2 LITERATURE REVIEW

2.1 Animal Breeding Programmes

2.1.1 General overview

A breeding programme is an organization in which information on performance of potential breeding animals is used to estimate breeding values, and superior animals are selected to breed the next generation (CHARFEDDINE, 2000). These programmes are long term in nature, with a lot of resources invested at the beginning, while returns keep accruing to infinity. This attribute makes them outstanding from other forms of investments (WELLER, 1994).

HARRIS et.al. (1984) suggested the following steps when carrying out breeding programmes:

Step 1. Description of the production system(s)
Step 2. Formulate the objective: both simplified and comprehensive
Step 3. Choose a breeding system and breeds
Step 4. Estimate selection parameters and (discounted) economic values
Step 5. Design an animal evaluation system
Step 6. Develop selection criteria
Step 7. Design mating for selected animals
Step 8. Design a system for expansion – dissemination – of genetic superiority

The above steps were summarized by GROEN et al. (1997) into three:

Step 1. Definition of the breeding goal: setting up the aggregate genotype and deriving cumulative discounted expressions and economic values
Step 2. Estimating the breeding value: deciding what traits to be included in the information index, derivation of the regression coefficients to be included in the information index, estimation of the information index value, i.e. the estimated breeding value for each potential breeding animal.
Step 3. Optimizing the breeding programme: optimizing the organization to routinely gather information on potential breeding animals and/or their relatives, and to select and mate breeding animals to breed the next generation.

These steps can further be grouped into two components of designing breeding programmes, namely, operational and genetic plans (FEWSON, 1993c; WILLAM, 2004).

2.1.2 Programmes in developing countries

Systematic breeding programmes in developing countries are difficult to find; however, there are some few which can be reconstructed within the framework of development cooperation projects. A review of such programmes by NAKIMBUGWE (1998) revealed a grim picture. Since they are implemented as projects, which projects want to show results within a short time, they seem, in the short run, to be successful, but hardly leave a mark in the long run. VALLE ZÁRATE (1996) underlines the complexity of setting up sustainable breeding work in developing regions. There are often no recognisable regional breeding structures and no systematic exchange of stock between farms. Geneticists already working successfully in developed countries are powerless in developing countries, where the majority of animals are kept in traditional environments (JASIOROWSKI, 1990).

REGE (1995) clearly stresses the distinct disadvantages which developing countries have in setting up successful programmes: Infrastructure needed for performance testing is normally lacking because herd sizes are normally small and variability between farms, farming systems and seasons are large; reproductive efficiency is low, due mainly to poor nutrition, especially in cattle; and communal grazing precludes implementation of systematic breeding and animal health programmes. The few attempts made, so far, towards animal breeding by setting up breeding stations (research institutes, government farms, military farms) are being abandoned due to neo-liberal policies (VALLE ZÁRATE ,1996). TRIPATHI, (2004) warns that although the role of such policies like that of privatisation in promoting livestock improvement is well recognised, it can be problematic in many ways. For example, the aggressive marketing style of the private sector promising high yields and big profits entice farmers onto a high tech treadmill without being made aware of the risks. Sale of high value genetics in form of semen at exorbitant prices by private firms to farmers with promises of high production as it is in the countries of origin has usually been a disappointment to many farmers in Uganda (NAKIMBUGWE, 2000a). Although classical economic theory assumes that public interest is generally best served by free competition this is not necessarily the case for genetic improvement (WELLER,1994). Experience in Uganda (NAKIMBUGWE, 2002) clearly shows that livestock breeding cannot wholly be left to market forces. Whilst animal breeding plans should be technically sound, their success in the field is overwhelmingly dominated by ruling policy environment (HAMMOND, 2001). Very few countries, in the developing world, have clear animal breeding policies. Issues pertaining to breeding are usually embedded in other policies (MESCHU, 2003).

In each country, the policies and practices for delivery of improved genetics and related services to farmers should be formulated in relation to: country situation (animal population, production milk and meat, etc.) environmental conditions and availability of resources for livestock production; and social and economic situation of farmers and people. Governments should formulate appropriate breeding policies and provide guidelines to AI services and farmers on the choice of suitable breeds, and if importation of semen is done, on its genetic value (GALLOWAY, 2003).

Some countries like Uganda and the Southern African Development Community (SADC) have put or are putting in place animal breeding enabling policies (MAAIF, 1997b; MSECHU, 2003). Farmers played a big role in drawing up Uganda's Breeding policy (NAKIMBUGWE, 2003); likewise they should play a big role in designing and implementing breeding programmes. OSTERTAG (2004) contends that reinforcing participatory methods in interventions has been one of the results of realising that people cannot be developed, they have to develop themselves. Small-scale farmers know more about the complex and diverse detail of their methods, of the possibilities and limitations of their own land, of the local environment, and of how to correlate and manage them (NAEGEL, 1996). Unfortunately, they are usually told what would happen rather than being asked what they would like to happen (ORSKOV,1993). CAMPBELL (2004) forewarns that unless development is evidence-based, and much of it is not, its chances of success are greatly reduced. Intervention priorities should reflect those of the farmer's needs (BISCOE, 2004). In the animal breeding projects which Sölkner et al. (1998) analysed, they found that breeding goals incorporating the specific needs and social circumstances of the target group were missing in virtually all cases.

