI
Repeatability	r_e	$\frac{V_{animal}}{V_{farm} + V_{animal} + V_{residual}}$ or $h^2 + c^2$	0.29	0.08
Heritability*	h^2	$\frac{V_A}{V_P}$	0.25	0.047
Relative environmental variance	c^2	$\frac{V_{EP}}{V_P} = \frac{V_{PE}}{V_P}$ or $r_e - h^2$	0.04	0.033
Variance due to animal effect	V_{animal}	$V_a + V_{PE}$	407170.1	808.3
Proportion of repeatability due to additive genetic effect		$\frac{h^2}{r_e}$	0.86	0.58
Proportion of repeatability due to permanent environment /effects of animal		$\frac{c^2}{r_e}$	0.14	0.41
Additive genetic variance	V_a	$V_{animal} \times \frac{h^2}{r_e}$	351,008	475
Variance due to permanent effects of animal	V_{PE}	$V_{animal} \times \frac{c^2}{r_e}$	56,161	333
Additive genetic standard deviation	S_a	$\sqrt{V_{animal} \times \frac{h^2}{r_e}}$	592. 46	21.79

* From literature

Table 3.15: Additive genetic standard deviation (S_A), economic weight (v in Ugcp), economic weights per S_A of the single traits in the index (S_A*v), and relative economic importance of single traits in the index (% S_A*v)

Trait	unit	S_A	v	S_A*v	% S_A*v
Milk Yield	kg	592.46	0.0256	15.166976	98.25
Calving Interval	days	21.79	-0.019	-0.41401[1]	2.63
Restricted index[2]					
Milk Yield	kg	592.46	0.0256	15.166976	74.28
Calving Interval	days	21.79	-0.241	-5.25139[1]	25.72

[1] Positive in breeding sense [2] A restriction is put on calving interval genetic gain

3.4.2 Economic parameters used in the model

The economic parameters which were included in the model were real interest rate, investment period, and the cost elements of the breeding programme. WELLER (1994) singles out measuring and recording the traits of interest, progeny testing, maintaining breeding stock, production and storage of seed, and statistical analysis as being the major costs. Costs are divided into fixed (independent of the number of breeding animals) and variable costs (dependent on the number of breeding animals). The former included, for example, personal costs, depreciations of building and equipment etc. (see table 3.8) while the latter included costs associated with performance recording of dams, and production and storage costs of semen.

3.4.2.1 Interest rate and investment period

Although businesses in Uganda, for the last few years, have had to contend with rates of 20 percent, normal interest rates average about 10 percent to 12 percent (FAWZIA, 2005). Basing on this, 10% interest rate was used in the model. In regard to the investment period, WELLER (1994) contends that a number of considerations that may not be important for relatively short-term processes are of major importance for most animal breeding programmes, which by their nature are long-term processes. One such consideration is the profit horizon or investment period. Breeding programmes are generally analyzed in terms of ten to twenty year profit horizon, and all returns occurring after this period are considered to have no value. For this study, an investment period of 15 years was considered.

3.4.2.2 Semen costs

The cost of animal maintenance during the waiting period can be reduced by collecting and freezing large quantities of semen over a relatively short period but the cost of semen collection and storage is increased (WELLER, 1994).

Table 3.16: Variables used to derive semen production costs

		Per year	
			UGS
On the day of semen collection:			
Number of bulls in service	4		
Doses of semen produced	650	67,600	
Cost of processing material (UGS)	40,000		4,160,000
Cost of electricity (UGS)	15,000		1,560,000
Costs of man power (UGS)	27,000		2,808,000
Number of days in a year collecting semen (2 times/week)	104		
Cost of keeping a bull/ year (UGS)		2,000,000	
Cost of keeping 4 bulls/year			8,000,000
Total cost of semen production			85,280,000
Cost/dose of semen (85,280,000/67,600)			245
In Ugcp		**0.012**	

I Ugcp = 20,000 UGS

Table 3.17: Variables used to derive semen storage costs

			per year
Cost of a litre of LN_2		500 UGS	
Size of LN_2 container		45 lt	
Storage capacity of LN_2 container		12,000 doses semen	
Frequency of refilling container in a year (once a week)		52 times	
LN_2 needed for refilling in a year (45 lt x 52 weeks)		2,340 lt	
Cost of LN_2 used for refilling (UGS) (2,340 lt x 500 UGS)			1,170,000
Depreciation of LN_2 container (UGS)			300,000
Storage cost in a 45 lt container (UGS)			1,147,000
Storage cost per dose of semen:			
(1,147,000/12,000)	in UGS		122.5
	in Ugcp		**0.006**

