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**DEVELOPMENT OF A BREEDING OBJECTIVE FOR BEEF CATTLE  
IN GHANA**

**A thesis presented in partial fulfilment  
of the requirements for the degree of  
Master of Agricultural Science in  
Animal Science at**

**Massey University**

**SEREKYE YAW ANNOR**

**1996**

**This thesis is dedicated to my late elder Sister,**

**Margaret Akua Addae Nsiah**

**who died on 21st. May, 1995, in the early stages of the thesis preparation**

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## ABSTRACT

Beef contributes slightly more than 30 % to Ghana's meat requirements. About 57 % of beef consumed annually is imported, with only 43 % being produced locally. Although Ghana has the potential for increased beef production, it has not achieved self-sufficiency in production. Constraints in animal production indicate that this impasse has resulted from lack of simple livestock production policy in the past. A policy on livestock production and development was passed recently, and the livestock industries in Ghana are undergoing major restructuring. The first requirement of such a programme which requires much research effort and planning is to identify the planned production, processing and marketing system(s). Using this information, the economic merit for various traits can be defined and subsequently the breeding objective for the individual livestock species.

The objectives of this work were to study the marketing and production systems of the beef cattle industry in Ghana and to calculate the economic values of traits of economic importance in N'dama and Zebu cattle. The results were used to draw guidelines needed for the genetic improvement of beef cattle in Ghana.

The marketing and production systems were studied using information in the literature. A computer model simulating life cycle production of breeding cow and growth performance of her offspring was developed to estimate economic values of survival, reproduction and growth performance traits, and food intake. Economic values were calculated based on difference between income and expense (profit) and with discount rates of 0, 10 and 20 %. They were defined as the marginal profit per cow per year resulting from 1 % change in the average level of each trait, whilst holding the level of all other traits constant. Income was partitioned between 3 year old bullocks and surplus heifers, and cull cow. Expenses included food, husbandry and marketing costs; these were calculated for all ages and class of stock.

The study of the production systems revealed that local cattle breeds are late maturing, with relatively small body size, poor reproductive and milk production capacities, but

are well adapted to their environment. On the other hand, Zebu have poor reproductive performance with large body size, medium milk yield and a relatively low adaptation. Trypanosomiasis was identified to be the most important environmental factor affecting the survival of cattle. Profit per cow per year of N'dama was on average 17 % more than that of the Zebu. Profit per cow per year almost doubled in both breeds, when food intake was removed from the objective, but the difference between the two reduced to only 7 % in favour of N'dama. Economic efficiency for N'dama and Zebu production systems were 31 and 24 % respectively. In general, survival traits had the highest economic value, followed by reproduction, growth rate and food intake, respectively. Predicted economic values for individual traits decreased with increasing discount rates. This was much more pronounced in reproductive traits than in all other traits. Removal of food intake from the objective tended to slightly increase the relative economic importance of reproductive traits and survival from birth to weaning, but trends in economic values almost remained the same.

It was concluded that smallholder cattle owners should be encouraged to use local breeds of cattle, whilst efforts are made to breed trypanotolerant larger cattle breeds.

**Keywords:** Beef cattle, Ghana, marketing and production systems, breeding objective, economic values, survival, reproduction, growth, food intake

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## CHAPTER 1

### INTRODUCTION

The share of Ghana's agriculture (defined to include crops, livestock, forestry, and fisheries) in the national gross domestic product (GDP) has varied from 44 % in 1965 to 49 % in 1992 (World Bank, 1994). The contribution of livestock to the agricultural GDP is estimated at 9, or 4 % of the national GDP. The contribution of cattle, small ruminants (sheep and goats), poultry and the pig industries to the total domestic meat supply in Ghana is estimated at about 38, 20, 25, and 17 %, respectively (FAO, 1993b).

The total domestic meat supply is inadequate to feed the ever growing population, although there have been major increases in the number of all livestock species in the last 30 years. Indeed, the average Ghanaian diet is deficient in protein (FAO, 1993a). Current projections indicate that the population of Ghana which presently stands at about 16 million is expected to reach 20 and 36 million by the years 2000 and 2025 respectively (World Bank, 1994). Although the annual population growth rate is about 3.2 %, the percentage of economically active people in agriculture continues to decline (FAO, 1965-1993a). This is the direct result of rural-urban migration (Kurian, 1992; Alpine and Pickett, 1993), which is an indication that more meat would be required in the urban centres in the near future, a situation which will worsen the existing protein deficiency problem, unless the productivity of those remaining in rural areas can be markedly improved.

In order to reverse the deterioration in the national diet, Ghana imports meat and live animals from neighbouring countries such as Mali, Burkina Faso, Guinea, and Niger, in addition to the importation of dairy products, eggs, and fish and fishery products. These imports have constituted about 36 % of the average annual cost of all foods imported into Ghana (FAO, 1965-1993b). Beef imports alone constitute about 82 % of the total value of imported fresh and frozen meat. When imported live cattle is included into this amount, then, Ghana produces only 43 % of its total beef, with the rest being imported. Although, the importation of meat and meat products, and live animals continue to increase with the increasing population, there is still less meat available per capita (FAO,

1993a). Meat consumption in Ghana is limited by high prices and supply is always considerably smaller than demand. Given the anticipated demand for beef and the inadequacy of present production systems to meet this demand, coupled with the scarcity of foreign exchange, immediate steps must be taken if this trend is to be reversed.

The contribution of the non-ruminants (pigs and poultry) have made a significant impact on the domestic meat supply in Ghana over the last 30 years, due mainly to developments in technology and the importation of new breeds. Further developments in these industries require a major expansion in numbers but this is being checked by the restricted availability of grain and fish in excess of human requirements. The ruminant livestock industries in Ghana are the least developed within the livestock sub-sector of the private sector. The contribution of livestock to the agricultural GDP is somewhat low, when the enormous potential of ruminant livestock production in Ghana are enumerated (ISNAR, 1991). One of the major potentialities is the vast quantities of natural grazing lands, which constitutes about 70 % of the total land area of Ghana, and covering the entire north and the coastal grassland area of the south (Alhassan and Barnes, 1993). Despite this advantage, the ruminant livestock industries have many problems of which the most important deserve to be mentioned.

The ruminant livestock population density in Ghana has been low, given the vast areas of natural grazing grasslands. There have never been any concerted efforts made by both farmers and government to improve the productivity of the natural grasslands. In addition, more than two-thirds of the country's ruminant livestock is located in the arid north, which faces severe water and feed shortages during the long dry season, whilst the remainder is found in the south, where the incidence of trypanosomiasis is very prevalent. In the south, great quantities of high quality forage are produced throughout the year, because of the favourable climatic conditions. Thus, ruminant livestock production in Ghana tends to be limited in the north by aridity and south by tsetse borne trypanosomiasis.

Although the local or traditional breeds of cattle in Ghana (N'dama and West African Shorthorn) are trypanotolerant, they are small in size, have low milk production and are

late maturing. In addition, they have older ages at first calving and long calving intervals. They are therefore considered by farmers to be unproductive. This has led to the importation of Zebu cattle from neighbouring countries, which are increasingly becoming popular with the smallholder livestock farmers mainly as a sire breed to improve the size and milk production of the local cattle. Although the Zebu is a fairly large animal, they are trypanosusceptible and have almost the same attributes as the local breeds, in respect to reproductive performance.

These problems have existed for the past 30 years because of the lack of a simple animal production policy in Ghana. Hitherto, there has never been any national breeding programme to improve the productivity of these animals, although some few government livestock breeding stations have existed for more than 20 years. There is no wonder most livestock farmers in the north still rear cattle for socio-religious reasons, and the entire ruminant livestock industry is unorganized and unstructured. However, most farmers in the south see livestock production as an economic venture.

The livestock production potential of Ghana, especially that of ruminant livestock was recognized by the government of Ghana in the early part of this decade (MTADP, 1990; ISNAR, 1991). As a result, a national livestock development policy has been developed, and a National Livestock Development Programme, jointly sponsored by the Government of Ghana and the World Bank, has been initiated (NLDP, 1991). Emphasis is being placed on the development of the ruminant industry, in view of the fact that it is the least developed within the private sector and also because ruminants do not compete with man for feed resources, notably grain. The objective is to improve the productivity of ruminant livestock through better animal health, nutrition and water supplies, and in the long term breed improvement. Priority is accorded to the breeding of beef cattle, because their current contribution to the meat supply (in both domestic and export markets) is far larger than the combined production of sheep and goats. The main objective of the cattle breeding programme is to develop cattle that are hardy and in particular trypanotolerant, but also have greater productive capabilities than the existing local breeds. Such a programme which is long-term requires much research effort and proper planning. Nevertheless, no breeding objectives have been defined for

any of the ruminant livestock industries. Further, there is even confusion among smallholder cattle farmers and scientist as to which breed of cattle to utilize.

There is a well-established series of logical steps to follow in designing animal breeding improvement programmes (Ponzoni, 1982; Harris *et al.*, 1984; Harris and Newman, 1994). The first step is to identify the planned production, processing and marketing system(s). Using this information, the economic merit for various traits can be defined and subsequently breeding objective for the individual livestock species. Choosing selection criteria and organizing logically based performance recording is difficult unless the traits that have to be improved have been identified and their relative economic importance have been established. An improper definition of breeding objective can also undermine the effectiveness of a breeding programme. The objectives of this work are therefore to:

- (1) study the production, processing and marketing system(s) of the beef cattle industry in Ghana,
- (2) calculate economic values of traits of economic importance in beef cattle, and
- (3) use the calculated economic values, in conjunction with the study of the production system, to evolve appropriate guidelines needed for improving the beef cattle industry in Southern Ghana.

## CHAPTER 2

### PRINCIPLES OF BREED IMPROVEMENT

#### 2.1 Beef cattle breeding programmes

There is a well-established series of logical steps to follow in designing animal breeding improvement programmes (Ponzoni, 1982; Harris *et al.*, 1984; Harris and Newman, 1994). The general structure of a breeding programme for all species of livestock can be described as follows:

- (1) Describe the production, processing and marketing system(s)
- (2) Formulate the objective of the system
- (3) Choose breeding system and breeds
- (4) Estimate selection parameters and economic weights
- (5) Design animal evaluation system
- (6) Develop selection criteria
- (7) Design matings for selected animals
- (8) Design system for expansion, and
- (9) Compare alternative combined programme.

Thus, the first step in the design of a breeding programme is to identify the planned production, processing and marketing system(s) and to define economic merit, which is the breeding objective.

A methodology has been defined for the development of breeding objectives in sheep (Ponzoni, 1986, 1988) and beef cattle (Ponzoni and Newman, 1989). The procedure is general for all livestock species and can be described in terms of the following four phases:

- (1) Specification of breeding, production, processing and marketing system,
- (2) Identification of sources of income and expense,
- (3) Determination of biological traits influencing income and expense and
- (4) Derivation of the economic value of each trait.

The establishment of breeding objectives should involve input from nucleus breeders,

commercial farmers, consumers, processors and retailers (Blair and Garrick, 1994), who together form what is known as "The Industry Structure".

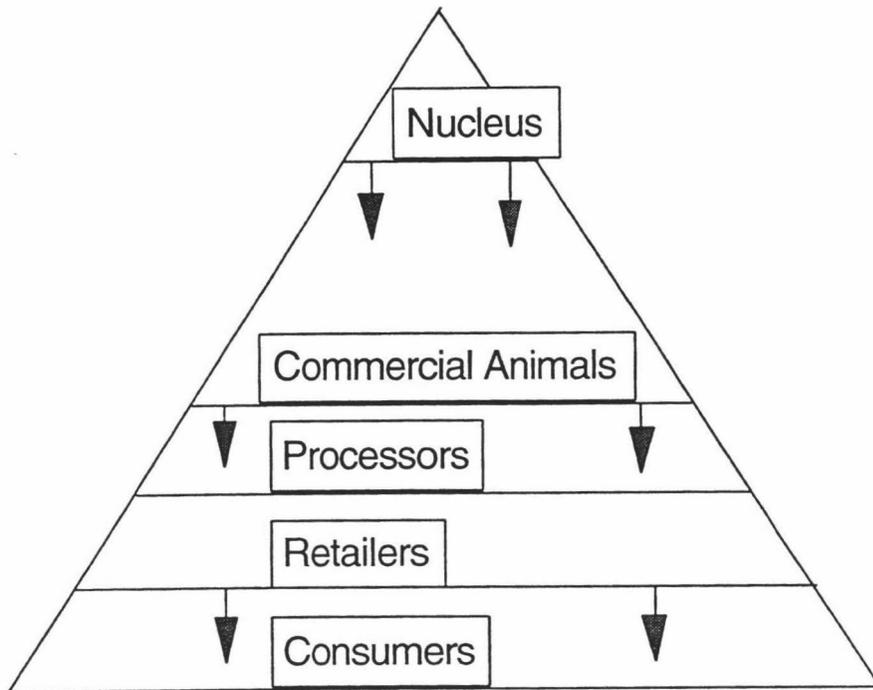
## 2.2 The industry structure

### 2.2.1 Definition of industry structure

A livestock industry consists of farming units which are typically structured in such a way that a small proportion form nucleus or seed-stock or stud units where selection within breed is undertaken. A higher proportion of animals are managed by farmers who run commercial units, and purchase animals (mainly sires) from stud breeders, thereby importing genetic change. This means that stud breeders obtain a significant proportion of their income from the sale of breeding stock (genotype), whereas for those in the commercial sector (farmers), their main source of income is from the sale of products (e.g. meat, milk, wool). Such a structure can be represented in pyramid form consisting of tiers, which should include not only the nucleus and commercial units, but processors, retailers and consumers (Fig. 2.1) (Harris *et al.*, 1984; Blair and Garrick, 1994). Improvement from genetic selection passes not only from the top tier to the commercial tier but also influences concerns of processing, retailing and consumption.

The importance of industry structure lies in its determination of the pattern of gene transmission through the population and the potential rate of genetic progress as well as difference in genetic merit (*genetic lag*) between nucleus stock and commercial animals (James, 1977; Garrick, 1993). It has also a considerable influence on the cost-effectiveness of applying genetic and reproductive technologies (e.g. artificial insemination, embryo transfer, and marker assisted selection).

Industry structures may consist of either simple isolated sub-populations or complex ones with downward flow of genes from nucleus units to commercial animals. Alternatively, genes may flow up the pyramid from the commercial tier into the nucleus herds/flocks. These variations lead to different types of structures, which will be described below in more detail.



**Fig. 2.1:** A pyramid livestock industry structure in which genetic improvements should flow from the top to the base.

### 2.2.2 *Unstructured breeding industries*

An unstructured livestock industry is the one which consists of a number of independent or closed flocks/herds, each of them having its own selection objective, and developing its own rate of genetic progress in the traits that each farmer/breeder considers important. Most new livestock industries normally go through this phase where each flock/herd breed all of their own male and female replacements.

The rates of genetic gain achieved will vary from substantial gains made by farmers operating an effective selection programme to zero for a farmer not imposing any selection pressure or, sometimes even genetic losses (Garrick, 1993). Genetic changes may take place in a closed herd/flock as a result of random genetic drift, natural

selection, or artificial selection. The expression for the estimated annual rate of genetic improvement for a known selection method was given first by Dickerson and Hazel (1944) in their paper on progeny testing. The key equation is given by:

$$\Delta G = \frac{r_{Am, \hat{Am}} i_m \sigma_A + r_{Af, \hat{Af}} i_f \sigma_A}{L_m + L_f} \dots\dots\dots (2.1)$$

where,

$\Delta G$  is the annual rate of genetic gain,  $i_m$ ,  $i_f$  are the intensities of selection for sires and dams respectively,  $r_{Am, \hat{Am}}$ ,  $r_{Af, \hat{Af}}$  are measures of accuracy of ranking (correlations between true and predicted breeding values for sires and dams),  $L_m$ ,  $L_f$  are the generation intervals of sires and dams, and  $\sigma_A$  is the genetic standard deviation of the selected trait. Garrick (1993) noted that the benefits from genetic improvement in an unstructured industry, can only be obtained from extra production within the selected flock/herd. This limits the opportunity to apply high cost technologies.

Most livestock industries in developing countries fall into this category of industry structure (Jasiorowski, 1991; Smith, 1988). This is one of the main reasons why little or no genetic progress is being made in these countries and application of new technologies (artificial insemination and to some extent, embryo transfer) have typically failed in these countries. This is because most developing countries did, and still do, not have adequate infrastructure and means to organize, on a sufficient scale, reliable productivity recording. For these reasons, substantial international assistance, provided in the past to some of these countries for building modern selection programmes to improve indigenous livestock breeds, has in general failed and proved not sustainable (Brumby, 1973; Jasiorowski, 1973, 1991).

### 2.2.3 Closed nucleus structure

A nucleus breeding system is said to be closed if replacement stock for the nucleus herd/flock are bred entirely from within the nucleus and genes (sires) can only move in one direction, i.e. from the nucleus into the commercial layer (Roden, 1994). Such a system will consist of populations either divided into two tiers: the nucleus composed of genetically elite individuals, and the commercial, which forms the majority of the population, or three tiers: in which case there is a third tier (known as the *multiplier*) formed between the elite nucleus breeders and the commercial layer. The primary function of the multiplier is to expand the genetic material of the elite nucleus into greater number of animals to pass onto the commercial tier. Thus, the multiplier is a replicate of the original closed nucleus which develops into two tiers: one tier being the true nucleus whilst the other tier involves satellites of the nucleus.

The closed nucleus structure is one of the most commonly encountered structures in countries where livestock production has passed through the unstructured phase. Usually, a registration barrier exists between either the nucleus and commercial layer (two-tiered) or between the multiplier and commercial layer (three-tiered). This barrier is normally under the control of breed societies and is primarily an attempt to maintain genetic purity in the nucleus tier. The beef cattle industry in New Zealand for example, would conform to a three-tier structure (Blair and Garrick, 1994). An estimate by these authors suggested that of the 1.098 million breeding cows in New Zealand, only approximately 70,000 (6.4 %) registered breeding cows would occur in the registered sector of the beef cattle industry, and these are required to produce an estimated 55,000 purebred bulls that are used each year. Under these circumstances, cattle in registered herds are separated from commercial beef cattle herds through the provision of registration barrier thereby preventing cattle from commercial herds entering the registered herds.

In some cases the registered herds may exist offshore (Garrick, 1993). This is seen in the New Zealand Angus breeding industry where some registered herds are located in the USA, suggesting that the New Zealand Angus sire breeding industry is currently

acting simply as multipliers. This is common in many other countries for pig, poultry and new dairy industries, i.e. genetic change is purchased from overseas and imported. However, those concerned with the importation of genetic change have to be aware of genotype by environment interactions. An interaction between the genotype and the environment means that genotypes respond differently in one environment than in another. The genotype by environment interactions may limit response to selection, because the ranking of a series of genotypes in one environment may be different from their ranking in other environments (Dickerson, 1962; Butler-Hogg and Cruickshank, 1989; Bondoc and Smith, 1993). Clearly, the problem is made more complex to the extent that the phenotypic ranking of a series of genotypes is altered by changes in the environment.

As has been described above, there is only one-way flow of genes within the pyramid, i.e. downwards from top to bottom. This means that the genetic progress made at the commercial level is primarily dictated by improvements that occur at the top of the pyramid. The difference in genetic potential (*genetic lag*) between the commercial and the nucleus tiers has been given by Garrick (1993). The genetic lag concept is visualized in Fig. 2.2. For a two-tiered structure, this is given by:

$$2 \times \text{generation interval in commercial tier} \times \text{annual rate of genetic gain} \dots \dots \dots (2.2)$$

This is to say that the commercial tier lags behind the nucleus tier by two generations. This lag increases to:

$$4 \times \text{generation interval in commercial tier} \times \text{annual rate of genetic gain} \dots \dots \dots (2.3)$$

in the three-tiered structure, since the major impact of this structure is that the commercial tier now lags behind the multiplier tier by twice the commercial tier generation interval and the multiplier tier lags behind the nucleus by twice the generation interval in the multiplier layer. However, in practice this is not the case because the multiplier buys above average sires from the nucleus breeder and also apply selection for female replacements, which reduces the lag. The lag, usually expressed

in years, is suggested to be about 10 years in the New Zealand beef cattle industry (Blair and Garrick, 1994). That is, the genetic merit of the commercial producers herd is twice the generation interval ( $2 \times 5$  years for beef cattle) behind that of the nucleus unit.