2.2 Production systems

The production system involves interaction between ecological and socio-economic factors. However, the approach to animal breeding work in the tropics has largely been to study the individual animal production or components of a production system (growth, milk production, reproduction, nutrition and management) in isolation (TANEJA, 1990). Therefore, introduction of new technology in the past (such as introduction of superior breeds or crossbreds) often failed because of lack of an integrated approach of the new technology with other factors (SIVARAJASINGAM, 1990). To obtain a high yield per cow, a whole production system is required, not just the animal component (ORSKOV, 1993). VALLE ZÁRATE (1996) complains of the little attention given to the description of production systems and outlines the various attempts that have been made to classify them basing on the level of management, the resource base, animal-human relationship, bioclimatic situation (irrigated, rainfed areas), products, marketing possibilities (near urban centres) etc. This break down, in her opinion, is very useful in indicating farming requirements and, together with economic factors, should be included in the definition of the breeding objectives.

2.3 Breeding objectives

A precise definition of the breeding objective is the first and probably most important step to be taken. Without it, the programme could result in genetic change, but in the wrong direction. Improving the wrong traits is equivalent or even worse than no improvement at all (VAN DER WERF, 2004; PONZONi, 1992). The breeding objective in any livestock species is to increase profit by improving production efficiency (CHARFEDDINE, 2000). Maximising profit seems to be a logical objective, but then, whose profit is being maximized ? (GIBSON, 1992). The many stakeholders involved in animal breeding, whose goals or interest are not identical complicate the definition of the breeding goal (WELLER, 1994). These include breeders who may either be commercial or farmer cooperatives, farmers, food processors, mechants, consumers, government etc.

On a national level the goal may be to increase the efficiency of production while at the individual farm it may be to increase the farmer's profit. This poses the question of who actually benefits from genetic improvement. After thorough analysis of the "Progress-Surplus-Bankruptcy Cycle", as defined by MOAV (1973), WELLER (1994) is of the opinion that generally, it is the consumers - ironically the ones who don't make major decisions that affect breeding programmes - rather than either the farmer or the commercial breeders are the beneficiaries of genetic improvement. As a solution, DICKERSON (1970) suggests that in the competitive world the primary goal of animal breeding should be to increase economic efficiency (ratio of production income divided by production costs) at a national level. In view of this discussion, WELLER (1994) proposes the use of systems analysis as a means of determining realistic breeding objectives. First, it provides a framework for consideration of breeding decisions within the total production framework. Second, it puts breeding decisions into perspective with other management decisions. The breeding programme that gives maximum genetic gain is not necessarily the programme that gives maximum net profit, hence optimization rather than maximization of the genetic potential of livestock is what is required.

In index selection, the breeding objective (total merit, aggregate genotype) is defined by a linear function of economically important traits (CHARFEDDINE, 2000). The aggregate genotype is used to represent the genetic of an animal, i.e., the weighted sum of its genotypic values for several traits (GROEN, 1997). Assuming a distinct genotype for each economic trait, each genotype is weighted by its predicted contribution to the increase in the overall objective (BRASCAMP, 1978).

In developing countries, rarely has adequate attention been given to evaluating and setting realistic and optimum breeding objectives (goals) prior to embarking on breed improvement programmes. Mistaken objectives are sometimes then followed by breed improvement schemes which are totally inappropriate to the existing or available infrastructure (CUNNINGHAM, 1992). A notable weakness in most breeding objectives is that technical and production coefficients are often over-optimistic. They are often defined in terms of "what we would like to improve" rather than "what we can improve" and thus lack the consideration of the practical limitations and possibilities of improvement (MATHUR et al. 1991). BAKER and REGE (1994) stress the fact that defining objectives in those comprehensive economic terms (i.e. returns minus costs) is difficult enough in temperate agriculture and much more difficult in the tropics. If defined explicitly at all, simplistic breeding objectives e.g., improvement of growth or of milk yield prevail (SÖLKNER et al., 1998).

According to WOLLNY (1995) the developmental objective which he calls the 'principal thrust' should be to improve overall biological and economic efficiency of livestock production through provision of an optimised genetic potential fulfilling the needs of the market or the subsistence farming system. GROEN (1997) points out that the difference between biological and economic efficiency is restricted to the way of defining costs and revenues. In the biological definition costs and revenues are expressed in energy and/or protein terms; in the economic definition this is performed in terms of money. The problem with the former definition is that not all costs and revenues can be expressed in terms of energy and/or protein. With the latter definition the problem is with the weakness in stability in time and place of monetary units (SCHLOTE, 1977). However, money is the standard for measuring value, therefore efficiency of production is usually considered to be economic efficiency and the contribution of improvement of a trait to the improvement of efficiency is called economic value (GROEN, 1997; STONIER and HAGUE, 1964). VALLE ZÁRATE (1996) points out that whereas more recent initiatives to define breeding aims strive harder to include ecological aspects, no examples can be found of attempts to quantify the social costs and benefits of animal production. She makes a comparison of breeding objectives (the conventional definition with and without ecological and social aspects) between industrial and developing countries.