*1 Ugcp = 20,000 UGS LN₂ – Liquid Nitrogen

3.4.2.3 Deriving milk recording costs

Although the main objective of most recording systems is genetic selection, it should be noted that the information recorded has other uses as well (WELLER, 1994). In Uganda, records are used for farm management as well as a marketing tool. Animals with records fetch a higher price than unrecorded ones. Since the derivation of these costs was based on recording in the dispersed nucleus and on zero grazing farms in the base population, it was assumed that only half of these costs are directly related to breeding while the rest of the costs were assumed to be borne by the aforementioned other uses of records.

Table 3.18: Number of farms and cows taken care of by one record assistant in a year

Farm type	Number of farms	Recorded cows/farm	Recorded cows/system
Fenced Dairy system (FD)	3	20	60
Zero grazers (Z)	20	1.5	30
Total	23		90

Table 3:19: Cost of recording material for farms visited by one record assistant

		Cost/year
i) Cow Lifetime cards		
Targeted production system	FD and Z	
Number of cows recorded	90	
Cost per card (UGS)	1000	
Required quantity per year (One card for entire life of animal)*	13.433 cards (90/6.7)	
Total cost of cards/year (UGS)	1000 x 13.433 =	13,433
ii) Daily milk record sheets		
Targeted production system	FD	
Number of farms	3	
Cost per card (UGS)	1,000	
Required quantity per year (1.5 sheets/farm/month)	54 sheets (1.5 x 12 x 3)	
Total cost of cards/year (UGS)	1000 x 54 =	54,000
iii) Daily milk record book		
Targeted production system	Z	
Number of farms	20	
Cost per book (UGS)	5000	
Required quantity per year (1 book/farm)	20	
Total cost of books/year (UGS)	5000 x 20 =	100,000
Total cost (UGS)		**167,433**

*Lifetime years of a cow ~ 6.7 (2.7 AFC + 4 years productive life)

Table 3:20: Other costs related to performance recording

	Cost/year (UGS)
i. Personnel costs	
Salary for one record assistant	6,000,000
Allowances monitoring supervisor - 2 days in a month	1,200,000
ii. Transport cost	
Fuel for motorcycle	2,500,000
Servicing motorcycle	240,000
Fuel for car used by supervisor	2,120,000
iii. Data processing costs	
Data entry equipment, stationery	1,200,000
Total costs	13,260,000

Total cost of recording animals under one record assistant:		
Recording material + other recording related costs =	13,427,433	UGS
Cost of recording per cow (13,227,433/90)	149,194	UGS
1 Ugcp = 20,000 UGS	7.5	Ugcp
Cost of recording directly related to breeding (50% recording costs)	**3.75**	**Ugcp**

3.4.3 Quantity of semen needed to be collected from a bull

Since the costs of semen collection and storage are not prohibitive, we decided that semen from bulls be collected, stored, and the bulls then slaughtered. WELLER (1994) is of the opinion that semen collection during the waiting period is, in any event, desirable because the male may die or become infertile at any time. The amount of semen to be collected from each YB was based on the following:

i. The average amount of semen the artificial insemination unit of NAGRC collects from each bull per year.
ii. The present storage capacity of the artificial insemination unit and its prospects of expanding the same.
iii. The proportion of the base population, which is to be serviced by each PB. At anyone given time, semen from 16 PB will be servicing the population. 4 bulls are selected per round of selection and are in use for 4 years in the base population.
iv. The number of services needed per conception (insemination index).

3.4.4 Average age of Proven Bulls when their first offspring are born

Table 3.21: Timeline of a Proven Bull

Step	Event	years
1.	Age of YB when 1st offspring are born	2.4
2.	Age of daughters of YB when their 1st offspring are born	2.3
3.	1st lactation of daughters	1.0
4.	Waiting period to get all daughter records	0.5
5.	YB becomes PB; cows inseminated with PB semen; waiting period for cows to conceive	0.35
6.	Gestation period of cows	0.75
7.	Average age of PB when 1st offspring are born	7.3

3.4.5 Number of inseminations needed per daughter record (Ins/DR)

In order to be able to get at least one daughter record, the minimum number of Ins/DR needed with the present number of 2.4 inseminations per conception (INS) is 6. This minimum number was used in the model because it was assumed that given the strict supervision, which will be in the nucleus, it is attainable.