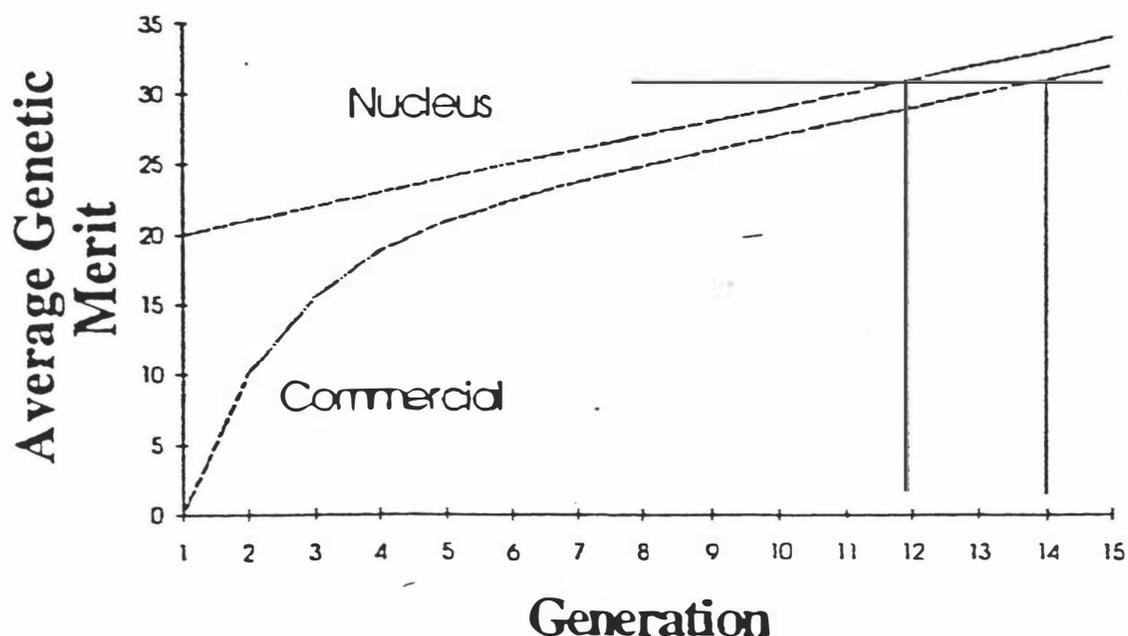


Fig. 2.2: Relationship between genetic gain in the nucleus and commercial tiers (From: Garrick, 1993).

The two most important factors that affect the size of the genetic lag are the age structure in the lower tiers, and the source and merit of sires and dams used in the lower tiers (Nicholas, 1987).

#### 2.2.4 Open nucleus breeding scheme

A nucleus is said to be open when replacement stock for the nucleus population are selected from both the nucleus and from the base, leading to a two-way flow of genes. Thus, animals are allowed to move in all directions between the nucleus, multiplier or commercial units. Most often, it will be females that are moved between tiers but on

occasions, exceptional sires may be moved from the commercial tier to the nucleus or multiplier or from multiplier to the nucleus. However, it should be recognized that movement of animals from commercial tier into the nucleus can only take place if adequate recording takes place in the former.

Garrick (1993) and Nicholas (1987) have given reasons for the movement of animals from bottom to top of the pyramid: (1) Mendelian sampling can generate offspring in the commercial tier that may be superior to the average of their parents and it would be worthwhile including such animals into the nucleus. (2) In selecting for lowly heritable traits, the lower response per generation will reduce the size of the lag between the nucleus and commercial tier and this may increase the benefit from continual screening of the commercial females into the nucleus. (3) Again, if selection objectives changes to favour a trait that has not undergone selection, or has been achieving little or no genetic change, then, it is possible that the commercial tier with greater proportion of animals will have majority of the elite animals. It would thus make good sense to transfer superior animals from lower tiers into a higher tier in order to increase the average genetic merit of the nucleus herd/flock.

There is evidence that the annual response to selection is increased, and that the rate of inbreeding in the nucleus is substantially reduced in an open nucleus breeding scheme (James, 1977). James (1977) showed that for a well-designed sheep or beef cattle open nucleus breeding scheme, response to selection could be increased by 10-15 %, and the rate of inbreeding could be halved, when compared with a closed nucleus scheme of the same size. However, the advantage of the open nucleus system is apparently reduced when the cost of running a selection nucleus is high relative to selection costs in the base population, or when female reproductive rate is high (Roden, 1994).

Presently, the Food and Agricultural Organization of the United Nations (FAO) is exploring the open nucleus breeding scheme as a new possibility of improving the organization of nucleus flocks and herds in developing countries (Jasiorowski, 1991; Smith, 1988). By this means, the local population is screened for outstanding females which are brought into the nucleus herd. This is in contrast to the closed system, where

no new females are brought into the nucleus. More recently, a breeding system that combines crossbreeding and selection of crossbred animals within open nucleus units (open nucleus crossbreeding system), has been suggested for cattle breeding in the tropics (Osorio, 1994). Combined with embryo transfer, FAO believes the approach can offer new promise for genetic improvement in developing countries. However, it should be realized that screening animals will add extra cost of identification of elite animals, transportation of those animals into the nucleus and the risk of disease introduction to the nucleus. These effects might tend to reduce the rewards from continually screening animals into the open nucleus scheme, particularly if the identification of animals to be screened is either time-consuming or costly (Garrick, 1993).

The most popular form of the open nucleus breeding scheme is the group breeding scheme or co-operative breeding scheme (Jackson and Turner, 1972; Rae, 1974; Hight and Dalton, 1974; Nicholas, 1987). With this system, a group of breeders and/or farmers come together and agree to co-operate in the formation and subsequent running of an open nucleus. They identify and transfer, through recording, animals of high producing ability from the large commercial populations into the nucleus, and in return transfer breeding stock from the nucleus for use in the commercial herds. Normally, females are introduced from the commercial tier into the nucleus and sires are sourced from the nucleus for use in the commercial herds. For large populations the optimum nucleus size is 5-10 % of the population size and approximately half of the female nucleus replacements should be selected from the base population, the rest being sourced from the nucleus itself (Jackson and Turner, 1972; Roden, 1994). This can vary, and can be less than 1 % in which case the nucleus should be closed.

#### *2.2.5 Sire reference scheme*

Sire selection and evaluation form an important aspect of a breeding programme. The genetic problem of the stud breeder is to select sires that produce progeny which are superior to those currently being produced. The concept of breeding values provides a way of defining the superiority or inferiority of the progeny of some group of sires relative to others by estimating breeding value differences among flocks/herds. A sire

may then be chosen as a superior animal on the basis of the deviation of the mean of his progeny from the mean of the progeny of one or more reference/link sires. Developing procedures to make comparisons among sires (the value of one progeny relative to some base standard) is therefore the issue. Selection within flocks/herds alone do not permit the comparison of animals reared on different farms because of the difficulty in separating genetic and environmental effects.

Alternative options available for estimating breeding value differences between studs (Jackson and Roberts, 1970) are: (i) bringing sires and dams from different flocks/herds for test (including progeny) in a common environment, and (ii) using a team of sires across a number of flocks/herds in comparing stock. Apart from overcoming the environmental differences of comparing animals from different flocks/herds, the second method is the most efficient in terms of experimental resources (Hill, 1981; Lewer, 1984). It is also more effective than individual selection in producing annual genetic change (Morris *et al.*, 1980), provided superior sires identified through the programme are widely used as parents. This second method is known as sire reference scheme.

A sire reference scheme involves the widespread use of common sires (reference sires) across many flocks/herds in two or more environments to provide a genetic link between the flocks/herds (Lewer, 1984; Nimbkar and Wrang, 1991; Garrick, 1993). If the environments are flocks, the scheme can be described as a "distributed nucleus", whereby the nucleus animals are distributed over a range of the contributing flocks/herds, rather than grouping animals in a common environment (Garrick, 1993). The progeny of the reference sires provide a "reference" by which all other sires can be ranked across herds/flocks because sires are connected by having progeny in different flocks/herds.

Sire referencing is much more developed in the dairy industry than in other species because of the widespread use of artificial insemination in the former. In order to obtain a fair comparison of potential breeding stock from different sources, a sire reference scheme should have adequate numbers of reference sires and progeny per sire. Where the use of artificial insemination is not possible due to its high cost, difficulty in

detecting oestrus such as occurs in beef cattle, and where breeders are located in close geographic proximity and can control diseases, genetic linkages can be achieved through physical exchange of sires (e.g. ram circle in Norway) (Gjedrem, 1969; Stein, 1982), if mating dates are sufficiently spread or through grouping females together in one location for the mating period.

A potential problem associated with sire referencing is genotype by environment interactions because genotypes often differ in their expressions in different environments, as the best genotype in a good environment, may not be the best in a poor environment (Dickerson, 1962; Butler-Hogg and Cruickshank, 1989; Bondoc and Smith, 1993). Environments that minimize the expression of genetic differences will tend to prevent sires tested in these environments being chosen. Therefore, the presence of a sizeable genotype by environment interaction may lead to a major reduction in the accuracy of across flock/herd breeding value estimation. In addition, non-genetic effects such as age of dam, date of birth and birth rank also need to be accounted for. Analysis of performance records from a sire reference scheme is therefore considerably more complicated than is typically necessary for within flock/herd analysis. This can be catered for by the technique of Best Linear Unbiased Prediction (BLUP) (Henderson, 1949; 1973). However, the risk of the scheme not being viable could partially be alleviated by limiting the range of environments or by grouping breeding values according to classes. Under these circumstances, the most desirable selection approach is to select animals within the environment in which sires will finally generate their commercial offspring.

## 2.3 Development of breeding objectives

### 2.3.1 Introduction breeding objectives

Before the foundation papers of the 1940s (e.g. Hazel, 1943), breeding objectives for all livestock classes were predominantly visual (Harris and Newman, 1994). The objective was toward an ideal type, and animals that deviated sufficiently from this ideal were culled. The "ideal animal" was an attempt to provide selection criterion to achieve an unwritten objective of high performance animals. Capabilities for genetic predictions have now encouraged recording of some performance traits in most classes of livestock, including beef cattle. Most breeding industries have now evolved from objectives of appearance to objectives involving performance, measured in an economic form.

The breeding objective is a statement of the economic worth of an animal from a genetic perspective (Harris *et al.*, 1984; Harris and Newman, 1994). In more general terms, the breeding objective can be stated as an equation based on economic values and breeding values. It can be determined as a mathematical function or sets of functions that describe the contributions of the various aspects of the production system to its production efficiency (Harris *et al.*, 1984). The breeding objective for the improvement of  $n$  traits can be represented in the form:

$$H = a_1T_1 + a_2T_2 + a_3T_3 + \dots + a_nT_n \dots \dots \dots (2.4)$$

Where  $H$  is the breeding objective, and  $a$ 's and  $T$ 's are economic values and breeding values, respectively. As will be seen later, economic values of traits can be derived from a profit equation. A profit equation is a statement which uses functions of inputs and outputs to estimate profit of a system. Inputs include items such as food, husbandry and marketing costs, and outputs come from the sale of surplus heifers and bulls, and cull cows.

Dickerson (1982) stated that a breeding objective relevant to increasing efficiency of livestock production is important to all consumers of animal products as well as to

livestock producers and thus to animal breeders and research administrators. James (1982) also stated that the most important decision of all in any animal improvement programme is the choice of a breeding objective. However, care should be taken when defining the breeding objective. If the objective is badly chosen, then any genetic progress may not be optimal, and in the worst case, may even lead to economic deterioration of the population (James, 1982). For example, if no consideration is given to an important economic character and it is not included in the objective, the consequences can be serious if the "forgotten" trait happens to have disadvantageous genetic correlations with the selection criteria. Again, if the breeding objective is based purely on the economics of the commercial enterprise at the exclusion of seed-stock producers own economics, this will ignore the effect of the seed-stock producers own cash flow on the viability of genetic improvement.

Decisions about which traits should be included in the breeding objective should be based on purely economic grounds, and not on whether they are difficult (food intake) or easy to measure (growth traits) or difficult to change genetically (reproductive traits) or have been researched adequately (James, 1982). The reason is that when net profit is chosen as the objective, all sources of income and expense must be taken into account. Theoretically, this may be desirable but practically, it would be difficult to implement. This is why only the traits of major economic importance are typically included in the profit equation.

The breeding objective has been assigned different names, which are often used interchangeably by different people in different strata of the industry (Barlow, 1987). These include aggregate genotype, aggregate breeding values, breeding goals, selection goals, selection objectives and bio-economic objectives. Geneticists and economists usually prefer defining the goal as an aggregate of breeding values for all traits influencing income, and or expenses, with each breeding value weighted by an appropriately derived economic value. By contrast, others (breeders in particular) usually think about the breeding objectives in terms of a specific combination of target levels for different traits. The former group focuses on profit directly, whereas the latter hopes to improve profit, but by concentrating on traits to be improved by predetermined

amounts (Newman and Ponzoni, 1994). In this context, the most important question to ask is: "what constitutes an improvement in profit from a breeding herd or flock within the business context?". In other words, in what ways can the herd or flock be changed genetically that will increase the difference between return and cost? Identifying the characteristics of the animals and herd or flock that contribute to change in profit and their relative worth, is what geneticists usually refer to as defining the breeding objectives (Barlow, 1987). Some confusion also exists about the use of selection criteria and selection objectives. The distinction between the two will be made clear in section 2.4.

The primary objective of most producers (commercial farmers) would be to improve the net profit of their farming enterprises. Since the sire-breeder is providing replacement sires for the commercial farmer, their objectives should coincide. The objective should be defined in terms of economic performance, and directed towards the improvement of profit. The list of traits to improve can however differ considerably between different sectors of an industry, namely breeders, producers, processors and consumers. Since it is the consumers satisfaction that ultimately dictates produce price, preferences should be transferred back to the breeders through market forces, whilst making sure that the feedback message from the consumer to the breeder is not distorted. In addition, the objective must relate to future requirements since any genetic change made by the breeder takes considerable time to be passed onto the consumer. In some cases the list of traits that the breeder wishes to improve will include characteristics that are expressed early in life (e.g. growth to weaning) as well as traits that are expressed late in life (e.g. longevity or mothering ability). The relative importance of various traits in the objective should account for the time of expression, because rewards that come earlier may be more valuable than rewards that are due much later. This can be accounted for by discounting which differentially weighs returns at different time periods (Hill, 1971; McClintock and Cunningham, 1974; Cunningham and Ryan, 1975; Smith, 1978; Bird and Mitchell, 1980; McArthur and Del Bosque Gonzalez, 1990).

Breeding objectives have been developed for beef cattle in Australia (Morris, 1981; Ponzoni and Newman, 1989; Barwick and Fuchs, 1992); New Zealand (Rae and Barton,

1970; Newman *et al.*, 1992); United Kingdom (McClintock and Cunningham, 1974; Simm *et al.*, 1986); Canada (MacNeil *et al.*, 1992; MacNeil *et al.*, 1994) and Czech Republic (Wolfova *et al.*, 1995). No detailed work on breeding objectives for beef cattle production in tropical Africa has been cited in the literature. Since most of these countries are now structuring and putting performance recording schemes in place (Jasiorowski, 1991; Smith, 1988), it would seem prudent if they first define the breeding objectives for their beef cattle industries. Below is a general description of the methodology used by Ponzoni (1986) and Ponzoni and Newman (1989) for the development of the breeding objectives for sheep and beef cattle respectively.

### 2.3.2 *Specification of breeding, production and marketing systems*

#### *Breeding system*

Specifying the breeding or mating system involves defining the role of the breed in the production system, for which the breeding objective is being developed in the production system (Harris *et al.*, 1984; Ponzoni and Newman, 1989; Barwick, 1992; Barwick and Fuchs, 1992). This also involves specifying whether the animals are to be purebred or crossbred. The roles could be general purpose, maternal line, or terminal sire line.

The way in which breeds are utilized influences the fraction of genes present in various segments of the production system (Fig. 2.1). It is necessary to identify some features of both the herd in which genetic selection is to be practised and a representative commercial herd in which the improved genes will ultimately be expressed (Barwick and Fuchs, 1992). For seed stock herds, there is the need to identify the breed and environment involved, as this affects the description of the trait heritabilities and genetic correlations which might be utilized.

In most tropical countries, some of these mating systems utilize the dual or multi-purpose nature of cattle, particularly those that predominate in lesser developed countries. In these situations, cattle are not only kept for their meat, hides, horns, and bones, but are often a vital source of draught power, milk, fuel, fertilizer and are even

utilized for sport and recreation. Establishing the breeding objective in such multi-product situations is extremely difficult since often little is known of the relative magnitude of inputs and outputs, including socio-economic factors which are often of overriding significance (Franklin, 1986).

#### *Production and marketing system*

A detailed description of a production and marketing system has been made by Harris *et al.*, 1984. Market requirements have the major impact on breeding objectives. Beef breeders and producers must respond directly to both current and predicted market movements. In describing the production and marketing system, inputs and outputs should be quantified. Environments and marketing situations that are to be targets of the breeding programme should be included into the system. The livestock species, products and purposes, and geographical and climatic areas of interest should be specified. The benefit and cost considerations should be emphasized.

The description should include the normal life cycle of parents and production animals specifying the following: ages for breeding; timing of offspring production; expected fertility and fecundity; ages or weights for weaning; intensive feeding, marketing and slaughter; and all other relevant and important points in the life cycle. The nature of feed, labour, land, buildings and equipment requirements, and the corresponding cost in various stages, are all necessary to fully describe the system. The length of grazing periods and the length of intensive feeding periods (e.g. provision of supplementary feed due to drought in the dry season) and cost of all such feeding relative to grass feeding should all be included in describing the production and marketing system. The management of animals and the replacement policy should all be specified.

There is a wide variety of production systems in the tropics. They vary from fully intensive systems where land size is very small and animals are handled daily, to those based on extensive rangelands in which cattle are run at extremely low stocking rates and are harvested on an annual or even less regular basis (Preston, 1977).

### 2.3.3 Identification of sources of income and expense

Income is the sum of products of number of sale animals in each class of livestock and the value per individual. The value of the individual animal is influenced by the weight of each and the price per kilogram of each, for each class of sale animal. There are also other sources of income that are derived from the live animal e.g. dung, milk and sport. Costs include feed costs, husbandry costs and marketing costs for all relevant classes of livestock. Costs can be classified as either being fixed or variable. Fixed costs are those costs incurred by the producers (e.g. interest and insurance) that are independent on the level of herd production. All other costs are known as variable costs because they vary with the level of production.

The identification of income and expense in commercial herds enables the development of a profit equation (P) as:

$$P = I - C \dots\dots\dots(2.5)$$

where I is income and C is cost. For the Australian beef cattle example of Ponzoni and Newman (1989):

Income includes:

male calves x value per individual  
 + surplus heifers x value per individual  
 + cull-for-age cows x value per individual

Expenses includes:

male calves' food intake x cost per kg  
 + heifers' food intake x cost per kg  
 + cows' food intake x cost per kg  
 + male calves' husbandry costs  
 + heifers' husbandry costs

- + male calves x marketing cost per individual
- + surplus heifers x marketing cost per individual
- + cull-for-age cows x marketing cost per individual
- + fixed costs

Alternatively, Harris (1970) proposed that profit can be expressed in the form,

$$E = I / C \dots \dots \dots (2.6)$$

where E is efficiency, or its inverse, cost per unit product (Q), also proposed by Dickerson (1970).

$$Q = C / I \dots \dots \dots (2.7)$$

All traits which perceptibly contribute to P or E should be considered for inclusion in the breeding objective regardless of their heritability and/or measurement problems.