2.4 Breeding schemes

2.4.1 Progeny selection schemes

Progeny testing is a robust system of improvement that overcomes the sex-limitation of dairy improvement. It is characterised by selecting bulls with high accuracy but with a long generation interval (WOOLLIAMS, 1990). Well as the system is credited for livestock improvement in developed countries, this has not been the same in developing countries. TANEJA (1990) reports that attempts at field progeny testing programmes in India have not been successful. The story was not different when this was done in single closed herds of limited size. REGE (1995) goes further to point out that the general failure of the extensive use of AI in developing countries has implied that progeny testing schemes cannot be operated with much success. GALLOWAY (2003) suggests the use of contract mating on progressive smallholder farms, where some form of approved milk recording can be used to obtain information necessary for sire selection. Additionally, an incentive scheme should be introduced for farmers participating in the progeny test programmes. Herds accepting semen from bulls to be progeny tested may have the cost of that semen discounted. The main advantage of the scheme is the high accuracy of evaluating sires. Accuracy of 0.7-0.8 as compared to 0.4 in young bull schemes was found in studies conducted by SYRSTAD and RUANE (1998) and JAITNER and DEMPFLE (1998). Its major disadvantage is that the generation interval along the sire-to-dam path is much longer than necessary by biological considerations. Semen is first collected from the young sires at the age of one year, but an additional four years will elapse until these sires can be genetically evaluated based on their first crop of daughters (GALLOWAY, 2003). A study done by SYRSTAD and RUANE (1998) under tropical conditions showed that progeny testing of bulls would give 20% lower genetic gain as compared to selection based on pedigree information. Furthermore, experiences from a progeny testing scheme in a herd of Sahiwal cattle in Kenya confirm that such schemes can be inefficient in practice (REGE and WAKHUNGU, 1992).

2.4.2 Half-sib selection schemes

OWEN (1975) suggested a half-sib selection scheme, in which sires of cows are selected based on the performance of their sisters, while sires of sires are selected based on daughter performance. The advantage of this scheme is a major reduction in the generation interval along the sire-to-dam path. The disadvantage is that the accuracy of evaluation is only half of that obtained by progeny tests based on an equal number of production records. A study conducted by JAITNER and DEMPFLE (1998) for the N'dama cattle breeding scheme showed that half-sib selection was more efficient than progeny testing.

2.4.3 Young bull selection scheme

Efficient breeding programmes are characterised by selecting animals at a young age, leading to short generation intervals and faster genetic improvement per year. Selection can be based on the candidate's, half-sib, or pedigree performance. Results of a study conducted by MEINERT et al. (1992) indicated that the average genetic merit of cows and the rate of within-herd genetic improvement are higher in herds that participate in a young sire sampling programme. In the tropics, use of young bulls was shown to be more efficient than progeny testing. Furthermore, it could also be used in smaller herds, the response was almost independent of the herd size, it was easier to operate and the least expensive (SYRSTAD and RUANE, 1998; JAITNER and DEMPFLE, 1998).

Risk is a factor in young bull use. Pedigree information is not as accurate as progeny test information. It indicates what genes a calf might have inherited from its parents, but does not reveal whether an individual calf inherited a better or worse than average sample of genes from its parents. About half of all young bulls will inherit a better than average sample of genes while the remainder will be less fortunate. The problem is that progeny test information is required to tell which young bull received the best sample of genes.

In developed countries, use of pedigree information in selecting young bulls (CASSELL, 1996) has not always been reliable because bull mothers are usually given preferential treatment and their genetic evaluations overstate their merit. This causes the pedigree evaluation of their sons to be too high and ultimate progeny test information is frequently disappointing to producers who milk their daughters (WEIGEL et al., 1995).

The economic incentives to use young bulls make them a good choice for reasons unrelated to genetic merit. For example, in the USA, it is standard procedure that AI institutes pay farmers to inseminate cows with semen from unproven bulls. In other countries, farmers are obligated by cooperative agreements to inseminate a fraction of their cows with semen from young sires. However, genetic progress is higher from using top proven bulls than from using average AI young bulls (WELLER, 1994; WEIGEL et al., 1995; CASSELL, 1996;).

2.4.4 Nucleus schemes

These are hierarchal (pyramid) breed structures with a genetically superior group of animals, the nucleus or elite group, at the top of the pyramid which supplies breeding animals, normally males, to the groups or tiers below it. The scheme, normally, could be a two-tier (nucleus and base populations) or three-tier structure (nucleus, multiplier and base or commercial populations). The multiplier group uses sires from the nucleus and in turn, provides sires to the base herds (BONDOC and SMITH 1993b; WIENER, 1994). In the multiplier group, any genetic gains made in the top tier are halved (because the sires pass on only half their genes to each offspring), but large numbers of such animals can be produced. Supplying the commercial herd halves the genetic gains further (WIENER, 1994). With every additional tier another lag in the flow of genes from elite to commercial herds is introduced. If the elite group is not making any genetic gain, then the multiplier and commercial groups that are dependent on it will not be making any gain either. And even worse, if errors are made and selection in elite flocks is in the wrong direction (PONZONI, 1992). An open nucleus allows the introduction of exceptionally good animals from the lower tiers, while a closed one doesn't.

JAMES (1977, 1978) came to the conclusion that open nucleus is superior to a closed nucleus of the same size because of a higher expected mean breeding value of nucleus replacements. This is because nucleus female replacements coming from the base can be very highly selected compared with the replacements which would otherwise have to be chosen from within the nucleus. The open nucleus system may also be thought of as a means of increasing genetic variance in a population (due to lower inbreeding and higher selection intensity) over both nucleus and base, and making of that extra genetic variance by selecting base-born females to be used in the nucleus. Dispersed or pre-nuclei have been recommended to avert the risks associated with concentrating of stock in one place and to increase on the nucleus size (HODGES, 1990b). In a study conducted by KASONTA (1990) on the Mpwapwa cattle Open Nucleus Breeding Scheme (ONBS) in Tanzania, they were found to be of great use.