Table 3.22: Comparison of 4 and 6 inseminations per daughter record (Ins/DR)

			Ins/DR			
			4		6	
Inseminations per pregnancy	INS		2.40[1]	1.60[2]	2.40[1]	1.60[2]
Pregnancies expected	Ins/DR / INS		1.70	2.50	2.50	3.75
Females expected	Ins/DR / INS	x 0.5	0.80	1.25	1.25	1.88
Rearing proportion[1]			0.80	0.80	0.80	0.80
Females reared to be able to record their performance	Ins/DR / INS	x 0.5 x 0.8	0.64	1.00	1.00	1.50

[1] present situation

[2] with improvement in fertility management

3.4.6 Population size

Uganda's cattle population is estimated at 5.97 million heads of which 285,000 are exotics, mainly Holstein-Friesian and their crosses (MAAIF/MFPED, 2000). Breeding of exotics is usually by AI. Records at NAGRC show that about 30,000 inseminations, using exclusively semen from exotics, are carried out per year; however, many AI technicians do not send in their activity reports to NAGRC as they are required to do, thus this number is higher than what is officially recorded. In view of these facts and NAGRC's capacity of providing AI services (i.e., semen and liquid nitrogen), a breeding population of 100,000 animals was found to be appropriate for the programme. The nucleus is to be made up of two units, the central unit based at Njeru stock farm and the dispersed unit made up of farms in the fenced dairying system. Its size of 700 animals was based on the heads of cattle which Njeru stock farm is capable of supporting and the available resources for monitoring the farms in the dispersed unit.

3.4.7 Gene flow

Following GIBSON'S (1992) recommendation on the steps that need to be followed in order to be able to follow the transmission of genes through the population and know the economic value of genes and the time they are expressed, a clear specification of the following was done:

i) The population structure, made up of a breeding (central and dispersed nucleus) and base unit, and consisting of 7 selection groups was defined. The central and dispersed nuclei were modelled as one unit. Differences between the two occur during the operationalization phase of the programme.

ii) The way in which genes are passed on from animals at one time period to animals in the following time period was specified. A progeny testing system with a high proportion of recorded cows in the nucleus mated with young bulls (YB) was used. Genetic gain is realised in the nucleus and passed on to the base population by proven bulls (PB). There is no gene flow from the base to the nucleus. ZPLAN uses a top-down approach making it impossible to model gene flow from the bottom up to the nucleus. In practice, excellent males/females from the base population will be brought into the nucleus. This will be taken into consideration during the operationalisation phase of the programme.

iii) The structure of the population in terms of age classes of each sex of animal we are interested in was defined e.g., length of use of PB in the nucleus and base population, average age of PB when their first offspring are born etc.

iv) Each age class represents a time unit of one year. This was based on the CI, which is roughly one year.

Figure 3.3: Gene flow method: Selection groups in the transmission (P) matrix

PARENTS

OFFSPRING		Nucleus: YB, PB	Nucleus: CN	Base: CBP
Nucleus	YB, PB	1. PB > PB	2.CN > PB	–
Nucleus	CN	3. YB > CN 4. PB > CN	5. CN > CN	–
Base	CBP	6. PB > CBP	–	7. CBP > CBP