There has been some discussion about the use of profit versus efficiency as a measure of overall desirability (James, 1982). Dickerson (1982) argued that a breeder should seek to minimize cost per unit product, essentially on the ground that, as productivity rises, prices will fall. Dickerson (1982) assumed a fixed market since he used the unit of product as the basis, but in practice, this is not really accurate, since there is never really only one product and the different products must be weighted by their relative values. James (1982) also recommended the choice of "cost per unit product" on the basis that the markets for products function as the limitation, so that total returns cannot be increased, so cost should be minimized. Smith *et al.* (1986) also indicated that I and C should be combined as a ratio, which requires an estimate of fixed costs, but Ponzoni (1988) found that in a practical example with Merino traits, the way in which I and C were combined had a very small effect. If economic profit is set to zero, the same

economic values are obtained whether income and expense are expressed as a difference or as a ratio. In the Ponzoni and Newman (1989) example above, fixed costs were ignored since I and C were combined as a difference, and terms not involving the traits in the breeding objective vanish when obtaining the partial derivative of P with respect to each trait. Thus, the advantage of using efficiency, or its reciprocal value, is that fixed costs are included and economic efficiency depends more on minimizing average total costs than on reducing marginal costs (addition to cost), which are variable (Pirchner, 1993).

However, more recently, economic theory has been shown to provide a valuable background from which to make the most appropriate choice of method (Amer and Fox, 1992; Amer, 1994; Amer *et al.*, 1994). This involves the need to account for reoptimization of the farming system in production input use, and output levels, in response to genetic changes. In addition, changes in output or input prices which can result when genetic change occurs across a large proportion of a competitive industry must also be accounted for.

Feed costs are a function of the amount eaten and the cost per kg of feed. There is a controversial problem of how to account for changes expected in feed intake. Often, feed costs are ignored in the breeding objective because it is difficult to measure. Land, labour and capital associated with feed are difficult to apportion to any segment of the herd (Upton *et al.*, 1988). Again, with respect to feed intake, important genotype by environment interactions may be observed given that cattle have been selected for high genetic merit for production traits under conditions of unlimited feed of high quality. These cattle will inevitably have higher maintenance requirements and be less efficient when nutrient restrictions prevent the expression of genetic differences in appetite. This becomes very important when temperate breeds of cattle of high genetic merit are imported into tropical countries where seasonality in feed availability is very pronounced. Even, on the local scene, animals bred in a nucleus breeding station, under conditions of optimal feed quality and quantity, transferred to villages, where feed is of poor quality and sometimes scarce, may not be able to perform sufficiently well to express their genetic potential.

Feed costs, whether prepared feed or range forage cannot be ignored from the breeding objective because they are often the largest of all costs (Barwick, 1992; Harris and Newman, 1994). Barwick noted that under ideal conditions, feed intake should be included as a trait in the breeding objective, but a shortage of genetic parameter estimates for this trait, and concern about the reliability of the estimates that are available, often preclude this approach. A less desirable approach sometimes used is to presume feed requirements are a direct function of live weight. The costs of any additional feed needed are then incorporated as a cost in the economic values calculated for live weight traits.

Upton *et al.* (1988) used the partial budgeting approach to side-step some of these problems. First, they assumed that the producer stocked their property at an optimal level with respect to both expected profit and risk. They adopted the philosophy that the stocking pressure should remain equivalent to that of the herd before change, thereby implying that the herd feed requirements were regarded as a fixed cost and only the extra feed required needed to be costed as part of the economic value for those traits which changed feed requirements. Secondly, they assumed that feed pricing affected the seasonal distribution of feed throughout the year. In areas that had a seasonal pattern of rapid feed growth at a particular time of the year, it was assumed that there was surplus feed and if not eaten, the extra feed was simply wasted. The cost of the extra feed required at this time was assumed to be zero. Conversely for periods of the year where feed requirements of the herd closely match the feed available, any extra requirement during this period must be paid for in full. Two approaches can be used to cost such feeds. The first allows additional feed to be purchased, in some form, while the second requires that the extra feed needed is offset by reducing stock numbers, usually breeding females (Barwick, 1992). In the latter, costs incurred will be via the reduced number of cows contributing to the income of the herd. Should some of the normal sale stock be sold before the sales period, then the cost (opportunity cost) is the forgone income, compared with the original system where sale stock were carried through to normal sale time.

Various workers have highlighted the effect of removal of feed intake from the selection

objective. Ponzoni and Newman (1989) observed that setting feed cost equal to zero shifted emphasis from reproduction to growth traits with a consequent increase in feed intake. This had the effect of doubling the rate of genetic gain for carcass weight and fattening depth, but halving the genetic gain for calving day for all classes of stock. Newman *et al.* (1992) also observed in New Zealand that selection response shifted to growth-related characters and increased feed intake at the expense of reproduction when feed intake was ignored in the breeding objective. The correlation between the two objectives (ignoring vs not ignoring) in this latter study was 0.66, which is close to the 0.69 obtained by Ponzoni and Newman (1989) in Australia. When the objective of not ignoring feed intake was assumed to be optimal (Newman *et al.*, 1992), the objective ignoring food costs accounted for only 44 % of the variation in the former. Considering the loss of predictive value between the two objectives in both studies, there is a great justification for the description of breeding objectives to include feed intake as a major input of the production system.

#### *2.3.4 Determination of biological traits influencing income and expense*

The selection objective is a list of the traits that we wish to improve. The profit equation is expressed as a function of the principal biological traits contributing to each source of income and expense. It is therefore necessary to identify the list of traits that affect the satisfaction of the animal manager. Satisfaction should relate to economics of production and therefore profitability. As was noted earlier, the list of traits that are considered important will differ between each of the industry strata, namely breeders, producers, processors, retailers and consumers (Fig. 2.1). That is, each sector of the industry may have a different selection objective, incorporating different traits and obviously putting different emphasis on each trait. For example, the commercial breeder selling weaners is interested in highly fertile cows that wean heavy calves. The finisher desires animals which give rapid and efficient gains but has little interest in the traits of the breeding cow, whilst the eating qualities (fat depth, marbling etc.) of the beef produced must be acceptable to the consumer. Since it is the satisfaction of the consumer we wish to improve, the consumer's selection objectives should be transferred back to the breeder through market forces, but this seldom occurs in practice.

The production cycle of the beef animal can thus be classified into two phases (Rae, 1973; Cartwright, 1982). The first phase is that of calf production. Here, it is the traits of the cow that are of most significance (high fertility, and regularity of calving, adequate milk production and mothering ability to wean heavy calves). The second phase is that of growth or weight production. This refers to the post-weaning stage of growth up to the slaughter of the beef animal, and yield of meat and its quality, in terms of tenderness, flavour and juiciness. For the purpose of organizing this discussion, traits will be grouped into the following six categories:

- (1) Reproductive traits
- (2) Maternal ability traits
- (3) Survival traits
- (4) Production traits
- (5) Carcass traits
- (6) Aesthetic or personal preference traits.

#### *Reproductive traits*

Reproductive performance, usually measured by the number of calves weaned per 100 cows mated, is the most important trait in controlling financial returns from the breeding herd (Rae and Barton, 1970). Morris (1979, 1980) and Boggs (1993) pointed out that since a large proportion (about 50-70 %) of the total herd food intake is required by the breeding cow for non-productive purposes (maintenance), increasing net calf crop weaned can decrease parental costs per calf and thus spread annual herd maintenance costs over more animals marketed. This can be achieved by reducing the age at which a heifer has her first calf, increasing pregnancy rate (by reducing postpartum anoestrus intervals, increasing conception rates), and reducing calf losses. In addition, higher reproductive rate permits greater selection intensity because of surplus breeding stock, and this lead to an increase in the annual rate of genetic gain.

Reproductive traits are lowly heritable (Table 2.1). Values range from about 1-19 % (Koots *et al.*, 1994a). This means that they are predominantly determined by non-genetic factors. As a consequence, it has been assumed that reproductive traits will take

a long time to improve via within-breed selection. Although, culling of cows which fail to breed regularly or to wean calves is usually recommended in the stud tier, where shorter generation intervals are always sought, this may not be a good idea as much of the overhead feed costs might have been incurred in rearing the cow and infertility has low repeatability. However, it would be seen later that reproductive traits can be improved through crossbreeding and can therefore be included in the selection objectives, depending on the production system.

**Table 2.1:** Heritability of quantitative traits of possible economic importance in beef cattle.

Trait	Heritability
Weight	
Birth	Low
Weaning (205-day)	Moderate
Yearling	Moderate
Gain to market	Moderate
Age at market	Moderate
Mature	High
Maternal ability	Moderate
Carcass	
Fat depth	Moderate
Rib eye area	High
Dressing percentage	Moderate
Marbling	Moderate
Yield grade	Moderate

Table 2.1 continued

Reproduction	
Age at first breeding	Low
Calving difficulty	Low
Live births	Low
Calving interval	Low
Services per conception	Low

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Source: Van Vleck *et al.* (1987)

#### *Maternal traits*

Traits in beef cattle which contribute to maternal ability are milk production and mothering ability, both of which are measured by the weight of calf weaned by the cow (Rae and Barton, 1970). It is these traits that provide an important component of a young animal's environment. The milking and mothering ability of the dam are environmental effects from the view point of the young calf, and they are affected by the genotype of the dam for milking and mothering ability (Willham, 1980). This means that weaning weight is determined by the individual genotype for pre-weaning growth (direct effect), genotype of the dam for milking and mothering ability (maternal effect) and effect of the environment.

Although the heritability of maternal ability is moderate (Table 2.1), which means that it can be improved effectively by selection, several factors complicate improvement programmes for traits with maternal influence (Van Vleck *et al.*, 1977; Willham, 1980; Baker, 1980; Garrick, 1990). First, there may be a negative genetic correlation between direct and maternal effects. Second, the dam contributes both the maternal effect and half of the direct genes towards the weaning weight of her calf, leading to difficulties in accurately separating direct and maternal contributions. Third, the expression of maternal effects are sex limited and typically occur after initial selection, a generation

behind the direct effects. Finally, there is evidence of a negative environmental covariance between generations such that the dam either gives her offspring a plus set of genes for the direct effect and a poor maternal effect or the other way round. One approach to improve traits with large negative covariance is to form separate lines (Van Vleck *et al.*, 1977). A sire line would be bred to improve the direct genetic growth and a dam line selected for maternal ability. Slaughter progeny can possibly be obtained by crossing these lines.

### *Survival traits*

Mortality in offspring from birth to weaning adds significantly to loss of income from farm animals. The effects of survival (percentage alive at a certain period) on income are relatively more important in cattle and sheep with smaller number of progeny weaned per dam (Dickerson, 1970). There are significant additive genetic differences among breeds for direct transmitted and maternal effects on survival. Estimates of breed maternal additive genetic effects and breed direct additive genetic effects from sheep, cattle and swine indicate that breed direct additive genetic effects are relatively more important than breed maternal additive effects on survival from birth to weaning in these animals (Cundiff *et al.*, 1982). This suggests that among breeds, the genotype of the offspring is relatively more responsible for survival from birth to weaning than the genotype of the dam. These indicate clearly that a certain degree of adaptation is required for a breed to survive and produce in its environment. However, within breeds, heritability of survival is low (3-14 %) and tends to be greater as a trait of the dam than as a trait of the offspring (Cundiff *et al.*, 1982). A certain degree of good maternal ability is therefore needed to increase survival from birth to weaning within an existing breed.

Adaptation is a broad term used to describe the ability of animals to adjust to environmental conditions or to infer genetic modifications that make animals more suitable for existence under specific environmental stresses (Cundiff *et al.*, 1982; Franklin, 1986; Baker and Rege, 1994). In evolutionary terms, adaptation can be defined as the fitness of an animal to its environment. Survival in itself is not an all or

none trait, consisting of several components. Some biological components of survival include reaction to cold and heat stress, disease resistance or tolerance, endo- and ecto-parasitic resistance and ability to survive on low quality feed.

Longevity is a trait of importance in adult cattle. It is a measure of how well an animal suits the environment (adaptation), and therefore can be said to measure similar traits as survival. Stayability is sometimes used in place of longevity (e.g. Snelling and Golden, 1994), the former being defined as the probability of surviving to a specific age given the opportunity to reach that age. Survival at both pre- and post-weaning stages is of major importance in breeding objectives in livestock breeding programmes, especially in the tropics. Heat stress, diseases, poor nutrition and parasites all lead to large economic losses in the tropics. The ideal objective is resistance to these environmental factors, but this is rare (Franklin, 1986). There are speculations that in many subsistence tropical farming systems, survival in the face of multiple stress is one of the most important economic traits, while even increasing growth rate is of less economic value (Upton, 1985; Baker and Rege, 1994). Very little research has been undertaken on this topic in the tropics.

Rising labour and treatment costs make it important to have easy-care animals. A longer productive life may increase returns in several ways (Rae and Barton, 1970):

- (1) By reducing the annual costs of replacements
- (2) By increasing average weight of calf weaned per cow as a result of greater proportion of cows being in the more productive age groups.
- (3) By an increase in the intensity of selection of the replacements.

It should however be realized that the longer an animal remains in the herd, the longer will be the generation interval which may reduce the annual rate of genetic gain. This is particularly important in stud herds, who need an indicator trait that avoids long generation intervals. On the other hand, it is more or less irrelevant in the commercial herds as farmers in this sector of the industry want long-living stock.

Survival as a trait is lowly heritable (*see above*), therefore little scope for improvement by selection is apparent. There are two broad options for genetic improvement of

production and adaptation in tropical livestock (Franklin, 1986; Baker and Rege, 1994). The first is to concentrate only on breeding for production traits and let adaptation be maintained by forces of natural selection. The second is to attempt both a biological and genetic understanding of adaptation and its inter-relationships with production, and so to develop breeding systems that improve both adaptation and production. In the latter situation, which is becoming popular with breeders, genetic improvement can be achieved by choice of genotypes best adapted to the environment and selection within the genotype for factors associated with environmental adaptation (Cundiff *et al.*, 1982; Franklin, 1986; Rudder, 1989; Baker and Rege, 1994). However, unlike most production traits which have well-defined selection criteria, many adaptive traits have no selection criteria, and strategic research is required to define simple measured selection criteria, to estimate their heritabilities, genetic correlations among them and with production traits.

#### *Production traits*

Most body traits such as weaning weight, yearling weight, gain to market and mature body weight are referred to as production traits. Most of them have moderate to high heritabilities (Table 2.1), suggesting that selection should have a significant impact on the levels of production attained. Heritability values range from about 22-79 % (Koots *et al.*, 1994a). Inspection of the efficiency equation of Dickerson (1970) reveals that selection of animals that more efficiently convert food to lean tissue will also increase efficiency. Such animals grow faster, attain heavier weights at sale age and receive higher returns, and have reduced maintenance cost as a result of their early sale. Growth traits therefore form an important component of beef cattle breeding objectives and are regarded as the traits of highest economic importance in slaughter cattle (Rae and Barton, 1970; MacNeil *et al.*, 1994). The reasons usually advanced for this are that growth rate has a high genetic correlation with efficiency of feed conversion, live weight is the major determinant of carcass weight and yield of edible meat, and since faster growing cattle are younger when slaughtered at the same weight, they will produce more tender meat with less fat.

Unfortunately, a strong correlated response, when increasing the ability of an animal to grow fast, occurs in mature size. That is, faster growing breeds of cattle tend to be breeds with larger mature size. Selection for birth, weaning or yearling weights all cause correlated increases in mature size. This has two undesirable effects (Morris, 1979, 1980; Boggs, 1993). First, the larger breeds tend to require heavier weights to achieve puberty and it can therefore be more difficult to achieve a high pregnancy rate to calve at two years of age. Second, larger adult cows will result in less cows being able to run on a given area of land. Maintenance costs, which are a function of mature weight, typically account for 50-70 % of the total cost in a cow calf operation (Morris, 1979, 1980; Boggs, 1993). Therefore, selection decisions which increase mature size have a significant effect on feed requirements. It is often suggested that selection should be for small cows (low maintenance) that attain puberty early with high fertility, easy calving and good milk production (Cartwright, 1982), if these are used in a crossing programme.

### *Carcass traits*

Carcass traits can be classified into weight, yield and meat quality traits. Carcass weight refers to the weight of the animal measured immediately after slaughter. Carcass yield is the yield of saleable meat produced per carcass or per unit carcass weight, mostly referred to as the dressing percentage. Meat quality traits include fat depth, fat colour, and marbling.

Carcass traits are moderately to highly heritable (Table 2.1), which means that genetic improvement can be achieved through selection. Heritability values range from 20-65 % (Koots *et al.*, 1994a). However, these traits are given little economic consideration by breeders, though they are the traits of importance to processors and consumers. Yield traits are important to meat processors because an increase in lean meat yield will result in an increase in weight of saleable meat product per carcass processed, whilst meat quality traits are of importance to consumers because they determine the monetary value of produce and also affect the satisfaction of the consumer. The problem is therefore typically a lack of feedback from the consumer through the processor to the

breeder, which needs to be improved.

One major problem which restricts the efficient use of carcass quality as a breeding objective is the lack of simple accurate live animal measurement techniques (Rae 1970). The traditional methods of measurement include the use of subjective assessments ("the hand-eye" approach), live weights and measurements of height at withers or hips, and body length, but more recently, ultrasonic methods (A-mode and B-mode ultrasonics), body water diluents, use of scanners developed for medical purposes and metabolic markers are being studied (Blair, 1989). An additional difficulty is that consumer requirements differ within and between markets and over time and the raw product may have several end uses each with a different demand.

Despite the above problems, it seems there are advantages derived from the inclusion of carcass traits in the selection objective. For example, Charteris (1995) noted that carcasses in the Japanese beef market are rewarded for increased yield and superior meat qualities such as marbling, fat colour and firmness and texture of meat. Therefore, genetic improvement may provide a low-cost alternative for improving beef quality destined for the Japanese market from New Zealand, based on the existing pasture feeding of beef cattle in New Zealand, compared to the relatively high cost of feedlotting of cattle in North America and Australia. It may therefore be desirable to include carcass traits into the breeding objectives provided that farmers will be rewarded for them in the near future.

#### *Aesthetic traits*

These are personal preference traits which constitute the visual appearance of the animal. They include traits such as colour of coat or pattern, conformation, and head shape. The relative economic value of aesthetic traits is often a function of eye (or mind) of the person buying. Most of these traits are not included in the list of traits of economic importance in farm animals. Emphasis on these traits in selection is therefore unlikely to result in greatly improved financial returns to the commercial breeder as Rae (1970) has indicated. He showed, after allowing for the relation between carcass weight and

live weight, that of the available selection potential which the breeder can devote to these two traits, 90 to 95 % should be directed to live weight growth and only 5 to 10 % to conformation in the traditional sense. Thus, there are two sectors in the stud industry; those who select for improved profit via productivity or efficiency, and those who select for improved profit via "good looking" stock.

The second group are hopefully a declining percentage of the numbers but they do have a valid objective while farmers continue to buy their bulls. This is the traditional approach to selection, in which selection objectives in the beef cattle industry were based on personal preference traits (Bendall and Bendall, 1993; Blair and Garrick, 1994; Harris and Newman, 1994). Blair and Garrick (1994) noted that in New Zealand, most breed societies describe an "ideal animal" which tend to focus on conformation traits as a means of satisfaction rather than on traits affecting profitability via production. These traits conjure up in the minds of breeders and judges the picture of an "ideal beef cattle" to market their products in the show ring. In some cases prices paid for stock are grossly out of proportion with respect to genetic merit of the stock due to successful stock preparation and marketing strategy, coupled with earlier economic and social achievements. When this happens, the value paid for breeding stock and the benefit passed on to the buyer bear little relation to the economic values derived by technical advisers.

In a paper which consider how farmers interpreted breeding objectives in New Zealand, Bendall and Bendall (1993) concluded that many farmers base their selection decisions on visual appearance, rather than being prepared to accept the selection index as a reliable predictor of breeding merit. This unfortunate situation should not be the case, especially in places like New Zealand where adequate recording and genetic evaluation information are available for the stock on sale. Unpublished observations by the author suggest that in countries like Ghana, where recording and genetic evaluation programmes are not available, farmers base their judgement of animals through visual appearance.

### *Conclusion*

The main conclusion to draw from the above discussion of traits to be included in the objective is that the characters to improve should not be based on whether they are cheap or expensive to measure or even impossible to measure on the candidate or relatives, but should relate to economics of production and satisfaction of the consumer. Furthermore, it would appear additional research is required to clarify the roles of feed costs and survival in the breeding objective.

#### *2.3.5 Derivation of the economic value of each trait*

Equation 2.4 could be summed into that for an aggregate genotype:

$$H = \sum a_i T_i \dots \dots \dots (2.8)$$

where H is the aggregate breeding value,  $a_i$  the economic weight or value for trait i, and  $T_i$  is the breeding value for trait i. Thus, the net genetic improvement which can be brought about by selecting among a group of animals is the sum of genetic gains made for the several traits which have economic importance. Hazel (1943) defined the relative economic weight for each trait as the amount by which net profit may be expected to increase for each unit of improvement in that trait, holding all other traits constant.