The publication of NICHOLAS and SMITH (1983) about the potential which ONBS in combination with Multiple Ovulation and Embryo Transfer (MOET) could offer, generated a lot of interest, and many geneticist thought that such schemes would offer a solution to animal breeding in developing countries. ONBS was considered to be simpler than the conventional methods which required mass field recording. Thereafter, FAO included it among its main priorities in the field of livestock improvement in developing countries. Numerous meetings, discussions, and courses were held. FAO went further and instituted ONBS for Awassi sheep in Turkey, Syria, Iraq and Jordan (JASIOROWSKI, 1990).

BONDOC and SMITH (1993a) propose a local testing and selection programme in nucleus breeding units to improve genetically the local dairy cattle populations (indigenous, adapted exotic, composite or stabilized crossbreds) in smallholder production systems of developing countries. It seems to be the only possibility if an active breeding population hardly exists and farms are too small for selection within the herd (VALLE ZÁRATE, 1996). WOLLNY (1995) is of the opinion that simple nucleus schemes could function well, if the participation and integration of farmers or villages is ensured. These may be used to offset lack of money, expertise, and the infrastructure required for operating an efficient improvement programme based on AI and field milk recording (BREM, 1986). Additionally, they provide an opportunity to record information on more traits than is possible in a decentralized progeny testing scheme (REGE, 1995). Hodges (1990b) mentions other advantages of ONBS which include:

Genetic lift in establishing the unit
Faster rates of genetic changes
Control over husbandry and testing
More effective selection is possible for economic merit
Concentration of breeding resources
Possible use of expensive technologies
Economic benefits obtained sooner
Low cost on a national scale
Separate nucleus units for different sets of breeding objectives/environments

Studies of ONBS under tropical conditions show substantial genetic gain with their use. (KASONTA, J.S.; 1990; KAHI, 2004b; SYRSTAD and RUANE, 1998). HODGES (1990b) outlined the principles that could be applied when establishing ONBS in developing countries.

Screening stock for the nucleus

Elite herds are established through screening the population for outstanding individuals. Screening can be viewed as a two-step selection programme, divided into a foundation selection programme and a continuation selection programme (GEARHEART et al. 1989). The foundation selection programme involves the initial screening of high producing animals to form the nucleus herd. The continuation selection programme involves selection in the nucleus and base population (in case of open nucleus). Some information is generally available to select better animals even at the beginning of the programme. (WELLER, 1994). In case of an unrecorded base population, a common feature in most developing countries, females could be screened through a simple recording system introduced temporarily or permanently in the field or by relying upon the farmer's knowledge of the animals. GALLOWAY (2003) suggests the use of a likeability score to obtain information necessary for screening. Farmers could be asked to rank cows on the basis of likeability as in the example below:

5 = Excellent animal; liked in all aspects

4 = Very good animal; likable with respect to most characteristics

3 = Average animal

2 = Below average but acceptable

1 = Not a good animal; not liked at all

This would be a useful guide to cows and bulls whose daughters were best fulfilling the farmers' needs. For dairy breeds likeability would include milk production, temperament and resistance to disease. In beef breeds it could include calving ease, weight gains and fertility.

JASIOROWSKI (1990), DIOP (1993) and YAPI-GNAORÉ et al. (1997) give detailed accounts on how they screened stock, amidst lack of records, for the nuclei in the Middle East for the Awassi sheep, N'dama cattle in Senegal and Djallonké sheep breed in Ivory Coast, respectively.

Shortcomings of Nucleus schemes

Although such schemes seem to be the best option, they are being advocated for without reflecting about their pertinence, expenses, sustainability and the possible genotype x environment interactions (ZUMBACH and PETERS, 2002). In developing countries, differences between nucleus breeding units, characterised by high level production environments in the elite/nucleus herd, and commercial base herds, usually in marginal environments, could be very large; thus, leading genotype by environment interaction (G x E) to become a critical issue (BONDOC and SMITH, 1993b). According to FALCONER (1989) a G x E interaction can be expressed as the genetic correlation between the genotypic merit of an animal in different environments. It may be expected where considerable variation exists within genotype, within environment, or both (BONDOC and SMITH 1993b). In the semi-arid and arid climatic zones of Southern Africa selection within the less favourable environment, even taking into account reduced rates of response to selection especially for traits of lower heritability might be more appropriate than selection conducted in a non-representative environment (WOLLNY, 1995).

HODGES (1990b) mentions the reluctance of farmers to part with their best animals as an old problem for ONBS. One of the problems anticipated during the establishment of a nucleus of trypanotolerant N'Dama cattle in the republic of Guinea was convincing the Fulani herdsmen to sell or lease their best cows to the project (DIOP, 1993). To the often raised issue of inbreeding, SYRSTAD and RUANE (1998) assert that accumulation of inbreeding in the nucleus herd should not be a major problem as long as it can continuously be monitored and animals from outside the herd introduced. HODGES (1990b) mentions other shorting comings which include: the risk of concentrating stock and resources in one unit and that funds are needed to set up and operate the schemes.