YB = Young Bulls PB = Proven Bulls

CN = Cows in the Nucleus CBP = Cows in the Base Population

Table 3.23: Input parameters used in modelling the breeding programme

Population parameters	
Population size	100,000
Proportion of nucleus to total population	0.007
Proportion of base to total population	0.993
Proportion of recorded cows mated with young bulls (PCYB) and Proven bulls (PB)	0.6; 0.4
Number of young bulls (YB) tested per year	10
Number of proven bulls selected per year out of these	4
Number of proven bulls mated with bull dams in the nucleus and cows in the base population.	4
Inseminations needed per daughter lactation record	6
Biological-technical coefficients	
Calving interval in the nucleus (years)	1.15
Calving interval in the base population (years)	1.21
Number of inseminations per pregnancy	2.4
Proportion of dams which go into consecutive lactations (survival) in the nucleus	0.85
Proportion of cows which go into consecutive lactations (survival) in the base population	0.80
Proportion of YB reared	0.8
Proportion of dams reared	0.8
Calving rate	0.8
Use of YB and PB in nucleus (years)	1 ; 2
Use of PB in the base population (years)	4
Use of bull dams (CN) in nucleus (years)	4.5
Use of cows (CBP) in base population (years)	4.5
Age of PB when 1st offspring are born	7.3
Age of YB when 1st offspring are born	2.3
Age of cows in the base (CBP) when 1st offspring are born	2.5
Age of dams (CN) in the nucleus when 1st offspring are born	2.0
Semen doses per PB	13,774
Mean generation interval	5.59
Storage time of straws (years)	7
Proportion of viable straws after storage	0.9
Economic parameters (Ugandan currency points – Ugcp)	
Milk recording costs per cow	3.75
Production costs per semen dose	0.01
Storage costs per semen dose per year	0.01
Interest rates calculating returns and costs (%)	10
Fixed cost – in overall nucleus	3,900
Investment period (years)	15

3.4.8 Evaluated breeding schemes

ZPLAN has two main steps. First, a basic situation of a breeding programme is defined and evaluated. In a second step, alternative strategies or schemes are defined by varying certain parameters of the basic situation (NITTER, 1993). Six schemes were evaluated. They were grouped into three according to their similarities in the queries (what if question) they are trying to address (see table 3.24).

Group 1 Defining the basic breeding plan

Scheme I — Simultaneous varying of young bulls (YB) and the proportion of cows mated to young bulls (PCYB).

Question: What is the optimal option when YB (5,10,15,20) is varied against PCYB (0.5, 0.6, 0.7, 0.8)?

Scheme II — Varying the number of YB at very close range around the optimal one.

Question: Is the optimal YB found in scheme I really the optimal number, or is it somewhere slightly below or above this number?

Scheme III — Varying the number of Inseminations per daughter record (Ins/DR).

Questions: What influence would the number of Ins/DR have on the optimal option found in scheme I? Which optimal Ins/DR should be used in the basic model?

Management greatly influences INS, which in turn also influences Ins/DR.

Therefore, the scheme delivers information on the influence of management on the breeding programme.

Group 2 Imposing restrictions on genetic gain

Scheme IV — Restriction imposed on calving interval genetic gain.

Question: How and to what extent is the monetary genetic gain for the aggregate genotype affected when deterioration in calving interval is curbed by restricting its genetic gain?

Group 3 Size of tiers

Scheme V — Nucleus size reduced to 500.

Question: In what ways does a reduction in the nucleus size affect the programme? Conversely, this would also give answers about what would happen when the nucleus size is increased.

Scheme VI Population size reduced to 50,000.
Question: How does a reduction in population size impact on the programme.? Conversely, what happens when the population size is increased?

Table 3.24: Details of evaluated breeding schemes

		Schemes					
		Group 1			**Group 2**	**Group 3**	
Input	Basic run	I	II	III	IV	V	VI
Population size	100,000	100,000	100,000	100,000	100,000	100,000	**50,000**
Nucleus size	700	700	700	700	700	**500**	700
YB	10	5 10 15 20	**8** **9** **10** **11** **12**	10	5 10 15 20	5 10 15 20	5 10 15 20
PCYB	0.6	0.5 0.6 0.7 0.8	0.6	0.6	0.5 0.6 0.7 0.8	0.5 0.6 0.7 0.8	0.5 0.6 0.7 0.8
Ins/DR	6	6	6	**4** **6** **8** **10**	6	6	6
CI – restricted	none	none	none	none	**0.000**	none	none

YB = Number of young bulls
PCYB = Proportion of cows in nucleus mated to young bulls
Ins/DR = Number of inseminations/daughter record
CI – restricted = Genetic gain restriction on calving interval

The criteria used to evaluate the alternative breeding schemes are defined as follows:

i) Annual monetary genetic gain (AMGG): Monetary superiority per year of the progeny of the selected animals of one selection round in the nucleus (breeding unit)

ii) Discounted returns (R): accumulated discounted returns per cow in the whole population (nucleus and base population) within the investment period of 15 years based on the genetic superiority of the selected animals of one selection round.

iii) Discounted profit (P): Discounted profit per cow in the whole population - discounted returns minus discounted breeding costs per cow.

Figure 3.4 Schematic representation of materials and methodologies used in the study and for the anticipated operational plan