Different methods are available for the computation of economic values of traits. The first of these methods involves regressing prices of animals against estimated breeding values available at the time of sale (Schroeder *et al.*, 1992). Using multiple regression analysis can sometimes be very complex, especially where breeding values for the different traits are highly correlated, and the results can be very difficult to interpret (Amer, 1994). Since prices can reflect short term (fashionable) trends which are inconsistent over time, a knowledge of the expected market trends need to be considered when deriving relative economic values in this way. Forecasting to predict future prices is therefore essential in this process, since it is in the future that current selection will

produce its benefits. This method cannot be applied in many developing countries because in many markets, no breeding value information is available. In these countries, animals are purchased based on subjective assessments.

The above method considers only gross returns (prices of animals) without taking into account the cost of production. In applying the method, it is assumed that the only effect of the genetic change is on the value of saleable animals. It does not reflect the net value of changing the trait. Cost of production therefore needs to be taken into account when deriving economic values because it is the marginal returns from a small change to the current system that is important. For example, when additional feed needs to be purchased, due to improvement in average live weight of stock, the economic value for sale weight is estimated as the difference between the value of a kilogram of finished sale animal and the cost of extra feed needed to produce the extra kilogram, the estimate then being discounted to the present value. Relative economic values can therefore be obtained from long-time price averages (income) and cost of production (expenses) figures (Hazel, 1943).

In combining income and expenses, the economic value of a trait can be derived as the partial derivatives of profit (or efficiency) with respect to the trait, holding all other traits constant (Melton *et al.*, 1979; Brascamp *et al.*, 1985; Smith *et al.*, 1986). This approach appears to be the most desirable method of deriving economic values, and shall be referred to as "conventional or traditional" method in the rest of the text. The partial derivative approach is similar to the partial budgeting approach. The change in profit from a small increment in a trait is estimated using partial budgeting. When the increment is small, this procedure will give the same result as the partial derivative approach (Upton *et al.*, 1988; Barwick, 1992; Barwick and Fuchs, 1992). Thus, the economic value of a trait is calculated as the marginal change in profit (or efficiency) due to a small change in genetic level of the trait. This is done in a budgeting framework by considering only those parts or items of the budget that change with a small increment in the trait. For example, the economic value for the number of calves weaned per cows joined is the additional profit resulting from an extra 1 % of calves after accounting for additional feed costs and other costs, and from additional effects on

profit that arise from changes in the age structure of the herd. The age structure of the herd changes because higher replacement rates resulting from the extra calves produced may lead to a herd structure that contains fewer old cows.

As mentioned earlier, economic values can be derived by using either profit or efficiency equations. It has been shown (Ponzoni, 1988) that the way in which income and expenses are combined (either as a ratio or difference) has a very small effect on the derived economic values. In order to construct profit equations, it is necessary to consider the unit of comparison, such as profit per unit product, per production unit (e.g. per cow), per unit animal weight, per enterprise (farm) or for the entire national economy. The relative economic values derived from the partial derivative of profit of the different forms of the profit equation are different (Brascamp *et al.*, 1985; Weller, 1994). In most cases, economic values are equal to constants only in the case of expressing profit as per production unit. Most studies that have attempted to establish economic values, have therefore done so by the criterion of profit per production unit (e.g. Ponzoni and Newman, 1989; Newman *et al.*, 1992; Wolfova *et al.*, 1995). However, when profit is set to zero, the relative economic weights are the same for different forms of equations (Brascamp *et al.*, 1985).

In practice relative economic values may vary from breed to breed or from region to region within the same breed. They may change, even while a breeding programme is in progress, if permanent shifts in markets occur (Hazel, 1943; Melton *et al.*, 1979). If the relative prices of either inputs or outputs change, the economic value of traits must also change. Furthermore, if the average value of the trait changes, its economic value will change as well. The resulting economic value for each trait included in the objective therefore depends on specific profit function, input and output prices and the average level of all traits. Therefore, calculations of relative economic values require far more knowledge of a production system and may require modelling of the farm system (Wilton, 1979; Cartwright, 1979; Elsen, 1988).

Modelling which employs the conventional method, is used to assess the effects on some criteria of farm profit or efficiency due to a change in the average level of each trait.

Modelling the farming systems has been used to calculate the relative economic values of beef cattle (Ponzoni and Newman, 1989; Newman *et al.*, 1992; MacNeil *et al.*, 1994; Wolfova *et al.*, 1995). Models range from being very simple (single equations) to highly complex sets of specialized equations with technical input/output relationships based on scientific knowledge. The difficulty in practice is that the profit function for a real enterprise may be very difficult to write down (Elsen *et al.*, 1986). This is especially true of many developing countries, especially those in the tropics where some of the production systems utilize the dual- or multi-purpose nature of cattle, such as the production of meat, milk, hides, horns, bones, draught power, fuel, fertilizer and sport. Under such circumstances, the relative magnitude of inputs and outputs are difficult to quantify. It would therefore be preferable if the models can be structured so that only the important production inputs and outputs are optimized to avoid unnecessary complexities.

Not all traits in the objective are expressed at the same time, nor with the same frequency. The relative importance of various traits in the breeding objective should account for the time of expressions (time lag), since improvements that come earlier may be more valuable than improvements that are due much later. In theory, this can be accounted for by discounting (Hill, 1971; McClintock and Cunningham, 1974; Cunningham and Ryan, 1975; Smith, 1978; Bird and Mitchell, 1980; McArthur and Del Bosque Gonzalez, 1990). In applying discounting, real interest rate i.e. actual interest rate corrected for inflation should be used, rather than using the actual interest rate (Smith, 1978). The number of expressions of traits (frequency of expressions) must also be accounted for when determining the relative importance of traits in the breeding objectives.

Accounting for both time lag and frequency of expressions can be achieved using the discounted gene flow method of McClintock and Cunningham (1974). The number of discounted expressions of a trait is a function of the number of progeny or later descendants of the animal in question, and the annual discount factor. The discount factor accounts for an economic benefit that is harvested now is more valuable than an economic benefit obtained at some future time. Therefore, traits expressed sooner after

selection should receive more emphasis than those expressed later after selection. An alternative method which accounts for only frequency of expressions, but not time lag, involves calculating all income and expenses in one year (Ponzoni, 1986). Ponzoni (1986) showed that using either of the two methods had a small effect on the economic value of each trait, and consequently resulted in near negligible effects on the genetic gain achieved in each trait.

An alternative methodology was proposed by McArthur and Del Bosque Gonzalez (1990). Their method of diffusion coefficients differs from the previously mentioned of McClintock and Cunningham (1974) in that it accounts for the delay between the birth of an animal in the herd and the first time of expression of the improvement in the herd, which reflects the time that changes in cash flow occur. For example, if a farmer selects replacement heifers for increased birth weight in their progeny, the effect of that selection decision will not be realized for about two years, when the first calves of those heifers are born. Because additional cost is associated with the two year delay in the birth of calves, the value of increased birth weight to the farmer is reduced. The economic value of birth weight therefore needs to be discounted to reflect its present value (the time lag between implementing selection decisions and expression of the characteristic), since farmers will prefer to have the benefits today. This can be done by multiplying the marginal returns obtained at some time in the future by the factor  $1/(1+r_i)^t$ , where  $r_i$  is the discount rate and  $t$ , the number of years between the selection decision and the first expression of the trait.

Many other problems are encountered in practice when deriving economic values. Traits that are not directly related to production are difficult to assign economic values. Some of the more difficult areas are: the relative importance of reproduction versus growth traits, the value of growth rate or carcass yield *per se* relative to food conversion efficiency, the relative importance of lean to fat in growing animals, the importance of type or conformation in relation to production and longevity, the range of environments over which animals are to be raised commercially, and the importance of inherited disease resistance. One of the major problems is what the Economists term "reoptimisation of enterprise". For most agricultural products, genetic improvement may

lead to reduced cost per unit of production, as a result of which the equilibrium price of product may fall. Consequently, the profit of the producer may be less after genetic improvement than before. Under such conditions, the incentive for the individual producer to undertake genetic improvement is clearly reduced.

Smith *et al.* (1986) proposed the imposition of two conditions: First, any extra profit made from genetic change that could also be obtained by altering the size of the production enterprise or by rescaling should not be counted in assessing the value of genetic improvement, since it can be achieved without any genetic change. Only savings in cost per unit of product value should be included. Secondly, changes that correct previous inefficiencies in the production enterprise should not be included. These two conditions were based on the assumption that resources are scarce and are efficiently used, and changes in output will require proportional changes in input. This means that fixed costs, like variable costs, should be expressed per unit of output, rather than as a fixed total enterprise cost. However, it has been shown (Amer *et al.*, 1994) that economic values based on the rationale of rescaling tend to differ from those derived using economic theory.

Economic theory asserts that there is the need to account for the reoptimization of the farming system in production input use, and output levels, in response to genetic changes (Amer, 1994). Genetic changes result in shifts of levels of inputs and outputs. This requires that the new input and output levels, and maximum profit should be derived for the new level of genetic merit. This may be true for a national breeding goal (where adoption of technological change may be high), but may seldom be the case at the individual farm level. This is because individual farms are not large enough to individually influence market price for an input or output, since in these farms, input and output prices are usually independent of the level of genetic improvement. In fact, the potential contribution of economic theory to the definition of breeding objectives for livestock improvement programmes is still being debated. Developments are under way to integrate the conventional and economic theory approaches to improve the traditional method of estimating economic values (Ladd and Gibson, 1978; Amer and Fox, 1992; Amer, 1994; Amer *et al.*, 1994).

Considering the foregoing, it is difficult to calculate the value of genetic improvement net of all costs. But fortunately, the genetic gain in the objective seems to be relatively robust to changes in economic values (Vandepitte and Hazel, 1977; Simm *et al.*, 1987). Even in the absence of perfectly known economic values, some attempt at estimating economic values is better than no attempt. There is however the need to refine economic values as theory is advanced.

### 2.3.6 Crossbreeding

Although the primary objective of section 2.3.4 has been to examine biological traits influencing income and expense in the context of within-breed selection plans, mention should be made on the production benefits to be obtained from crossbreeding in commercial herds.

Crossbreeding is the mating of animals which are less closely related than the average of the population from which they came (Falconer, 1989). The advantages of crossbreeding are heterosis (hybrid vigour) and complementarity (Baker, 1982). Heterosis is the additional performance obtained from crossbred progeny over the mean of both parents. Crossbreeding may also be used to combine and improve the characteristics of two breeds; a phenomenon which is known as complementarity (Van Vleck *et al.*, 1987).

Highlights on the importance of reproductive performance of the cow in relation to efficiency have already been given in the previous section. While small cows have the advantage of lower maintenance requirements, this is offset to some extent by the fact that they have a lower rate of live weight gain and will pass this tendency on to their calves which are then at a disadvantage in the second phase (growth or weight production) of the production cycle of the beef cattle. Nevertheless, the traits (reproductive and maternal ability) which contribute to cow efficiency are very much more important than those contributing to the efficiency of calf production (Rae, 1973). It is necessary at this stage to note some of the genetic properties of the various cow and calf production traits, in relation to the rate at which they respond to selection and the

extent to which they show hybrid vigour in crosses (Table 2.2).

**Table 2.2:** Classification of traits based on response to selection and amount of hybrid vigour

Trait	Response to selection	Amount of hybrid vigour
Fertility		
Mothering ability	Very slow	Much
Calving interval		(10 % or more)
-----		
Growth rate		
Weaning weight	Medium	Medium
Conformation		(5-10 %)
Milk yield		
-----		
Mature weight	Fast	Little
Tenderness		(5 % or less)

Source: Rae (1973)

It is clear that the more important traits of the breeding cow respond only slowly to selection but show a substantial amount of hybrid vigour. On the other hand the calf traits can be changed rapidly by selection but show only a moderate amount of hybrid vigour. Consequently, it is important that every avenue should be explored in order to set up production systems which make maximum use of hybrid vigour primarily in the cow herd but also secondarily in the growth of the slaughter animal. In effect, crossbreeding has become important partly because more sectors of the industry can be

satisfied. Hybrid vigour for maternal ability results in more and larger calves at weaning. A terminal sire breed can be chosen to produce calves with rapid growth and desirable carcasses. The above leads to dam and sire lines which can then be combined to give better overall efficiency (MacNeil *et al.*, 1994).

Despite the advantages of crossbreeding, many Breed Societies prohibit the introduction of new genetic material into their breeds. The situation has been assessed in New Zealand, and Blair (1989) has given reasons for this. First, farmers have a dislike of crossbreeding animals as they are considered genetically impure. While this reason may be arguably pertinent to the sire-breeding sector, it has no place in the commercial sector. The second reason for the poor acceptance of crossbreeding in New Zealand is that it is perceived to complicate management, particularly at mating. Any farmer aiming to maximize income per unit area of land cannot afford to ignore the benefits of a properly operated crossbreeding programme which can be simple to manage, if coloured eartags are used to reduce management difficulties to acceptable levels. However, these attitudes are changing, as indicated by the work done by Garrick and Charteris (1995), which shows that about 23 % of the total beef cattle breeds in commercial herds in New Zealand in 1987 were crosses, and this percentage had increased to about 49 % in 1992/1993.

Crossbreeding appears to offer opportunities for genetic improvement of cattle in many developing countries, especially in the tropics. For example, in West Africa, Lhoste (1991) observed that crossing the Zebu (good growth traits) with the humpless cattle breeds (medium size and satisfactory fertility) seems to be an effective way of exploiting interracial variation. Franklin (1986) also noted that crossbreds can play an important role in the tropics, provided that their distribution is accompanied by appropriate changes in nutritional management and control of diseases. This latter issue involves genotype by environment interactions which are a serious constraint, especially when cattle of temperate origin are imported into the tropics. For maximum benefits, crossbreeding in tropical environments should be combined with within-breed selection, both of which seek to combine improved adaptation and performance (Franklin, 1986).

## 2.4 Selection criteria

It was seen in section 2.3 that the breeding objective is a statement of traits which affect the profit of the commercial farmer. However, some of the traits in the objective may be difficult or expensive to measure, may not show until after selection decisions are made or may be only poorly inherited. Under these circumstances, it may be possible to use a secondary indicator trait to aid in ranking of animals for selection (Cartwright, 1970; Blair, 1989). Such indicator traits are referred to as the selection criteria. The selection criteria are characters that will be measured to enable prediction of breeding values for traits in the selection objective. That is, they are traits on which selection decisions are based for selecting male and female candidates.

As an example to distinguish between breeding objective and selection criteria, suppose farmers are paid for lean carcass weight, and feed consumed by animals costs money. These traits can be included in the selection objectives. Carcass weight cannot be measured directly on the live animal (although semen/eggs may be collected from the animal prior to slaughter), and feed consumption is difficult or too expensive to measure. Therefore, it is necessary to choose selection criteria that could be used to improve these traits indirectly. Thus, the traits in the breeding objective are the ends whereas the selection criteria are the means to the ends. In this example, carcass measurements on relatives and growth rate could be used as the selection criteria for carcass weight and feed intake respectively. It should be noted that selection criteria need not be measured on the animals being selected but can be measured on relatives. However, modern techniques used for indirect assessment of carcass measurements allow ultrasonically measured fatness on the live animal to be used as a selection criterion.

The following are some of the important factors that need to be considered when choosing traits as selection criteria (Barlow, 1987). The characters chosen need to be:

- (1) heritable
- (2) correlated with traits in the breeding objective, and
- (3) measured simply and cheaply.

Under some circumstances, the set of selection criteria used in the selection programme

may be the same as the set of traits included in the selection objective for that programme. However, the criteria may be completely different traits from those in the objective. For example, Ponzoni and Newman (1989) included calving day in the objective and used the same trait as a selection criterion. They also used nine-month live weight and ultrasonic fat as selection criteria. Newman *et al.* (1992) also listed number of calves weaned per cow joined, birth weight, weaning weight, yearling weight and scrotal circumference as selection criteria. In the study of Newman *et al.* (1992), the number of calves weaned per cow joined was the only selection criterion that also appeared in the breeding objective.

Selection criteria should be adjusted for identified environmental variation (non-genetic effects), such as those for age-of-dam, birth- and rearing-rank, date of birth or age and sex effects, thereby making selection more accurate (Harris *et al.*, 1984). These environmental factors disguise the genetic expression for traits, and adjusting the measured performance of an animal for the various known environmental factors improve the rate at which genetic gain can be made (Blair, 1989). A technique known as Best Linear Unbiased Prediction (BLUP) is often appropriate as a procedure for simultaneously adjusting for fixed effects and predicting breeding values (Henderson, 1949, 1973).

The traits that are used as selection criteria should be appropriately weighted and included in an equation known as the selection index (I). The weights should be chosen to maximize the correlation between the index (I) and the breeding objective (H) (Ronningen and Van Vleck, 1985; Van Vleck, 1985; Van Vleck *et al.*, 1987). The index can be expressed as:

$$I = b_1 X_1 + b_2 X_2 + \dots + b_n X_n \dots \dots \dots (2.9)$$

where

I is the aggregate selection criterion which predicts the true genetic value of animals,

b's are the weights of the selection criteria,

$X$ 's are adjusted phenotypes of the selection criteria, and  $n$  is the number of selection criteria in the index.

To derive the weighting factors, the phenotypic variation in each trait, the heritability of each trait, the phenotypic and genetic correlations between traits, and the relative economic value for each trait in the selection objective need to be estimated.

## 2.5 Phenotypic and genetic parameters

Heritabilities, genetic correlations amongst criteria and traits in the objective, phenotypic correlations amongst selection criteria, and phenotypic variation (phenotypic standard deviations) are among the parameters that need to be estimated before weighting factors for the selection index can be calculated. The heritabilities and phenotypic and genetic correlations among the several traits included in  $H$  and  $I$  are required to solve the  $n$  equations resulting from the maximization of the correlation between the index and the objective ( $r_{HI}$ ). These estimates also enable prediction of response to selection for these traits or combinations of these traits within the production system.

Detailed definition, causes, characteristics and methods of estimating these parameters have been described in the literature (e.g. Hohenboken, 1985 a,b; Van Vleck *et al.*, 1987; Nicholas, 1987; Koots *et al.*, 1994a; Koots *et al.*, 1994b; Koots and Gibson, 1994). The magnitude of heritability of traits in relation to selection plans for various traits important in beef cattle production was discussed in section 2.3.4.

The phenotypic correlation between two quantitative traits describes the extent to which individuals above average for one trait tend to be above, below or near average for the other trait. It measures the linear association between traits; that is, it predicts the deviation from the population mean in one trait of an individual as a function of its deviation from the population mean of the other (when both are measured in their respective phenotypic standard deviation units). The phenotypic correlation can be partitioned into genetic and environmental components. The genetic correlation is a measure of the extent to which the same genes, or closely linked genes, cause co-variation in two different traits. It describes the extent to which individuals genetically

above average for one trait are genetically above, below or equal average for a second quantitative trait. Genetic correlations should be accounted for in any selection programmes for the following reasons (Blair, 1989):

- (1) if two characters are related, the consequence of increasing one upon the response in the other can be assessed. For example, an increase in weaning weight can result in some increase in mature body weight because of positive genetic correlations.
- (2) The accuracy of selection through using the information of all related traits to estimate the breeding value for any one trait is enhanced.
- (3) If characters are related, there may be an opportunity to select for one character and bring about a related or correlated response in a second character which might be harder or more costly to measure.

The theory of genetic selection indices as developed by (e.g. Hazel, 1943) and later elaborated by Henderson (1963), among others, is based on the assumption that the population parameters are known with precision. Ideally, estimates of these parameters necessary to predict response to selection should come from experiments with the particular breeds used in the breeding system and should involve all pertinent traits. This is however difficult to achieve in practise and estimates are usually developed from a search of the literature (Koots *et al.*, 1994a; Koots *et al.*, 1994b).