2.5 Modelling/Simulation methodologies

WOLLNY (1995) has stressed the necessity to conduct a detailed analysis of the predicted genetic and economic response before investments into costly strategies are made. The biological efficiency of breeding strategies may increase from a simple mass selection programme based on individual culling to various AI programmes including progeny testing and multiple ovulation and embryo transfer (MOET) schemes. Predictions can be done by use of computer simulation or numerical analysis of models that describe the system in which the intervention is to be done. Models are abstract, simplified representations of reality that are valuable in taking an idea that might have been expressed verbally and making it more explicit. In other words, a model is an equation or a set of equations that represent the behavior of a system. Modelling is also referred to as "systems analysis". Computer simulation makes use of models to imitate real life through exploring interactions between the complex multidisciplinary components of a system or predict the behavior of a physical system under a variety of operating conditions. Models may be deterministic or stochastic (probabilistic).

2.5.1 Deterministic modelling

In deterministic models outcomes or results are precisely defined, fixed and reproducible. For example, a model that uses a certain number of input parameters and a few equations that uses those inputs to give you a set of outputs (or response variables) will always give you the same results no matter how many times you re-calculate. However, when there is a change in inputs the results will also be different. Populations, in deterministic simulation, are described in terms of the means and variances (and sometimes higher order moments) of each group of animals in the population. One difficulty with this type of modelling is that it requires that all processes such as change in mean and variance of phenotypes, genotypes and selection criteria for all groups of animals, and all traits must be describable in terms of algebraic functions. In many situations these functions can become complex or are not known. These models are appropriate when large numbers of individuals of a species are involved.

2.5.2 Stochastic (Monte Carlo) modelling

Conversely, in a stochastic model different outcomes can result from the same initial conditions. These models depend on relatively simple rules which involve variability due to unknown random factors like, for example, inheritance from one generation to the next, along with description of the criteria on which all animals will be selected for breeding. Each single run of the simulation gives a different realisation from the model, a reflection of random sampling events. This allows variance of response to be estimated. Therefore, it is necessary to carry out repeated simulations and then look at the distribution of results to get a picture of the central tendency, the dispersion, and outliers. Because each animal in the population is individually identified, stochastic programmes can take up large amounts of storage space and involve a very large number of mathematical operations for every run. This combined with the need to replicate, means that stochastic programmes take much longer to run than deterministic programmes. They are usually used where either the number of individuals is small or where there is reason to expect random events to have an important influence on the behaviour of the system. Stochastic modelling or simulation is also known as Monte Carlo simulation. A Monte Carlo method is a technique that involves using random numbers and probability to solve problems. The term Monte Carlo Method was coined by S. Ulam and Nicholas Metropolis in reference to games of chance, a popular attraction in Monte Carlo, Monaco.

The 'art' in building a good model is to capture the essential details of the system, without burdening the model with non-essential details. A simulation can typically involve over 10,000 evaluations of the model, a task which in the past was only practical using sophiscated computers and programmes (METROPOLIS and ULAM, 1949; GIBSON, 1992 FRANCE and THORNLEY, 1984; LINDSEY, 1997; HOFFMAN, 1998; WITTWER, 2004).

2.6 ZPLAN

ZPLAN is a computer programme that uses deterministic simulation to predict responses to selection in genetical and monetary terms. It was developed owing to a need for a comprehensive methodology to evaluate both the genetic and economic efficiency of selection strategies, and it is as such designed to optimize selection strategies in livestock improvement programmes. It can be applied to straight- or cross- breeding programmes and allows several tiers in the scheme such as nucleus, multiplier and production levels to be modelled. Using the gene flow and selection index procedure, the programme calculates a number of criteria such as genetic gain for the breeding objective, genetic gain for single traits and return on investment adjusted for costs, that is, profit. (NITTER and GRASER, 1994; NITTER et al., 2000).

The programme was first written by KARRAS in 1984 basing on a thesis of NIEBEL (1974) and the gene flow method described by MCCLINTOCK and CUNNINGHAM (1974), HILL (1974), ELSEN and MOCQUOT (1974), and BRASCAMP (1978). It was developed further by NIEBEL as described in NIEBEL and FEWSON (1988) and documented in KARRAS et al. (1997). The present version contains changes of NIEBEL's extension such as the inclusion of maternal effects, changes in the construction of the gene flow matrix to enable selection of lines in crossbreeding schemes, a Cholesky decomposion of the correlation matrix and modifications to the format of outputs. It is written in FORTRAN 77 for a DOS environment, thus requiring the user to have basic knowledge in FORTRAN. ZPLAN requires that the breeding objective is formally defined by specification of both the traits to be improved and their (undiscounted) economic values. Only one round of selection is considered. A matrix of all traits with their phenotypic standard deviations, phenotypic and genetic correlations and heritabilities has to be provided. Selection groups have to be defined which are specific for their information sources and selection intensities. In order for ZPLAN to be able to assess the return on investment, the number of standard discounted expressions is required. This is got using the gene flow procedure.

The expressions are specific for each selection group and for each type of trait and depend on the user's parameters for the design of the transmission matrix, on the discount rate and on the time of investment. An approximate method is used to consider selection groups with a two-stage selection. The total return is calculated as the sum of returns for all traits in all selection groups in all tiers, each obtained by the product of its genetic superiority with its standard discounted expressions and its undiscounted economic value. Fixed and variable cost parameters are used to get the overall profit for one round of selection by subtracting overall costs from the overall return (NITTER and GRASER, 1994; NITTER et al., 2000).

Its advantages include being fast, flexible, and multi-trait modelling allows inclusion of returns and costs over a given time horizon. Its limitations include the following: lack of accounting for reduced genetic variance due to selection and inbreeding; a bias may occur due to correlations between estimated breeding values when family information dominates; it considers a closed population where returns from external sales of breeding products in a competitive market are not taken into account; the requirement of a basic knowledge in FORTRAN makes it user-unfriendly in comparison to other Windows based programmes like SelAction, and finally a deterministic programme cannot adequately consider the variance of responses such as is with stochastic simulation (DEKKERS and SHOOK, 1990a; NITTER and GRASER, 1994; NITTER et al., 2000; WILLAM, 2004).

2.6.1 Traits to include in the selection index

It is important to distinguish between traits in the breeding objective and traits in the selection criterion. The traits in the breeding objective determine profit but may not be the same as those traits that are actually recorded in practice (selection criteria) and used to make selection decisions. In theory, the decision about traits to be included in the aggregate genotype should only be driven by their economic importance under future conditions of production (FEWSON, 1993). Three basic conditions have to be met to in order to include a trait in the selection index. First, the economic impact of the trait has to be sufficient, second, information about the trait of interest on the selection candidates or their relatives has to be available and third, the genetic variation of the trait in the population should be available or could be determined (THALLER, 1998). Recordability is not required as long as correlated traits, which are more easily recorded, are available (SÖLKNER and FUERST, 2002).

In a harsh environment realised response in improvement schemes may be well below expectations if important traits are not included in the aggregate genotype (WOLLNY 1995). GALLOWAY (2003) suggests that selection of bulls, or cows for genetic improvement under African conditions should be based on fertility and production performance within African environments. Animals should be able to reproduce and produce efficiently. The first requirement is that the AI sires should be born without assistance. Their daughters should have regular and normal calvings. Cows for contract matings should have a record of regular and normal calving. Function in the herd is first based on production and freedom from disease, then on conformation and other traits.

Restricted index

The usual reason for using a restricted index is that the breeder believes that a trait is at its optimum value and should not change. In the index, such a trait is constrained to zero genetic change. Although a trait may be at its optimum value, it does not follow that it should be kept at that value. It is possible that maintaining a trait at its optimum value reduces the possible genetic improvement in other traits to such an extent that greater overall gain might be obtained by allowing the trait to move from the optimum, since the loss from this change would be less than the extra gain in other traits. The effect of the restriction on overall response should be evaluated before adopting a restricted index (BARWICK, 1993; GIBSON, 1992).

2.6.2 Gene flow

With overlapping generations, as is the case in livestock improvement programmes, the genetic improvement from any round of selection is not passed through the population immediately. HILL (1974) developed a matrix methodology which allows the following of "genes" through a population and the deterministic calculation of expected genetic gain. The first requirement in this method is the development of a P-matrix which describes the transmission of genes and ageing in all tiers of a breeding and production population (GRASER, 1993). WELLER (1994) points out four paths of inheritance or transmission of genes in vertebrates: sires of one generation to sires of the next, dams to dams, dams to sires, and sires to dams.

2.6.3 Economic aspects

Although inclusion of economic aspects into breeding objectives is crucial in determining the profitability of breeding programmes, it is not long ago that they were seriously considered and incorporated in the objectives. This can partly be explained to the basic lackluster or minimal training of breeders in economics and to the difficulties and uncertainties of predicting future production and economic conditions which will exist for progeny generations (CHARFEDDINE, 2000).

Economic aspects of breeding objectives, that is, efficiency of production or profit consist of either increasing returns or decreasing costs of production (WELLER, 1994). The main costs of animal production for most species will depend on three main functions: I) female production ii) reproduction iii) growth of young. For nearly all economically important species, male production cost is negligible (DICKERSON, 1970), and the major production costs are feed-related (WELLER, 1994).

The different costs and returns in animal breeding procedures are realized at different times, and with differing probabilities. Thus, factors that affect costs and returns over the long-term must be considered in the economic evaluation of genetic differences. These include among others, interest rate, investment period, semen production and storage, and recoding costs (WELLER, 2004).

Most studies that have discounted costs and returns in animal breeding programmes use real rather than nominal interest rates which range between 5 to 15% (Weller, 2004).

Since breeding is generally long term in nature, and gains are perpetual and cumulative, the question of how far into the future one should consider returns is important. These programmes are generally considered in terms of a "profit horizon", that is, all returns occuring after the profit horizon, are considered to have no value or to have a present value of zero. Thus, programmes are generally analyzed in terms of ten to twenty year profit horizon (Weller, 1994).

Rather than keep live animals it is possible to keep breeding stock in form of frozen semen or embryos. This saves the costs involved in keeping non-productive animals, but entails additional costs for the production and preservation of the "seed" (Weller, 1994).

In breeding programmes for large animals, recording traits is often a major cost. However, many costs that are considered part of breeding programmes accrue in any event, or else generate information which has value beyond the breeding programme. For example information for milk recording of individual cows is useful to the producer for other farm management decisions, hence actual breeding costs are lower than is usually presumed.