Underestimation of expected response in the aggregate genotype ( $H$ ) from selection based on a selection index ( $I$ ) can arise from sampling error of genetic parameters used in constructing an index (Williams, 1962; Harris, 1964; Hazel *et al.*, 1994). Constructing the index using estimates of these parameters is therefore likely to be less efficient than one computed from the true parameters. There are several reasons as to why estimates of parameters may be inaccurate (Hill, 1981). These include:

- (1) they may come from another population and perhaps not be appropriate,
- (2) they may be from a different generation, for example, the base population rather than the current population after some generations of selection, or if from the current population which is under selection, be obtained from relatives of selected individuals and be biased, and
- (3) all estimates are subject to sampling errors, because only limited numbers of

animals can be recorded.

The effects of errors in the parameter estimates and loss in efficiency in terms of size of sample used in estimation have been considered by various authors (Williams, 1962; Hayes and Hills, 1981; Koots and Gibson, 1994). Errors tend to increase as more traits are included in H (because there is a high probability that an array of genetic parameter estimates will be impossible), although, accuracy of estimation can be increased by using large data sets.

Estimates of parameters for economically important traits are scarce for several important traits, especially those involving food intake, food conversion efficiency, reproduction, carcass characteristics and disease traits (Koots *et al.*, 1994a; Koots *et al.*, 1994b). There is also a problem where the production system involves crossbreeding, because the correlations between purebred performance appropriate for selection criteria and crossbred performance involved in desired selection response have not been evaluated adequately for most classes of livestock (Harris *et al.*, 1984). In some cases it becomes very difficult to find estimates for genetic correlations. If this happens, genetic correlations can be assumed to be equal to phenotypic correlations (Simm *et al.*, 1987; Parrat and Simm, 1987; Ponzoni and Newman, 1989).

## 2.6 Selection index

The basic problem in animal improvement through breeding is to choose animals which have the greatest combined genetic value to be parents of the next generation. The value of an animal is usually affected by several traits. Therefore, the breeder has to consider all of these when choosing the most valuable animals as parents of the next generation. Hazel and Lush (1942) first examined three methods of selection for net merit, namely, "tandem selection", "independent culling levels" and "selection index" or "total score". These are the three methods of selection typically considered when selection is for multiple-traits. Abplanalp (1972) suggested a fourth method of "selection of extremes" whereby individuals are ranked for each trait separately, and set proportions of the highest ranking individuals in each trait are selected to give the

desired number of parents. It differs from the others in that selected individuals have to be the highest performing for any one trait, but not necessarily for several traits.

With respect to tandem selection, selection is practised for only one trait for one or more selection cycles until satisfactory improvement has been made in this trait. Selection efforts for this trait are then relaxed and efforts directed towards the improvement of a second, then a third and so on. Thus, animals are ranked on one trait considered important and culled on the basis for that trait. A question of interest is: "How is the amount of time determined that should be devoted to each trait and the order of priority for the traits"? Further more, if there is a long lists of traits, it will take considerable time before all traits have some selection imposed on them.

If there is a desirable genetic association among traits, selection for one trait will improve the others. If there is an undesirable negative genetic association among the traits, selection for one trait will nullify the progress made in another trait resulting in a poor overall efficiency. Though the tandem method is very simple to implement, these limitations make it inefficient to implement for multiple-trait selection and it is rarely used. However, if some traits are positively correlated, tandem selection can be used to improve traits whose phenotypic measures are expensive to obtain or cannot be obtained in every season (e.g. disease resistance).

With independent culling levels, selection is applied to each trait independently of the performance in any other trait. Selection may be practised for two or more traits at a time by setting a minimum standard (desired level of performance) for each trait and all individuals failing to make the standard for any one trait are culled or rejected without regard to their merit (superiority or inferiority) for other traits. The relative importance of each trait will determine the extent to which selection intensity is imposed on that particular trait.

The system has the advantage of being easy to operate even with large numbers of traits and also allows for progressive culling. When various traits are considered, it does not allow exceptionally high performance in one trait to balance poor production in another

trait. When two traits in the objective have an unfavourable genetic correlation, the use of independent culling levels will lead to animals that are elite for one trait, but being culled because some other trait fails to measure up. Other animals will be retained with average values for each trait. Thus animals desirable for one trait only are not allowed to contribute to the next generation. Independent culling levels are often used on temporal basis to improve conformation traits.

The selection index method involves the separate determination of the value for each of the traits to be selected for. Weighted combinations of these values are added to give a total score for all the traits i.e. by adding into one figure the credits and penalties given each animal according to the degree of its superiority or inferiority in each trait. The animals with the highest scores are kept for breeding purposes. The influence of each trait on the final score depends on its relative economic value, its heritability and the genetic correlations among the traits.

In general, whereas the independent culling levels technique is never less efficient than tandem selection, it is never more efficient than the selection index. In practice, the selection index is the best way to combine information from a number of traits, and it is the most efficient method which results in maximum genetic improvement per unit of time (Hazel and Lush, 1942; Young, 1961; Gjedrem, 1967a,b; Hazel *et al.*, 1994).

The first application of selection index theory to animal breeding was that of Hazel (1943). Since then many papers considering selection index theory, including reviews, have appeared in the literature (e.g. Legates and Lush, 1954; Henderson, 1963; Gjedrem, 1967 a,b; Vandepitte and Hazel, 1977; Philipson *et al.*, 1993; Hazel *et al.*, 1994). A formal definition of selection index is a weighted linear function of selection criteria or breeding values for each trait in the objective, with weights reflecting their relative importance. The selection index equation given in section 2.4 can also be expressed in the form:

$$I = \sum b_i X_i \quad (i = 1, \dots, n) \dots \dots \dots (2.10)$$

where

$b_i$  is the weight of trait  $i$

$X_i$  is the record for the  $i$ th trait in the objective, and

$I$  is the aggregate selection criterion which predicts the true genetic value of animals.

Note that  $X$ 's are expressed as adjusted deviations from the herd/flock mean.

In discussing the theory and use of selection index Henderson (1963) pointed out that the selection index can be used for several purposes, viz.: (1) selection on a single trait using information on the individual and certain of its relatives, (2) selection on two or more traits using records made by the individual, (3) selection on two or more traits using records from the individual and its relatives, and (4) selection of line crosses using data in addition to that on the specific cross. Van Vleck (1985), Ronningen and Van Vleck (1985) and Van Vleck *et al.* (1987) have presented the desirable properties of the selection index. Weighting factors for the index ( $I$ ) to predict some true value,  $H$ , should be chosen to: (1) minimize errors of prediction or the average or expected squared difference between  $H$  and its predictor,  $I$ , i.e. minimize  $E(H-I)^2$ , (2) maximize  $r_{HI}$ , the correlation between true additive genetic value ( $H$ ) and prediction of true value ( $I$ ) ( $r_{HI}$  can also be called accuracy of prediction or accuracy of evaluation), (3) maximize the probability of correct pairwise ranking of animals for their breeding values, and (4) maximize the average true value of the selected group. These criteria mean that the procedure is unbiased; that is, the average of  $H-I$  for all animals is zero. Whereas the first two of the above properties do not require records to have any special distribution, the last two require a joint normal distribution between  $H$  and  $I$  which is usually difficult to observe in practice, because the true additive genetic value ( $H$ ) is never known.

The solution of simultaneous equations, which maximize the correlation between aggregate genotype ( $H$ ) and the phenotypic index ( $I$ ), provide the unknown multiplier ( $b_i$ ) for each of the traits ( $i = 1, \dots, n$ ) in the selection index equations. The equations for  $n$  traits can be represented as:

$$\begin{aligned}
 & b_1 \text{Var}X_1 + b_2 \text{Cov}X_1X_2 + b_3 \text{Cov}X_1X_3 + \dots + b_n \text{Cov}X_1X_n = C \text{Cov}X_1H \\
 & b_1 \text{Cov}X_2X_1 + b_2 \text{Var}X_2 + b_3 \text{Cov}X_2X_3 + \dots + b_n \text{Cov}X_2X_n = C \text{Cov}X_2H \\
 & \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \\
 & \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \dots \dots \dots (2.11) \\
 & \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \\
 & b_1 \text{Cov}X_nX_1 + b_2 \text{Cov}X_nX_2 + b_3 \text{Cov}X_nX_3 + \dots + b_n \text{Var}X_n = C \text{Cov}X_nH
 \end{aligned}$$

The C in the first set of equations is given by  $\text{Var}(I)/\text{Cov}(H,I)$ . The constant C will not change the relative sizes of the b's or  $r_{HI}$  and is always set to unity (Ronningen and Van Vleck, 1985; Van Vleck, 1985; Van Vleck *et al.*, 1987), because  $\text{Var}(I)$  is taken to be equal to  $\text{Cov}(H,I)$ , thus making I a best linear predictor of H.

The alternative matrix representation is:

$$\mathbf{Pb} = \mathbf{Gv} \dots \dots \dots (2.12)$$

where,

- P is the phenotypic variance-covariance matrix among selection criteria,
- G is the genetic variance-covariance matrix between the selection criteria and traits in the objective,
- b is a vector of weightings to be solved for, and
- v is a vector of economic values of traits

The index weightings are given by:

$$\mathbf{b} = \mathbf{P}^{-1}\mathbf{Gv} \dots \dots \dots (2.13)$$

The difficulty with selection indices in trying to compile data from different sources such as different herds, breeds, sires etc. with numerous years, herds and seasons to consider in each category, the process of assessing correction factors become a tedious statistical exercise. This needs to be undertaken before sires/dams can be assessed as to their breeding value and then ranked in order. In addition, the true genotypic means of individual are not known in reality. The Best Linear Unbiased Prediction (BLUP)

developed by Henderson (1949, 1973) can be used to adjust for non-genetic and management effects and to predict genetic values simultaneously. BLUP allows appropriate economic weights to be applied as the last step for predicting aggregate breeding values for individuals of different age classes, and they simplify choosing the proportions of selected breeders from each age class that maximizes the rate of change in aggregate breeding value (Hazel *et al.*, 1994).

Except for large corporate breeding organizations, it is generally not feasible for individual breeders to develop their own selection indices, because these involve not only the relative economic weights for component traits, but also accurate estimates of heritability, variability, and genetic and phenotypic correlations (Hazel *et al.*, 1994). For this reason, it is helpful for an animal breeding enterprise to be part of a larger organization that can facilitate data recording and can compute individual breeding values for traits considered important, using information on relationships and on genetic parameters appropriate for the production system. The breeder can then apply the economic weights considered to be most appropriate for the breed role and for the production and marketing system to be served to obtain individual selection indices. These points suggest that it is very important for developing countries to organize the structure of their industries while attempting to define their breeding objectives.

### **Summary**

In practice, many beef cattle genetic improvement schemes do not have a stated breeding objective. Performance records and pedigree information are processed to provide genetic evaluations, based on estimated breeding values (EBVs), for each trait and for each animal. However, no attempt is made to combine these breeding values into an index. The list of traits that are typically considered in beef cattle selection programmes is often dominated by EBVs for growth traits, with little emphasis on reproductive and maternal characteristics. However, improvements in growth traits need to be combined with reproductive and maternal characteristics, because small cows with low maintenance requirements, high calving rate and good milking ability have the potential for an efficient breeding herd. Under such circumstances, beef breeders need

a breeding objective which considers all traits of importance to beef production, weighted according to their relative economic values. Index values can then be used to assess the economic consequences of selecting from among the available candidates. In this way, economic breeding objective can be defined to suit all sectors of the industry.

Since the desired endpoint of any genetic improvement programme is an improved economy of producing livestock products for the benefit of all consumers, the use of EBVs for genetic evaluation of beef cattle should be considered as a means to an end, and not the end itself. In the real competitive world of limited resources, the derivation of economic values is desired to define a breeding objective for beef cattle to provide economic direction for all breeding programmes. It is hoped that the integration of the conventional methods of deriving economic values with the economic theory approaches will provide a valuable background from which the choice of an appropriate method can be made. Whilst awaiting a clear definition of the breeding objective using economic theory, work on economic values should proceed alongside the establishment of logical target production levels (using EBVs) in breeding programmes, as was concluded by Newman and Ponzoni (1994).

## CHAPTER 3

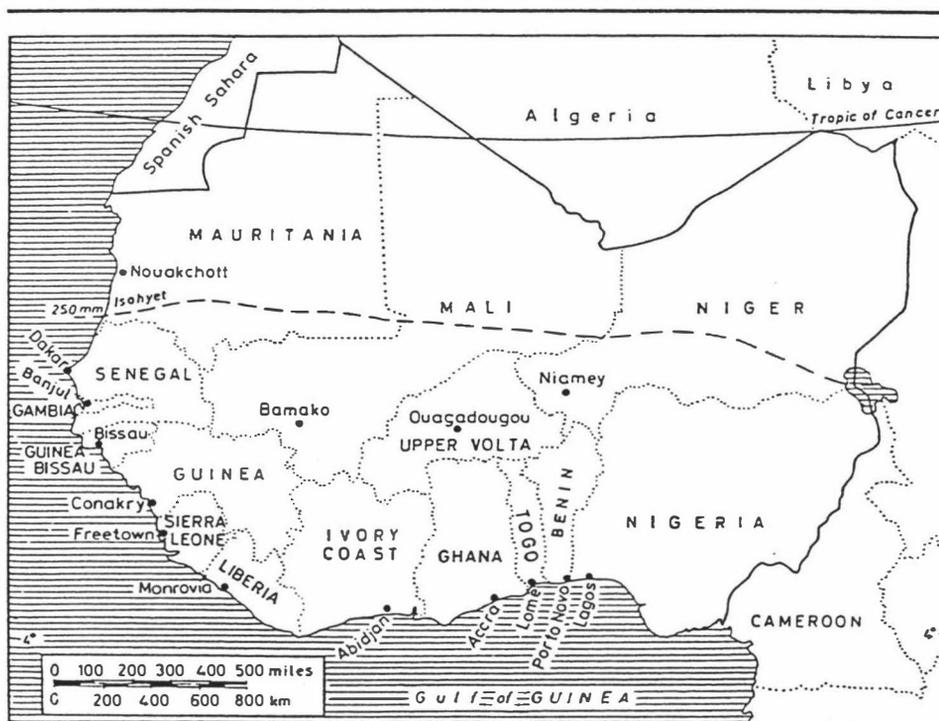
### CURRENT STATUS OF BREED IMPROVEMENT IN GHANA

#### 3.1 Ghana: Location, climate and vegetation, and population statistics

##### 3.1.1 Location of the country

Ghana is a tropical country located in the West African sub-region, south of the Sahara (Fig. 3.1). It is situated between latitude  $4^{\circ}$  and  $11^{\circ}$  north of the equator, and is approximately 644 km from the equator. Roughly rectangular in shape, it has a total area of about 238,540 square kilometres (land area is 227,540 square kilometres), which is slightly less than the United Kingdom (McFarland, 1985; FAO, 1993a). Located on the Gulf of Guinea, Ghana is bordered by three Francophone nations: Ivory Coast on the west, Burkina Faso (Upper Volta) on the north, and Togo on the east (Fig 3.1).

**Fig 3.1:** Ghana in its West African Setting (From: Udo, 1978)



### 3.1.2 Climate and Vegetation

Ghana's climate is determined by its position between the Atlantic and the Sahara. The southwest monsoon, with its cool moist breezes coming in across the Gulf of Guinea, brings rain to the southern part of the country, while the northeast Harmattan, with its desiccating gales from the desert, brings periods of drought to the northern parts (McFarland, 1985). These features divide the country into two main climatic zones; the humid and the sub-humid zones (Walker, 1962).

The humid zone occurs in the southern part of Ghana, and experiences a bimodal rainfall pattern with peaks in June to July (major rainy season) and September to November (minor rainy season). Major rains in this zone start in April and end in July, whilst minor rains also begin in September and end in November. August is a dry spell and is the coolest month of the year in this zone. In this zone, up to 55 % of the rains fall in the major rainy season, with 30 % occurring as minor rains, while the rest occur in the dry months of August and December to March (Osei *et al.*, 1991). The average annual rainfall of the humid zone is approximately 1500 mm.

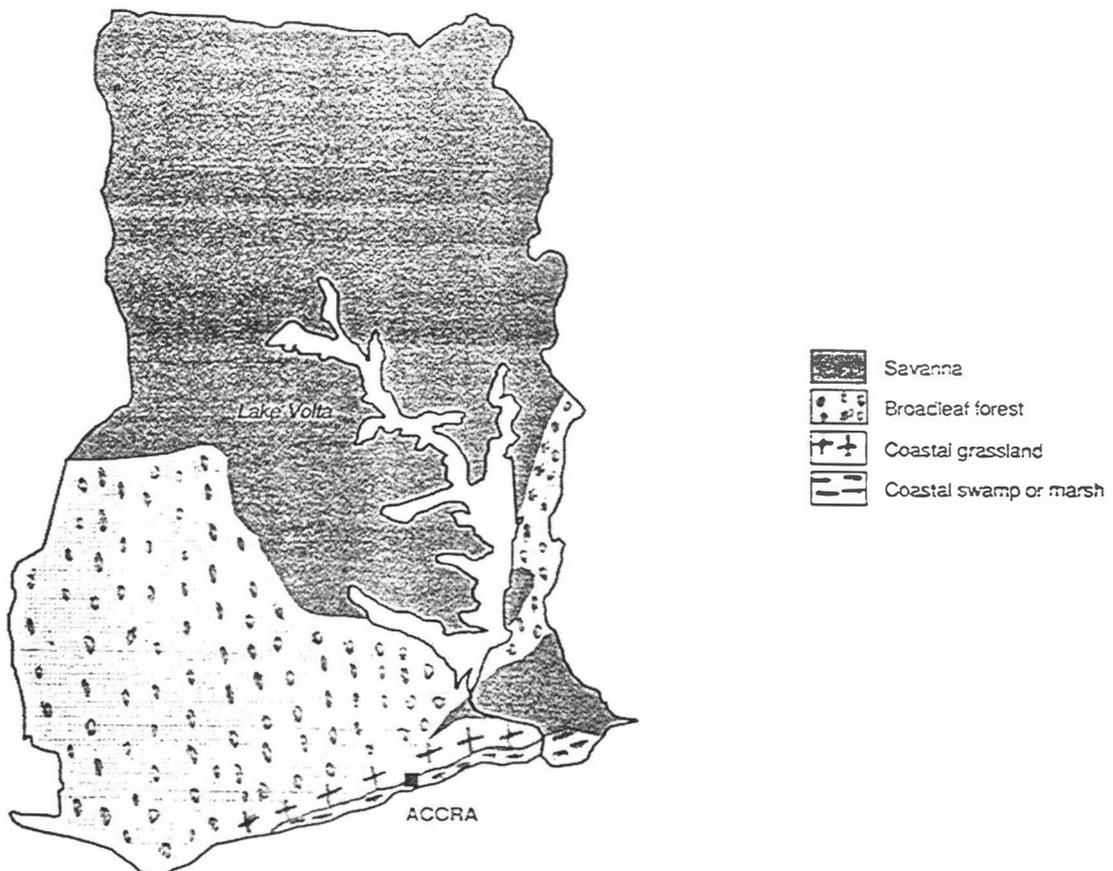
Rainfall in the north is unimodal, peaking in the June to July period, and is 1000-1100 mm per annum (Alhassan and Barnes, 1993). The north is characterized by rainfall that is seasonal, low, erratic and poorly distributed (McFarland, 1985). The dry season in the north, lasting from November to March, results in severe reduction in both the quantity and quality of forage. Feed shortage in this region is further worsened by rampant fire outbreaks during the dry season. The humid zone, on the other hand, has a well-distributed rainfall pattern which ensures the production of more adequate and high-quality herbage throughout the year (Tuah and Danso, 1985; Alhassan and Barnes, 1993).

Climate in the humid zone is generally hot and humid and the temperature ranges from 18°C at night to more than 30°C during the day, with average daily temperatures of 24°C (Alhassan and Owusu, 1980). Relative humidity in this zone varies: it is as high as 97 % during the wet season (April to November) and as low as 30 % during the dry

season (December to March). Mean minimum and maximum temperatures for the sub-humid zone are 26°C and 35°C respectively, with an average of 29°C. It is generally hot and dry in the sub-humid zone.