2.6.3.1 Deriving economic weights or values for traits

Index selection requires that economic values or weights of traits are known. The economic value of a trait expresses to what extent the economic efficiency of production is improved at the moment of expression of one unit of genetic superiority for that trait (GROEN, 1989). In other words, the marginal profit which one gets from the difference between marginal return and marginal costs (Fewson, 1993). Multiplying the economic value by the cumulative discounted expression gives the discounted economic value (CHARFEDDINE, 2000). Deriving these values is not an easy task because the best method from a theoretical point of view is not necessarily the method that is most practical to implement (GROEN, 1997). The values can be derived using either objective or non-objective methods.

Modelling or systems analysis is the principal tool used in objective methods. Two approaches can be distinguished under this method, namely, positive approach or data evaluation and normative approach or data simulation (JAMES and ELLIS, 1979). Data evaluation uses observed economic and technical data to derive the economic importance of traits. Its major drawback lies in its use of historical prices, while breeding is future oriented. For data simulation, on the other hand, economic values are derived by studying their reaction to a change in production factors related to the genetic merit of a specific animal trait, without changing other traits. The terms “profit function” and “bio-economic model” are used in simulation. There are no major differences between the two. A profit function is a single equation while a bio-economic one is a multi-equation one (CHARFEDDINE, 2000). Using either partial budgeting or partial differentiation economic values are derived from profit equations (KAHI, 2004a)

Non-objective methods, in contrast to objective ones, do not derive economic values by direct calculation of influences of improvement of a trait on the increase in efficiency of the production system. Economic values are assigned in order to achieve a desired or restricted amount of genetic gain for some traits. They are of use when there is insufficient knowledge to model relevant aspects. (KEMPTHORNE and NORDSKOG, 1959; BRASCAMP, 1984). These methods are useful in commercial pig and poultry breeding systems.

A profit function is a procedure or rule that describes the change in net economic returns as a function of a series of physical, biological, and economic parameters (GIBSON, 1992). The use of the profit function in animal breeding is principally to define economic weights of traits contributing to economic genetic improvement. Therefore, profit should be defined as a function of additive genetic values of aggregate genotype traits ($P = f [g_1, g_2, \ldots, g_n]$). In some cases, for simplicity, and because it does not affect results, other inputs such as management contributions and economic parameters are considered as fixed.

For the profit equation to be useful, the following minimum criteria should be met:

(i) Change in profit should be a function of genetic changes not other changes of the phenotype.

(ii) The management conditions assumed should be relevant to the population in which genetic change is to be used at the time genetic change is used.

(iii) Economic parameters should reflect the marketing and management system in which genetic improvement is to be used at the time genetic improvement is used.

CHARFEDDINE (2000) and WELLER (1994) raise three questions that need to be addressed with the use of profit equations:

(i) Should profit be viewed from the perspective of the farmer, the industry or the consumer?

(ii) Should profit be considered or expressed per enterprise (farm), per production unit (animal), per unit of product (e.g. kg of milk or meat) or for the entire national economy. Different results can be obtained depending on the unit selected as the basis of evaluation.

(iii) Should the objective be:

- to maximize profit $P = R - C$

- to maximize return on investment $\Phi = R/C$
- to minimize cost per unit production $Q = C/R$

where, R stands for return, and C stands for cost.

GROEN et al. (1997) is of the view that regardless of who is to invest in the breeding progamme, derivation of economic values should be performed at farm level, where the profit is expressed per animal. In animal breeding the objective is usually maximizing profit and return on investment (GROEN and RUYTER, 1990).

Traits in the profit function should relate as directly as possible to sources of income and costs (HARRIS and NEWMAN, 1994). In dairy cattle, traits influencing the efficiency of production are roughly characterized as production traits (milk and beef) and functional traits. The term functional trait is used to summarize those characters of an animal which increase efficiency not by higher output of products but by reduced costs of input, for example fertility and health traits (GROEN et al., 1997).

In more practical terms, estimation of economic values requires a description of the production system, sources of income and expense, and the relationship between them and with the traits included in the breeding goal. Costs should be defined as fixed and variable costs. Fixed costs are those that the producer judges to have no change with the level of production of the flock or herd. By contrast, other expenses are assumed to vary with the level of production of the flock or herd, and are thus called variable costs (CHARFEDDINE, 2000).

Standardizing economic values

In order to be able to compare the relative economic importance of traits, their economic values are expressed in terms of genetic standard deviations. The use of genetic standard deviation suggests that the weights are proportional to selection response because the heritabilities of the traits are taken into account (PÄRNA, 2003). Ratios among economic weights in the selection index are more important than their actual values (HECKENBERGER, 1991).

2.6.4 Evaluation of schemes

To evaluate different designs for breeding programmes or to judge the value of a single selection decision for a breeding or production unit one has to know when and how often returns can be realised from this decision. Different traits are expressed at different times and with different frequencies (GRASER, 1993; GIBSON, 1992). This fact has to be accounted for in returns and as such MCCLINTOCK and CUNNINGHAM (1974) introduced "discounted expression" as a means to calculate these returns. Since these returns are made in the future, their present day values i.e., discounted values have to be calculated. Discounting deals with the economic investment principle that money today is worth more than money tomorrow (GIBSON, 1992).