The vegetation can be divided into (a) savanna (b) forest (c) coastal grassland and (d) coastal swamp or mash (Fig. 3.2). The savanna which covers the entire northern region experiences a unimodal rainfall pattern, while the rest of the forest, coastal grassland and swamp areas have bimodal rainfall patterns. The north characterized by the poor soils, long dry seasons, hot weather and periodic storms and floods make it an unattractive place to live (McFarland, 1985). About 70 % of the total land area of Ghana is potential grazing land made up of savanna woodland (71000 km<sup>2</sup>), unimproved pasture (36000 km<sup>2</sup>) and bush fallow (60000 km<sup>2</sup>) (Alhassan and Barnes, 1993). The bulk of ruminant feeds come from these three ranges.

**Fig 3.2:** Vegetation Map of Ghana (From: Kurian, 1992)



### 3.1.3 Human population statistics

The population of Ghana is about 16 million with an annual growth rate of about 3.2 % (FAO, 1993a; World Bank, 1994). Current projections indicates that the population of Ghana is expected to reach 20 and 36 million by the years 2000 and 2025 respectively (World Bank, 1994). Though the population has been increasing annually at about 3.2 %, the percentage of economically active people in agriculture continues to decline over the years (Fig. 3.3). This is the direct result of the migration of people (especially the young) from the rural areas into the urban centres, resulting in the higher concentration of people in the urban centres (Fig 3.4).

**Fig. 3.3:** Population growth and percentage of people involved in agriculture (Adapted from: FAO, 1974-1993a)

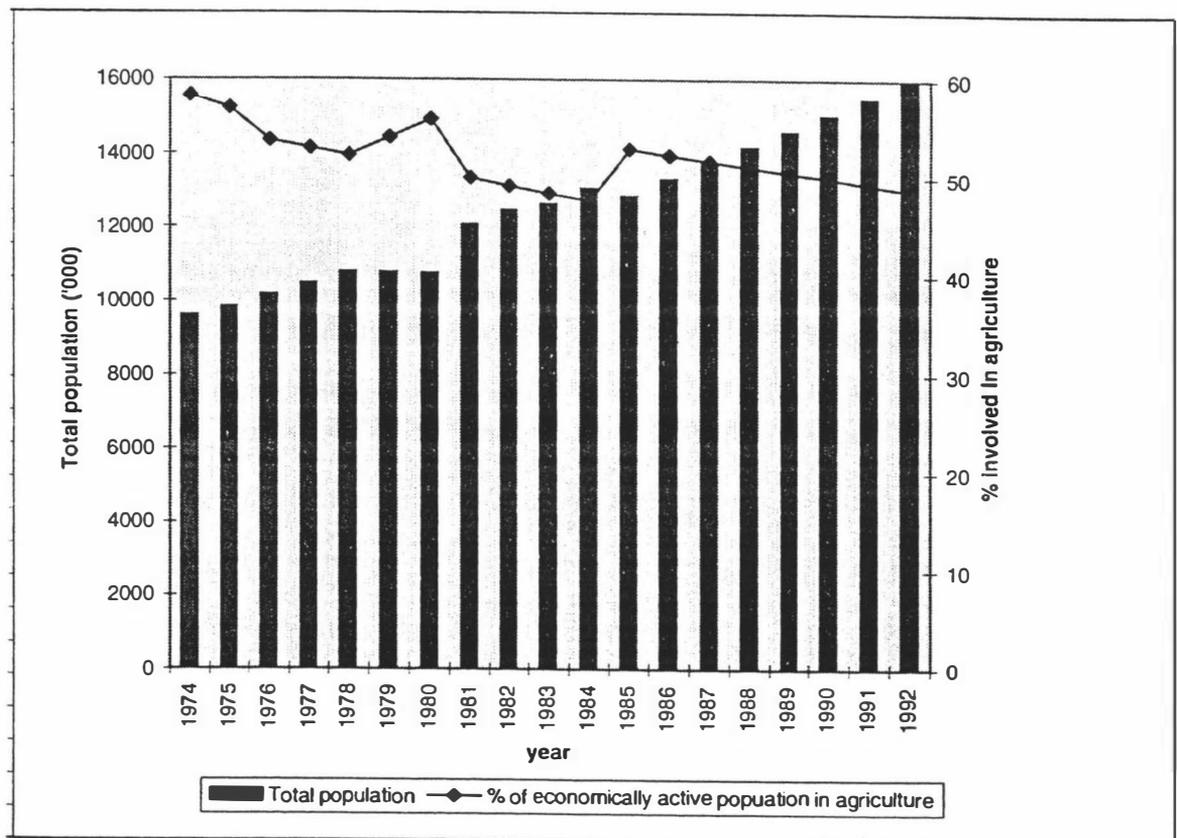
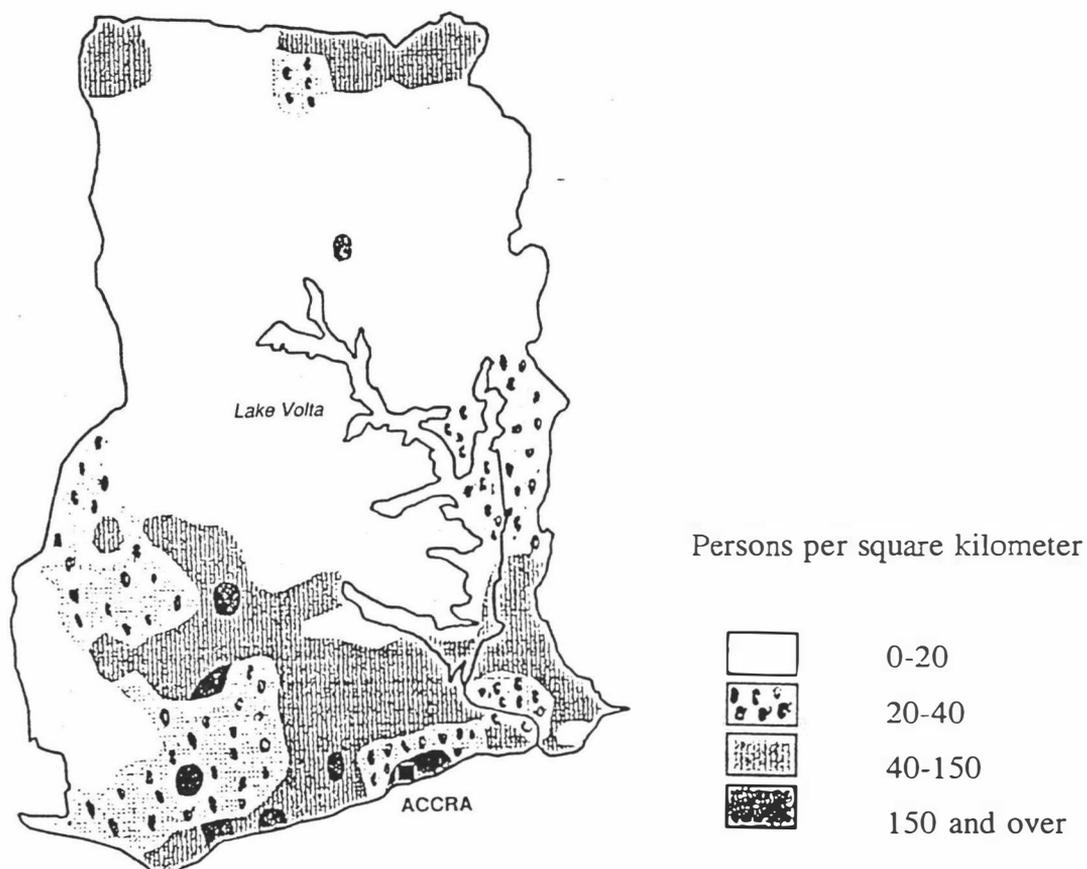


Fig 3.4: Population distribution in Ghana (From: Kurian, 1992)



There has been a tendency for the population increment to spill out of the countryside into towns and to forgo farming for urban occupations. This trend has existed since the 1960s. The 1960 census showed that while five-sixths of males (40-60 years old), lived in rural areas, only two-thirds of males (20-24 years old) did so, and while three-quarters of the former were farmers or fishermen, only half of the latter were (Caldwell, 1977). While 26 % of the total population in 1965 lived in urban areas, the comparable figures for 1970, 1988 and 1992 were 29 %, 33 % and 35 % respectively (World Bank, 1990, 1992, 1994). The majority of migrants belong to the poorer groups of the population, suggesting that migration is indeed strongly induced by economic reasons (Roe *et al.*, 1992).

The lowest concentration of people is found in the north where the vegetation is savanna, whilst the population is becoming increasingly concentrated in the more

economically advanced south of the forest and coastal areas (Fig. 3.4). Estimates from Alpine and Pickett (1993) indicate that only 19.5 % of the total population of Ghana live in the north.

There is a vast difference between the north and the south in terms of export, production, industrialization, transportation, and urbanization. The northern region is characterized by the predominance of subsistence agriculture. The south encompasses the area in which the export or "market" sector of the economy predominates. The main natural resources of the country, viz. timber, gold, diamonds, bauxite, manganese and rubber, and the cocoa farms are all located in the south (McFarland, 1985; Roe *et al.*, 1992). Although, it accounts for 47 % of the total land area of Ghana, the north produces only 14 % of the total agricultural produce in Ghana (Roe *et al.*, 1992).

Most of the largest towns are located in the south and because of this and its historical strength in the export industries, it also benefits from a disproportionate part of the infrastructure. There is major gap between the physical quality of life indicators (e.g. infant mortality, life expectancy and literacy rate) in the north relative to the country as a whole. For example, the physical quality of life indicator (PQLI) scores in rural areas in the north were found to be between 13.0 and 13.9 as against scores of between 36 and 52 in the south (Roe *et al.*, 1992). In more detail, the southern region is the area within which the traditional economy has been largely transformed through the production of agricultural crops for export resulting in commercialization, and through mining resulting in an exchange economy. The developed schemes in the north have been mainly agriculture and land planning schemes directed at soil conservation. Such schemes leave the majority of the people as subsistence farmers (Forde, 1968).

In relation to the provision of essential services such as education and health, it is well established that British colonial administrators paid far less attention to the north than to the more productive south (Caldwell, 1977). The minimal educational provision of that period has left the north with a serious legacy of deprivation in this regard. School enrolment rates in the north are considerably lower than national averages and some features of school organization - such as timing of school year are geared more to the

agricultural cycle of the south than that of the north. As a result, the north has a very low level of education, though they continue to enjoy free education (a facility which is not available to southerners) which was introduced since independence, 40 years ago. Though the average percentage of adult literacy rate in Ghana is about 55.5 % (World Bank, 1994), the figure for the north would be far less than the national average. In terms of health provision, reports indicate that some physical indicators of health attendance in the north stand at only one-quarter of the level that would be expected if access and usage were equal across the country (Roe *et al.*, 1992).

In summary, it can be said that the northern and southern parts of Ghana reflect the concept of regional inequality in the growth of economic development, similar to that occurring between the developed and the developing worlds. This socio-economic differential has led to constant southward movement of people who seek employment in the mines, towns, and cocoa farms in the southern region. The effect of this is the continual drain of labour, capital and other resources from the north to the south. The loss of the farming population from the north has also been accompanied by the abandonment of some farms and some farming lands. From the foregoing, one realizes that there would be increased demand for more meat in the south than in the north.

### **3.2 Meat production and consumption in Ghana**

The share of agriculture (defined to include crops, livestock, forestry and fisheries) in the national gross domestic product (GDP) has varied from 44 % in 1965 to 47 % and 49 % in 1970 and 1992 respectively (World Bank, 1990, 1994). The contribution of livestock to the agricultural GDP is estimated to be 9 %, or 4 % of the national GDP. The real contribution is likely to have been somewhat higher, as the limited production of milk and skins, and the contribution of animal manure and draught power provided by oxen to crop production was excluded from the estimates. For example, between 1991 and 1993, an annual average of 2,576.7 tons of cattle hides was produced in Ghana (FAO, 1993a).

The contribution of cattle to the total domestic meat supply is estimated at 38 %, the

poultry industry being the second largest contributor of 25 %, while the small ruminants (sheep and goats) and pig industries contribute about 20 and 17 % respectively (FAO, 1993b). Thus, ruminant and non-ruminant livestock provide approximately 58 and 42 % respectively of the total meat produced from domestic livestock. Wild game contributes some proportion, but there is paucity of information on this aspect. Food other than meat that provide animal protein include milk, eggs and fish.

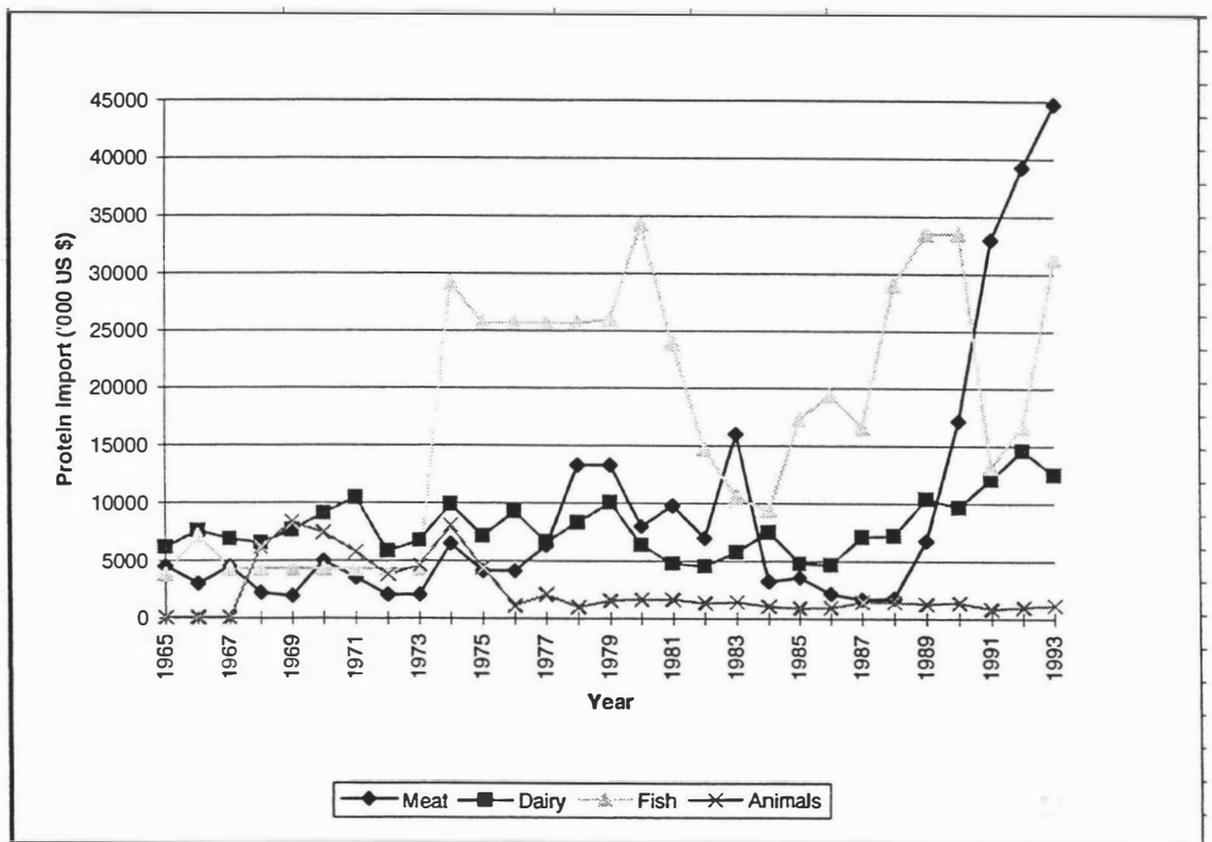
The importation of animal protein sources of food forms an important part of food merchandise trade in Ghana. The average contributions of meat and meat products, live animals, dairy products and eggs and fish and fishery products between 1990 and 1993 to the total cost of food imports was about 36 % (FAO, 1990-1993b). Beef imports alone contributes about 82 % to the total value of fresh and frozen meat imported into Ghana (FAO, 1993b). When imported live animals are included into this amount, then, Ghana produces only 43 % of the total beef consumed in the country, the rest being imported from neighbouring countries such as Burkina Faso, Niger, Mali and Guinea. Foreign exchange constraints dictate that such a situation cannot be allowed to continue.

Although, the importation of animal protein sources has increased dramatically since 1965 (Fig. 3.5), there is still less meat available per capita (FAO, 1993a). Meat consumption in Ghana is limited by high prices and supply is always considerably less than the demand, a state of affairs which is aggravated by a continually increasing population. The average protein supply per capita per day is only 13.7 g (FAO, 1993a), as against the normal requirement of about 60g per capita per day (Spedding *et al.*, 1981). Indeed, the average Ghanaian diet is somewhat deficient in protein, no wonder, kwashiorkor, the name of the disease that afflicts protein deficient children, is actually derived from a Ghanaian word.

If the deterioration in the national diet is to be reversed, then additional animal protein food will either have to be imported or produced locally. Milk production is likely to remain negligible in the tropics and production of eggs, poultry meat, and pork will depend upon adequate quantities of maize and other feeds such as anchovy fish being available in excess of human requirements. There is therefore a need to increase meat

production. Major increases in meat production can only come from ruminant livestock, for the simple reasons given above. This will entail a very large increase in the ruminant livestock population and improvements in individual animal productivity. This has been recognized, and a national livestock development programme has been put into place (NLDP, 1991).

Fig. 3.5: Importation of Protein Sources into Ghana (Adapted from: FAO, 1965-1993b)



### 3.3 Breeds of cattle in Ghana

The traditional or local breeds of cattle in Ghana are the humpless Shorthorn (*Bos taurus brachyceros*) and N'dama (*Bos taurus longifrons*) cattle (Monstma, 1963; Epstein, 1971; Sada and Vohradsky, 1984; Mason, 1988; Rege *et al.*, 1994a). The Shorthorn cattle can be distinguished into two subgroups: West African Shorthorn (WASH) and Dwarf

Shorthorn (Epstein, 1971; Maule, 1990). The exotic beef cattle breed in Ghana is the Zebu of the *Bos indicus* breed. Different types of Zebu can be found in Ghana and include: Maure Zebu, Nellore Zebu, Toureg Zebu, Azawak Zebu, Arabe or Choa Zebu, White Fulani and Sokoto Gudali (Ngere, 1990; Lhoste, 1991; Hoste *et al.*, 1992). Some European cattle breeds have been used for various crossbreeding projects in Ghana. These include Holstein Friesian, Santa Gertrudis, Red Poll and the Jersey. The national herd also contain Sanga cattle which are crosses between the Zebu and either the Shorthorn or N'dama (Mason, 1988; Lhoste, 1991).

### 3.3.1 *Origin and distribution of cattle in Ghana.*

The Shorthorn cattle were brought to West Africa by either the Barbary tribes of southern Morocco (Epstein, 1971) or by the first Portuguese sailors (Payne, 1970). The term "Shorthorn" is a literal translation of the Greek term "brachyceros" (more correctly brachykeratos); it has no connection with the British Shorthorn breed of cattle (Epstein, 1971). The southern coastal area of Ghana is the habitat for some typical Dwarf Shorthorn (forest type) known locally as lagoon cattle (Rege *et al.*, 1994a; Lhoste, 1991). Ghana is also home to reasonably large numbers of Savanna Shorthorn also known locally as Ghana Shorthorn and for which the broader name West African Shorthorn (WASH) is sometimes used. Distributed in all parts of Ghana, the West African Shorthorn form the largest population of cattle in Ghana (Sada, 1968; Hoste *et al.*, 1992). For this reason, most of the discussions on the Shorthorn cattle will be restricted to the West African Shorthorn.

The N'dama cattle in Ghana originated from French Guinea, where it has spread out from its centre in the Guinean Massif of Fouta Djallon mountains (Sada, 1968; Epstein, 1971). Like the Shorthorn cattle, it is also distributed in the forest and savanna areas of Ghana. The majority of the cattle found in the humid, tsetse infested areas of the south are the humpless N'dama and Shorthorn cattle.

Zebu cattle in Ghana originated from various sources. These include: Mauritania (Maure Zebu), Mali (Toureg Zebu), Niger (Azawak Zebu), Brazil (Nellore Zebu), Chad

(Arabe or Choa Zebu) and Nigeria (Sokoto Gudali and White Fulani) (Ngere, 1990; Lhoste, 1991; Hoste *et al.*, 1992). The Zebu population in Ghana is therefore represented by a diversity of genetic types and the actual dividing lines between these groups are not easy to specify. They are found in all parts of the country but are mostly restricted to the driest areas of the north, and are increasingly becoming popular with the smallholder livestock farmer mainly as a sire breed to improve the size of the Ghana Shorthorn and N'dama cattle (Lhoste, 1991; Okantah, 1992; Rege *et al.*, 1994a).

In the intermediary areas (transition between north and south), different crossbreed populations (Sanga) have developed. The incidence of crossbreeding is still very pronounced in certain areas according to ecological or socio-economic factors related to production methods. The process that occurs in the majority of cases is that the humpless breed is being replaced due to repeated crossing to the Zebu; the Zebu being the bigger animal. The new populations thus obtained reveal qualities favourable to breeding and to the needs of agriculture: size, draught power, acceptable meat etc. However, this trend, if uncontrolled, would threaten the existence of the humpless breeds whose genetic characteristics particularly favour adaptability to the environment (Ngere, 1990).

Jersey, Santa Gertridus, Red Poll and Holstein-Friesian have been used for crossbreeding at the University of Ghana Agricultural Research Station (Kahoun, 1970, 1972; Ngere and Cameron, 1972; Ngere, 1974; Sada and Vohradsky, 1978 & 1982; Danboro *et al.*, 1991; Ahunu *et al.*, 1993; Ahunu *et al.*, 1994; Rege *et al.*, 1994c), whilst Holstein-Friesians have been bred pure at the University of Science and Technology Boadi Project Farm (Kabuga and Agyemang, 1983, 1984a & b; Osei *et al.*, 1991). These projects aim to demonstrate the feasibility of raising exotic dairy cattle in the humid zone, and to evolve appropriate procedures for adoption by prospective dairy producers.

Since the inception of the University of Ghana Dairy Cattle Project, sires have continued to be bought in from offshore, with the importation of frozen semen from Europe. On the other hand, the Boadi Cattle Project was initiated by the importation of live animals from Canada. Based on the performance of these projects, coupled with the scarcity of

foreign exchange for the importation of milk and milk products, the government of Ghana established the Amrahia Dairy Cattle Project near Accra in the coastal grassland zone using Friesian cattle (Akwensivie and Acheampong, 1987).

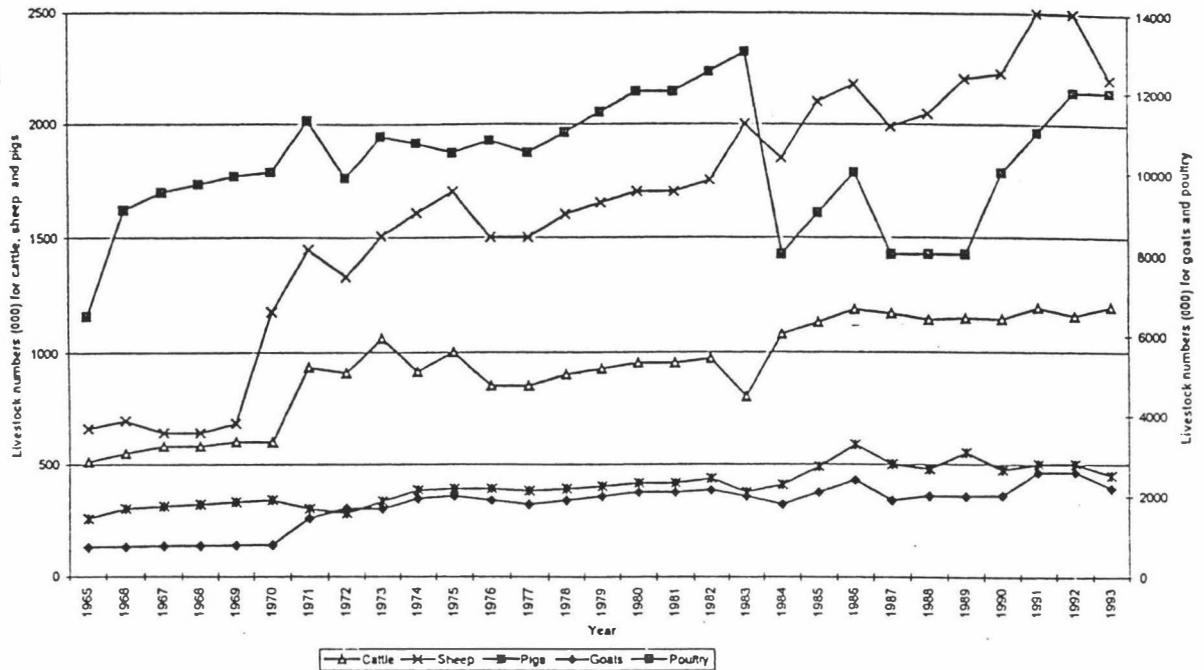
The distribution of cattle in Ghana remains uneven. Generally, cattle production in Ghana is restricted to the savanna zones of the northern region and the coastal grassland areas of the southern region. The northern sector of Ghana, which accounts for about 47 % of the total land area, holds about 74 % of the national herd, whilst the coastal plains of the southern grasslands accounts for 18 % (Hoste *et al.*, 1992). The remainder (8 %) of the national herd is distributed in the tsetse infested forest zone of the middle belt.

### 3.3.2 *Livestock population statistics*

The cattle population in Ghana have expanded during the last 30 years (Fig. 3.6). It increased during the nineteen sixties, declined slightly during the seventies, and increased more rapidly during the eighties and the early parts of the nineties. Sheep and goats numbers increased rapidly throughout the period (Fig. 3.6). The pig population has fluctuated widely in number but the total has almost doubled during the period, while the poultry population exploded during the late sixties and early seventies with the importation of new technology and new breeds. Poultry numbers have since been somewhat reduced and now appear to be more or less stable; expansion being checked by the limited availability of maize and other feed ingredients such as anchovy fish.

Trypanotolerant (ability to survive in tsetse infested zone) cattle account for 86 % of the total cattle population (Hoste *et al.*, 1992), which is estimated at about 1.2 million (FAO, 1993a). The Shorthorn cattle which forms about 70 % of the total cattle population accounts for 83 % of the trypanotolerant cattle population, with the N'dama contributing the remainder. The remainder of the national herd consist of N'dama (16.8 %), Sanga (12.4 %) and Zebu (0.8 %).

Fig 3.6: Livestock Numbers in Ghana (Adapted from: FAO, 1965-1993a; ILCA, 1993)



Although the number of ruminant livestock units has increased at about the same rate as the human population (4.0 % vs 3.2 %) (ILCA, 1993), the effect of this increase on the availability of total meat consumed per capita has not been marked. For example, animal protein consumption only increased from 10.9 g per capita per day in 1966 to 13.7 g per capita per day between 1988 and 1990 (FAO, 1966a & 1993a). It was primarily due to an increase from the non-ruminant sector, which slightly improved per capita supplies. It is therefore necessary to realize that large increases in livestock numbers do not necessarily mean an increase in productivity and hence an increase in protein per capita per head (Brumby, 1973; Josiorowski, 1973, 1991; Vohradsky *et al.*, 1993). For example, the average carcass weight of slaughtered cattle in Africa is 145 kg per animal as against 206 kg per animal in the World (Vohradsky *et al.*, 1993). On purely technical grounds, the most important progress is increased output per animal, which is a measure of overall efficiency (Harris, 1970; Dickerson, 1970; Spedding *et al.*,

1981; Morris *et al.*, 1994). Clearly, the increased meat production in Ghana which is largely due to an increase in livestock numbers, and not to increased productivity, cannot be allowed to continue, since this is not sustainable (Parry, 1994; Spedding, 1995). Resources are scarce, and the environment's ability to meet present and future needs must be controlled.

Since Ghana is a country with low cattle density (Table 3.1), an opportunity exists for a major expansion in both the number and productivity of cattle population. Any increase in the local production of animals will simultaneously assist in improving the national diet and spare foreign exchange used for the importation of meat and meat products.

**Table 3.1:** World cattle densities

Location	Head of Cattle/km <sup>2</sup>	Head of cattle/inhabitant
World	10	0.2
Africa	6	0.3
USA	11	0.4
New Zealand	32	2.5
Ghana	5	0.1

Adapted from: FAO (1993a)

### 3.4 Characteristics of cattle in Ghana

#### 3.4.1 Physical characteristics

##### *Shorthorn cattle*

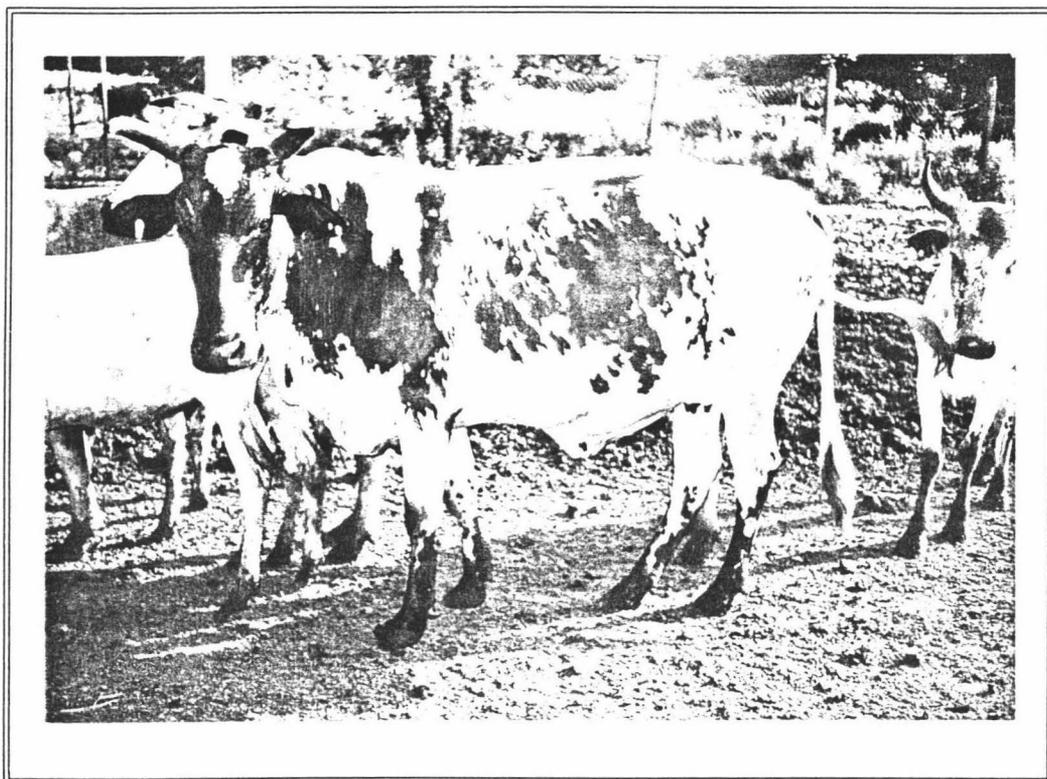
The characteristics of the West African Shorthorn (Ghana Shorthorn) and Dwarf Shorthorn cattle are quite similar. A general description for the two breeds shall be

given, but where real differences exist between the two, these would be specified. The physical characteristics of the Shorthorn cattle have been described (Epstein, 1971; Ngere and Cameron, 1972; Sada and Vohradsky, 1984; Maule, 1990; Aboagye *et al.*, 1994).

The Shorthorn cattle is a small-sized breed with short horns (Fig. 3.7). It is deep bodied with well sprung ribs giving it a back that is less level and broad with well developed musculature, an indication of good beef conformation. Its head is short and wide, neck short and thick and forehead flat. It has short and thin horns averaging about 20 cm in length, which are usually bent outwards and downwards. Polled Shorthorns are rare. The top line is concave with rising rump. The hump is absent and the dew lap is poorly developed, typical of *Bos taurus* breed. They vary considerably in colour markings: black and white animals are common, in addition to their patterns such as solid black, white and mottled black and white with various shades of brown and yellow. Spotted animals occur very frequently, and there is never a single-colour body coat, except for black or white animals which, however always have colour patches. The skin is thick and dark-pigmented and hair is fine and short.

The West African Shorthorn cattle is slightly larger and heavier than the Dwarf Shorthorn cattle. Summary of data from various sources (Monstma, 1959; Ngere and Cameron, 1972; Aboagye *et al.*, 1994) indicates that West African Shorthorn stand at about 109 cm at withers and are about 124 cm long, while the forest Dwarf Shorthorn stand at 92 cm at withers and is about 107 cm long. The size of the Dwarf Shorthorn may have resulted from natural selection in the humid forest environment, characterised by poor nutrition, a high prevalence of parasitic diseases, such as trypanosomiasis, and very harsh climatic conditions (Aboagye *et al.*, 1994).

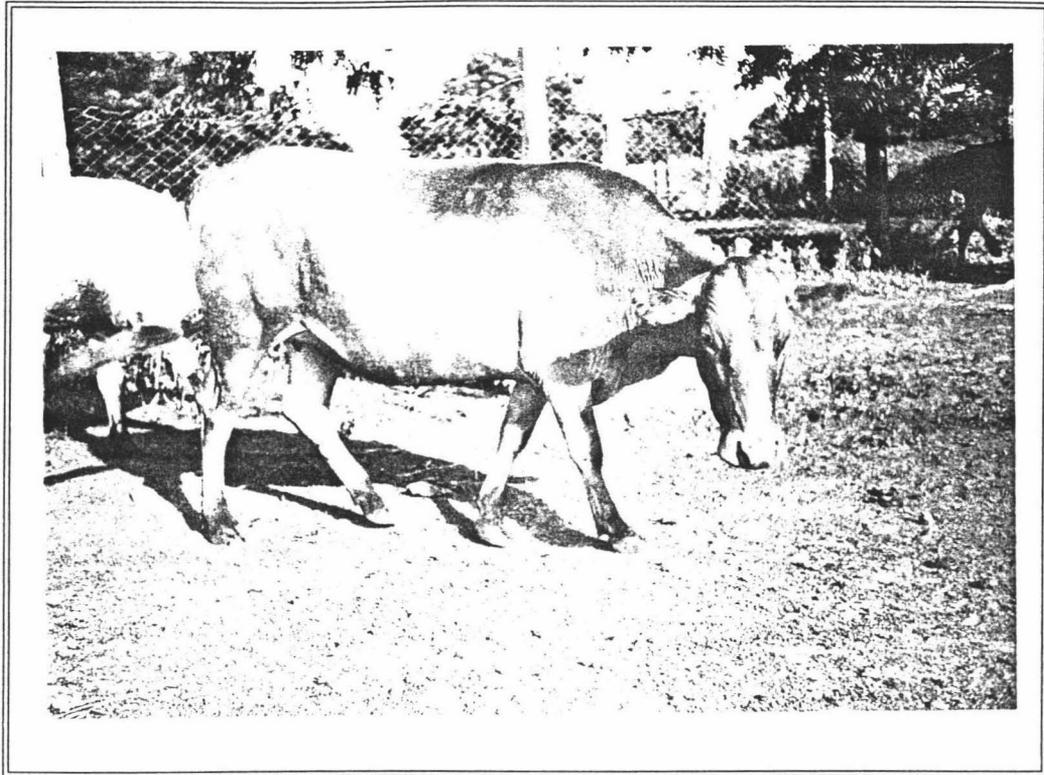
**Fig. 3.7:** West African Shorthorn cattle from Pong-Tamale Livestock Breeding Station, Ghana



*N'dama cattle*

The N'dama cattle have been described by Epstein (1971); Ngere and Cameron, 1972; Sada and Vohradsky (1979); Starkey (1984); Maule (1990), among others. They are small humpless breed characterised by their small size and long lyre shaped horns (Fig. 3.8). The horns are thick, about 40-60 cm in length and are light brown with black tips. The long horns are curved, round, projecting first outwards and then upwards with a turn at the tips giving them their characteristic lyre shape. Polled individuals occur in the N'dama breed. The characteristic coat colour is an attractive light brown or fawn. There are also variety of colours ranging from light yellow to dark red and brown. A Black-pigmented shading is sometimes seen on the chest, back, and rump of bulls. The skin is thin and hairs are fine and short.

Fig. 3.8: A polled N'dama cow from Pong-Tamale Livestock Breeding Station, Ghana.



The N'dama cattle have many characteristics associated with beef breeds: straight back, well-muscled rump and good beef conformation set on short legs. The bull is particularly thickset, with a short, strong neck and moderately developed dewlap. The female is of a lighter build, with a small dewlap, and has a fairly small udder with thin teats.

Although the N'dama is similar in conformation to the Shorthorn cattle, it is slightly bigger than the latter. The N'dama stand at about 114 cm at withers and are about 125 cm long (Ngere and Cameron, 1972; Sada and Vohradsky, 1979).

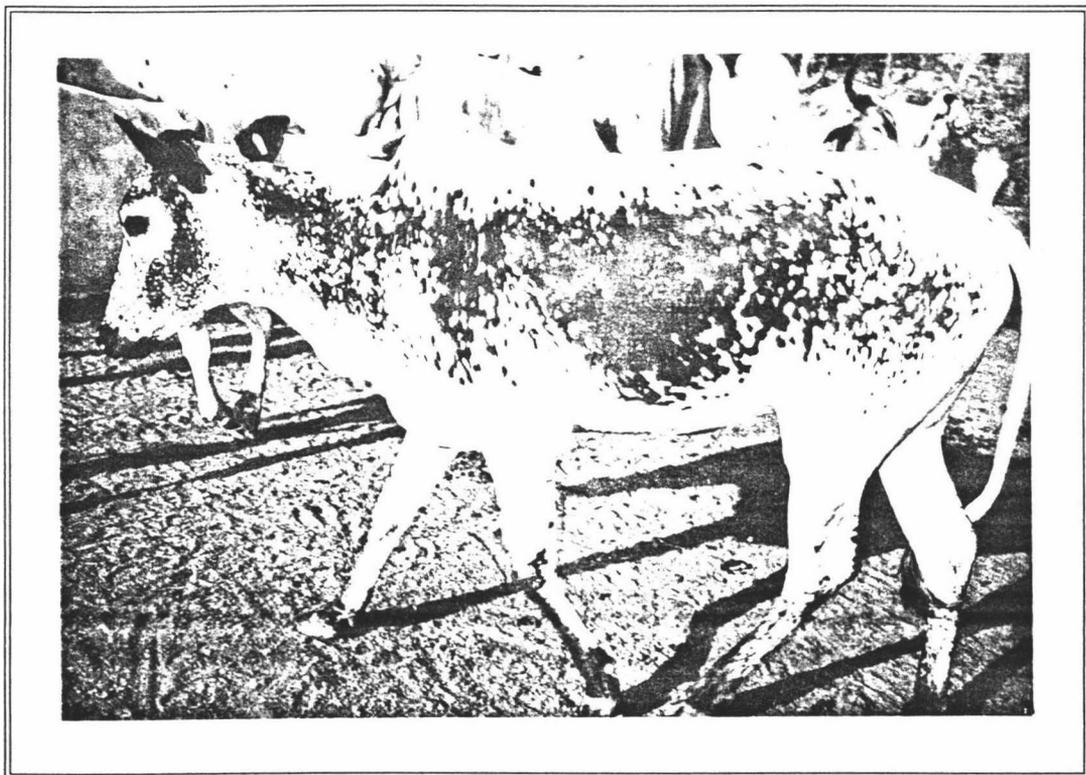
#### *The Zebu cattle*

Like any cattle of the *Bos indicus* breed, the Zebu cattle in Ghana are humped, and tall (Fig. 3.9). Due to the diversity of genetic types resulting from different origins of the breed in Ghana, it is difficult to draw the actual dividing line between these groups. They range from medium-sized animals with moderate thin horns to heavier and more

powerful animals with short to long horns. Four principal groups based on the length of the horns have been recognized (Lhoste, 1991). These include:

- (1) Short-horned Zebu e.g. Maure and Toureg
- (2) Medium-horned Zebu e.g. Adamawa
- (3) Lyre-horned Zebu e.g. Peul
- (4) Long lyre-horned Zebu e.g. red Mbororo.

**Fig. 3.9:** A Zebu heifer from Pong-Tamale Livestock Breeding Station, Ghana.



Generally, Zebus are taller, bigger, more powerful and heavier than N'dama and Shorthorn. There is paucity of data in the literature about the dimensions of the Zebu cattle in Ghana. As said earlier, the Zebu is mainly used as a sire breed in Ghana to improve the size of the local cattle through crossbreeding. Crosses between any of the locals and the Zebu are normally called Sangas.