2.7 Herd/Milk recording

Ideally animal recording schemes should be in place to allow for the selection of sires used in artificial insemination (GALLOWAY et al., 2003). In developing countries, unfortunately, data recording in the sense used by animal breeders in developed countries is often missing (SÖLKNER et al., 1997). Recording is possible provided the farmer as the recorder or supplier of the data is highly motivated, convinced of the benefit to himself, or if regulations exist that can enforce recording, e.g. as part of a credit contract (NAKIMBUGWE, 1998). Participating parties in a recording scheme, e.g., farm advisors, service co-ordinators or research workers should as well see their direct benefit as the main purpose no matter how varied these benefits are (JAKOB, 1991).

Countries should endeavor to put in place uniform data capturing formats to ease on processing the data e.g. the Herd/Milk recording scheme format in Uganda (NAKIMBUGWE, 2004). NYAKALO et al. (1992) mention lack of an established format for data collection to be responsible for the insufficient data including the most crucial ones on calving rates, weaning rates/weights, conception rates, mortality rates etc., at government or government affiliated parastatal farms in Tanzania. This, as well, applies to the only two AI centres in the country. As a rule, data should only be recorded for a clear, predefined purpose and the recording should be as simple as possible. The desired answer or use determines which data has to be collected. There is no such justification as recording a set of livestock production data with a view that they might be useful for future analysis (JAKOB, 1991).

The original accuracy and integrity of information, with its important source being the producers, is decisive in making right decisions. FRIES (1994) describes the situation in Brazil concerning unrealistic rules about animal breeding which have forced farmers to manipulate herd records. Decisions based on such manipulated records are of little use. In view of the limited resources, WOLLNY (1995) strongly recommends networking for Southern African countries to enable them to utilise facilities for testing purposes and data analyses together.

2.8 Use of biotechnology in animal breeding programmes

The reproductive rate of breeding animals is one of the most important limiting factors in a breeding programme. Therefore, technology to increase reproductive rates is a critical investment in these programmes. However, there is a need to find the right balance between what is possible from a technological point of view and what is accepted by the decision makers and users within the socio-economic context of a production system (VAN DER WERF, 2004). MASTERS (2004) asserts that these technologies have created new options that never existed before. For example, with better reproduction technology, e.g, MOET, to improve reproductive rates in the nucleus, a lower proportion of base-born females required to be selected as nucleus dams is expected (PARKER and RAE 1982). Though such an investment increases the rate of genetic advance, it also increases the cost of breeding programmes (WELLER, 1994). The role of biotechnology in addressing the livestock production constraints of small scale or resource poor farmers is well recognized. Regrettably, there are hardly any success stories of its application in Africa (REGE, 1995).

2.8.1 Artificial insemination (AI)

AI is one of the most widely available technologies in developing countries (REGE, 1995). DE HAAN (2004) notes that the small herd size of the poor doesn't allow the maintaining of sires at each farm, and therefore, artificial insemination is conceptually the main channel to reach these people with improved genetics. BANE et al. (1977) observe that its impact on cattle development is closely linked to the simultaneous introduction of reasonable standards of animal nutrition, disease control, and of infrastructure. Unfortunately, this has not always been recognized, and in some cases AI has been adopted purely as a technical method of getting cows in-calf thus leading to its failure.

Results of a Joint FAO/IAEA research in 14 tropical and subtropical countries showed that nearly half of failed inseminations were associated with factors of management deficiency or human error on the farm or in the AI service, thus adversely affecting the reproductive performance of the herds and leading to low efficiency of AI services (GARCÍA, et al., 2001). Before AI services are introduced to a farm, there needs to be a reasonable standard of management and hygiene coupled with an understanding of the importance of heat detection and pregnancy diagnosis (GALLOWAY, 2003).

It is also important to ensure that the service is reliable and that it results in acceptable conception rates. The introduction of AI by over-enthusiastic individuals who underestimate the resource requirements of such a service can do more harm than good, because once the farmers lose their confidence in AI, which is inevitable in such circumstances, it is difficult to regain it (BANE et al., 1977). Most AI services in Africa (WALSHE et al., 1991) have been heavily influenced by donors and use sophisticated liquid nitrogen technology and equipment. When donor funding ends, liquid nitrogen is frequently not available, the equipment cannot be maintained, and there is inadequate foreign exchange to purchase the spare parts, and chemicals and materials that are not available locally.

VAN DER WERF (2004) cautions that as new technologies in animal breeding allow faster genetic change, long term issues such as inbreeding and maintenance of genetic variation become important. Because of such issues, recording especially at farm level becomes very necessary (BANE et al., 1977). The joint FAO/IAEA Division has developed a computer database named Artificial Insemination Database Application (AIDA) which is being adapted for routine use in AI services in Asia and Africa (GALLOWAY, 2003).

2.8.2 Milk progesterone assays

Poor heat detection is one of the major set backs in AI programmes (BANE et al., 1977). Although poor management is responsible for problems associated with heat detection, heat stress aggravates it by shortening the duration and intensity of oestrus (GANGWAR et al., 1965). RHODES (2005) recommends the use of milk progesterone assays to augment oestrus detection. The measurement of progesterone using radioimmunoassay (RIA) in a series of milk samples (or blood in the case dairy heifers) can serve as a useful monitoring tool to assist in improving reproductive management by farmers as well as increase the effectiveness of AI programmes (GARCÍA, et al., 2001; WILLIAMS et al., 1992; WILLIAMS et al., 1993).