### 3.4.2 Adaptive (survival) characteristics

#### *Disease tolerance*

Trypanosomiasis has generally been held to be the most important factor limiting the spread of some types of cattle to all parts of West Africa (Ngere, 1990; Murray *et al.*, 1991). Trypanosomiasis is a disease caused by the tsetse fly (*Glossina spp.*) which transmit various species of pathogenic trypanosomes to livestock (Starkey, 1984; Murray *et al.*, 1986; Murray *et al.*, 1991). About 20 species of the fly have been recorded in Africa, each existing in its own fly belt which is determined by vegetation, though overlaps do occur (Caswell, 1962). The major pathogenic trypanosome species include *Trypanosoma congolense*, *Trypanosoma vivax*, *Trypanosoma brucei*, *Glossina Palpalis*, *Glossina morsitans*, *Glossina Pallicera*, *Glossina tachinoides* and *Trypanosoma simiae* (Murray *et al.*, 1991).

The disease is enzootic, and either precludes the rearing of Zebu cattle or cattle of European breeds, or makes it risky rearing any of these in tsetse infected areas (Roberts and Gray, 1973; Akol *et al.*, 1986; Pinder *et al.*, 1987). Tsetse-transmitted trypanosomiasis not only result in severe losses in production in domestic livestock due to poor growth, weight loss, low milk yield, reduced capacity for work, infertility and abortions, but also exclude domestic livestock from large areas of Africa (Murray *et al.*, 1991).

A survey conducted between 1979 and 1983 by the government of Ghana, in collaboration with the Federal Republic of Germany in the northern part of Ghana revealed that tsetse infestation was relatively low in the north except in a few areas around the Red Volta which had a high level of infestation (Taylor, 1984; Gyening, 1985, cited by Hoste *et al.*, 1992). According to the survey, *Glossina palpalis* and *Glossina tachinoides* were found in areas bordering the major rivers. *Glossina morsitans submorsitans* were also found.

The more humid tropical forest and the coastal grassland areas of the south of Ghana-

with thick undergrowth and densely wooded river basins which favour the *Glossina spp.*, vectors of this disease has long been held to be inimical to the Zebu cattle which otherwise might have been successful in these ecozones (Murray *et al.*, 1986; Sumberg and Cassaday, 1985; Ngere, 1990; Hoste *et al.*, 1992). The only breeds of cattle which can survive in those zones without heavy chemotherapy are the N'damas and the Shorthorns or their variants (Ngere, 1974; Turton, 1991; Lhoste, 1991; Murray *et al.*, 1991; Hoste *et al.*, 1992; Aboagye *et al.*, 1994). However, there is an evidence that the Accra plains of the coastal grassland zone of Ghana has a very low tsetse fly challenge and hence, scarcity of animal trypanosomiasis (Marchot *et al.*, 1989). Certain populations of humped cattle (Zebu) have been able to survive in this environment, regarded as unfavourable to breeding, for centuries without any veterinary care at all.

The N'dama and Shorthorn cattle are thought to possess some tolerance, if not resistance to trypanosomiasis and are referred to as being "trypanotolerant", in contrast to the Zebu cattle which is "trypanosusceptible" (Roberts and Gray, 1973; Murray *et al.*, 1986; Akol *et al.*, 1986; Pinder *et al.*, 1987; Murray *et al.*, 1991). This means that the N'dama and WASH can maintain a certain amount of production in a disease environment that would be fatal to some other breed(s). Trypanotolerance is associated with the ability to control parasitaemia and to resist the development of anaemia in the face of infection. In other words, trypanotolerant cattle can thrive in areas where other cattle would suffer high morbidity and mortality from the disease. The resistance of N'dama to the disease is not only to the local strain of trypanosomes, as in the Shorthorns, but extends to other strains, as evidenced by its satisfactory performance outside its natural environment (Ngere, 1974). However, Stewart (1951) and Vohradsky and Sada (1979, 1984) have provided evidence that both the Shorthorn and N'dama are resistant to all strains of trypanosomes.

The ability to control parasitaemia and to resist the development of anaemia (trypanotolerance) are highly heritable and genetically correlated with production (Murray *et al.*, 1991). Elevated or higher Packed Red Cell Volume (PCV) has been shown to be an indirect indicator of resistance to anaemia in cattle due to trypanosomiasis infection (Trail *et al.*, 1991). The repeatability and heritability are

reasonably high and there are positive genetic correlations of PCV with production traits. Results presented by Trail *et al.* (1991) suggest that cattle with improved resistance to the effects of trypanosomiasis can be identified and selection based on higher PCV could be used to improve both productivity and disease resistance.

Electrophoretically determined haemoglobin components of the blood, particularly component A, are also asserted to be important for determining trypanotolerance in cattle (Bangham and Blumsberg, 1958). Two forms of haemoglobin, A and B can be distinguished in the blood of cattle by means of electrophoresis. The presence or absence of the different electrophoretic forms of haemoglobin is determined by two allelic autosomal genes which are fully expressed in the heterozygote. The three phenotypes, bovine A (slow moving component in electrophoresis), bovine B (fast moving component in electrophoresis), and bovine AB (both haemoglobins present) have been found in N'dama cattle (Bangham and Blumberg, 1958). The presence of component A of haemoglobin is associated with a high degree of trypanotolerance.

The results of haematological studies performed in Ghana to determine the haemoglobin components of N'dama and West African Shorthorn cattle by the use of electrophoresis are presented in Table 3.2. The results indicate that both the N'dama and West African Shorthorn cattle are highly trypanotolerant. In neighbouring West African Gambia, trypanosomiasis incidence was found to be significantly higher in Zebu than in N'dama (Leperre and Claxton, 1994). Gene frequency for haemoglobin type A was higher in N'dama than Zebu cattle (Table 3.2), indicating that the former is more trypanotolerant than the latter. The high gene frequency for type A haemoglobin observed in the Zebu cattle in this work was attributed by the authors to some degree of crossbreeding with N'dama in some Zebu-type animals. In all these studies, there was no indication of the equilibrium state of the populations. If these populations were not in equilibrium, then, this might indicate a survival advantage to AA and AB animals.

There have also been some reports of increased susceptibility of crossbreds to trypanosomiasis in Ghana: F<sub>1</sub> Santa Getrudis x West African Shorthorn; F<sub>1</sub> Red Poll x West African Shorthorn (Ngere, 1974) and in Ivory Coast: F<sub>1</sub> N'dama x Jersey

(Leteneur, 1978). In all these studies, increasing the proportion of exotic genes in the crossbred increased the trypanosusceptibility of the crossbred.

**Table 3.2:** Electrophoretically determined haemoglobin components in N'dama, West African Shorthorn, and Zebu cattle.

Breeds of Cattle	No. of Animals tested	Haemoglobin Type and Gene Frequencies		
		AA	AB	BB
WASH <sup>1</sup>	127	96 (0.87)	30 (0.23) <sup>4</sup>	1 (0.13)
N'dama <sup>2</sup>	243	202 (0.91)	38 (0.16)	4 (0.09)
N'dama <sup>3</sup>	27	19 (0.83)	7 (0.28)	1 (0.17)
Zebu <sup>3</sup>	26	15 (0.71)	7 (0.41)	4 (0.29)

4 = Figures in brackets represent gene frequency of haemoglobin type in each study. Adapted from: (1) Vohradsky and Sada (1984); (2) Vohradsky and Sada (1979); (3) Leperre and Claxton (1994).

Several factors contribute to the magnitude of trypanosomiasis problem in Africa, one of the most important relating to the methods available for control. Because of the phenomenon of antigenic variation exhibited by the species of trypanosome that cause the disease in domestic livestock, no vaccine is available for field use (Murray *et al.*, 1986; Murray *et al.*, 1991; Trail *et al.*, 1991). The success of the trypanosome as a parasite is to a large extent due to the ability to undergo antigenic variation, i.e. change a single glycoprotein (Variant Surface Glycoprotein) which covers the pellicular surface, thereby evading host immune responses and establishing a persistent infection (Murray *et al.*, 1991). Control is dependent on the expensive and limited number of trypanocidal drugs that are available or on the reduction of tsetse populations by means of residual or non-residual insecticides (Doyle *et al.*, 1984).

While there is evidence that significant differences in resistance to trypanosomiasis occur among various *Bos indicus* types (Lhoste, 1991; Njogu *et al.*, 1985), most *Bos*

*indicus* types in tsetse-infested areas require expensive regular treatment (Murray *et al.*, 1986). The survival of the Zebu cattle, especially at the edge of tsetse belts, has been attributed to the development of an immunity to the local strains of trypanosomes which breaks down on exposure to heterogenous challenge (Pinder *et al.*, 1987; Akol *et al.*, 1986). It has therefore been advocated that consideration should be given to the use of trypanotolerant breeds of domestic livestock in tsetse infested areas of Africa (e.g. Baker and Rege, 1994).

In addition to the trypanotolerance trait, the N'dama and West African Shorthorn cattle have other genetic advantages that must contribute to their potential for use in livestock development programmes in Ghana. The N'dama cattle are reported to be resistant to several other important infectious diseases including a number of tick-borne infections such as dermatophilosis (a skin disease also known as streptothricosis) (Coleman, 1967; Mattioli and Cassama, 1995) and heartwater (Epstein, 1971). The Shorthorn cattle can also resist the effects of biting flies and ticks, and diseases transmitted by the latter (Aboagye *et al.*, 1994). West African Shorthorn cattle is known to be much more resistant to dermatophilosis than the Zebu cattle (Turton, 1991). Epidemiological studies on helminth infections of calves in southern Ghana suggest that the West African Shorthorn and N'dama cattle may also possess some degree of resistance to helminthiasis (Agyei, 1991).

Crossbred groups of Sokoto Gudali x N'dama and Sokoto Gudali x Sanga showed consistently greater tolerance to skin diseases and parasites than their Santa Gertrudis x White Fulani contemporaries (Kahoun, 1970). Jersey x WASH crosses have also been found to exhibit better disease tolerance than Friesian x Zebu crossbreds (Ahunu *et al.*, 1994). All these show the impact of the degree of adaptation of the local breed, when compared to the Zebu cattle or other exotic breeds, to diseases and parasites. However, Zebus have been found to be less susceptible to insect worry, to have better resistance to non-specific effects of ticks and to utilize low quality forages more efficiently than *Bos taurus* breed of temperate origin (Turner, 1980). It must be noted that cattle diseases such as rinderpest, contagious bovine pleuropneumonia (CBPP), streptothricosis, anthrax and even trypanosomiasis are presently under control in Ghana (Hoste *et al.*,

1992).

### *Heat tolerance*

In general, the domestic livestock of tropical Africa are physiologically adapted to their hot climatic environment and are more tolerant of heat than cattle from temperate regions of the world. This physiological adjustment and adaptation has been achieved through their ability to shed heat load and adjust themselves to the prevailing high ambient temperatures. This is done by producing a lower metabolic heat as a result of their lower metabolic rate, lower feed intake per unit of metabolic size, lower growth rate and reduced milk production (Oyenuga and Nestel, 1984). Lower fasting metabolism, more and larger sweat glands, larger skin surface (e.g. dewlap in Zebu), very little subcutaneous fat and a short, smooth coat are among the characteristics which are thought to be responsible for tropical cattle possessing better adaptation to tropical heat (Oyenuga and Nestel, 1984). They are thus able to survive the nutritional and climatic stress associated with the hot season and have less metabolic heat to dissipate as the ambient temperatures rise.

For a given level of heat stress, the depressant effect on performance increases as the genetic potential for live weight gain of the animal increases (Johnson, 1982). As Johnson points out, the weight gains of cattle are decreased at temperatures above the thermoneutral zone for most temperate breeds imported into the tropics, because appetite, and hence feed intake, are depressed, and there is a similar effect on milk yield. Within the thermoneutral zone, an animal's heat production is constant, and independent of the thermal environment. A lack of adaptation to high environmental temperature is expressed also in poor reproductive performance.

Shorthorn and N'dama cattle have been shown to have good heat tolerance (Kahoun, 1971; Vohradsky and Sada, 1979, 1984). Daily variation in body temperature in adult N'dama cows between 7.00 hours and 16.00 hours was found to range from 37.8 to 41.4°C, with the maximum occurring between 13.00 and 16.00 hours (Vohradsky and Sada, 1979). Vohradsky and Sada (1984) recorded mean minimum and maximum body

temperatures of Shorthorn cattle to be 37.6 (7.00 hours) and 40.9 (13.00 hours) respectively. Though, the maximum values quoted for the above studies were quite close to the upper limit of the normal standard temperature for cattle, these animals were able to survive and reproduce in their environment, showing their adaptation to their hot climatic environment.

Studies on the influence of thermal conditions on rectal temperature, respiration rate and pulse rate of lactating Holstein-Friesian cows in the humid tropics of Southern Ghana showed that the animals were heat stressed, but were able to cope somehow by storing heat in the day and dissipating it at night (Kabuga, 1992). The animals were heat stressed during about one-third of the days in the afternoon if rectal temperature was considered as a physiological heat stress index, but during all the days of the experiment if high respiration rates were considered. In heat stress, there appears to be an increased protein demand, one which cannot be met under grazing conditions, especially during the dry season in the tropics.

Though, high temperatures can be detrimental to the productivity of cattle in the tropics, it must be realized that the environment can be modified to make conditions suitable for animal habitation. In areas within the tropics, where traditional systems of animal management exist and where there are financial incentives to improve animal productivity through intensification of production systems, Richards (1981) observed that success in overcoming the effects of climatic stress is more likely to be achieved by a combination of animal and environment improvement. Heat tolerance *per se* is therefore not of paramount importance, but with good management regimes, average yields of animals in the tropics can be high (Ansell, 1985). For example, water drinking frequency and increase in time spent in shade were all found to be closely associated with maximum daily temperature (Kabuga *et al.*, 1992). Therefore, management practices such as increasing the number of watering points and shady trees on pasture can reduce the heat stress in animals. Evidence for increases in productivity due to a combination of both environment and animal improvements programmes comes from Israel, where the influence of warm climates on the types of cow housing has been manipulated (Domyan, 1995). Crossbred cattle from low-yielding but stress-resistant

local Damascus cattle crossed with imported Friesian cattle, produced average annual milk yields of 9092 kg (Domyan, 1995), which is comparable to yields obtained in temperate regions (McDowell *et al.*, 1976; McDowell, 1992).

### *Cattle mortality rates in Ghana*

Mortalities in Ghanaian beef cattle herds have been very variable (Table 3.3). Reports in the literature are mainly derived from research stations, and indicate exclusively only calf mortality. The high variation in the results presented in Table 3.3 might be due to the small herd sizes observed in the various studies. This makes the results unreliable and difficult to interpret. Pooled data from N'dama and WASH indicate that mortality rates for the local breeds are apparently higher than that of the Friesian cattle, which belies the true situation. Because of different levels of health care at the different stations for the various breeds, no true within trial comparison can be made. It must be pointed out that the relatively low mortality obtained for Friesian cattle under the tropical Ghanaian conditions was the result of effective control of trypanosomiasis (Osei *et al.*, 1991).

Mortality rates could be higher under village conditions where poor nutrition, high prevalence of parasitic diseases and poor management of village herds do exist. The values are also likely to be low in adults, as one study reported adult cow mortality of 4 % for West African Shorthorn cattle (Aboagye *et al.*, 1994). In most cases, mortality rates were higher in the rainy than in the dry season. For example, among N'dama calves, pre-weaning mortality up to three months of age was significantly ( $P < 0.05$ ) higher during the rainy season (11.9 %) than in the dry season (4.8 %) (Osei and Effah-Baah, 1989). The rainy season with its accompanying high humidity and the tropical high temperatures provide an ideal environment for the growth of disease vectors and pathogens.

**Table 3.3:** Calf Mortality Rates in Ghanaian Cattle Herds

Breed	Number**	Mean (%)	Source
WASH	109 (10)	9.2	Hoste <i>et al.</i> (1992)
WASH	46 (11)	23.9	Osei and Effa-Baah (1989)
WASH	38 (8)	21.1	Tuah and Danso (1985)
WASH	-	10.0	Aboagye <i>et al.</i> (1994)
N'dama	128 (12)	9.4	Osei and Effa-Baah (1989)
N'dama	190 (20)	10.5	Tuah and Danso (1985)
Zebu	129 (8)	6.2	Hoste <i>et al.</i> (1992)
Friesian	57 (5)	8.9	Osei <i>et al.</i> (1991)

\*\*= Number of births and deaths. Number of deaths in brackets.

### 3.4.3 Growth and live weights

The mean growth and live weights obtained from several sources for West African Shorthorn, N'dama, Zebu and Friesian cattle are presented in Table 3.4. Birth, weaning (6 months), yearling and mature (3 years) body weights, and growth rates of West African Shorthorn and N'dama were found to be low, when compared to values obtained for Zebus and Friesian cattle (Table 3.4). This supports the evidence in the literature that the local breeds of beef cattle in Ghana are small and their absolute weight gains are proportionately small (Monstma, 1963; Ngere, 1974; Turton, 1991; Rege *et al.*, 1994a & b).

The mean birth weight of 33.7 kg obtained for Friesian calves is within the of range 32-42 kg reported by McDowell (1992) for Friesian calves in temperate regions. While the reported birth weight in the temperate regions is achievable by heifers calving for the first time at two years of age, the average reported in this work was achieved for heifers calving for the first time at about three years (age at first calving of 34 months), and

thus reduces the overall efficiency. Older ages at first calving are likely to lead to long generation intervals that will reduce the overall annual rate of genetic gain. It is most likely that Friesian heifers in Ghana calving for the first time in two years would drop calves less than 33.7 kg, since the weight of the dam plays a prominent role in dictating weight of offspring.

**Table 3.4:** Live weights (kg) and growth rates (g/day) of WASH, N'dama, Zebu and Friesian cattle in Ghana

Trait**	WASH	N'dama	Zebu	Friesian
	18.4	18.0	22.4	33.7
Birth Weight	881	716	181	154
	14.6-19.2	14.4-19.0	22.2-24.6	30.4-35.6
Weaning	86.3	85.3	123.2	131.8
Weight	736	459	180	254
(6 months)	64.2-108.5	75.2-120.3	122.2-131.3	109.6-144.2
Yearling	115.2	116.1	184.2	222.6
Weight	363	232	15	106
(12 Months)	105.3-119.3	103.0-134.3	155.6-213.3	-
Weight at	176.9	173.1	241.9	377.9
Two Years	312	64	22	62
	168.8-195.1	162.1-179.1	232.4-302.2	-
Mature	244.4	239.4	323.1	520.3
Weight	334	176	15	62
(3 Years)	221.0-260.6	219.3-277.0	248.9-515.6	-
Pre-weaning	377	374	560	545
Gain				

Table 3.4 continued

Post-weaning gain (6 Months-1 Year)	161	171	339	504
Post-weaning gain (1-2 Years)	169	156	158	425
Post-weaning gain (2-3 Years)	185	182	222	390

\*\* = Each column indicates average value, number of observations and range of values in that order. Average growth rates were calculated from live weight data.

Adapted from: Ahunu *et al.* (1993, 1994); Danboro *et al.* (1991); Kabuga and Agyemang (1983, 1984b); Kahoun (1970); Monstma (1963); Ngere and Cameron (1972); Ngere (1974); Osei and Effah-Baah (1989); Osei *et al.* (1991); Rege *et al.* (1994b & c); Sada and Vohradsky (1979, 1984); Tuah and Danso (1985).

Crossing either the Zebu or exotic breeds of cattle from Europe (male line) with the locals (female line) improved the birth weight of the crossbred progeny (Table 3.5). However, crossing the two local breeds (N'dama x WASH) resulted in no significant improvement. Although, the birth weight of crossbreds with exotic blood were significantly higher than their local straightbred counterparts, there was no significant difference between their overall weaning weights (Table 3.5), when individual trials are considered. For the pre-weaning period, the tendency was even towards lower performance with increasing level of exotic blood, as indicated by crosses with more than 75 % of Jersey blood (Table 3.5). This is consistent with the results provided by McDowell *et al.* (1976), Leteneur (1978) and McDowell (1985), which indicate that in the tropics, there is a substantial depression in animal adaptation to environmental stresses in genotypes with more than 50 % exotic blood.

**Table 3.5:** Live weight (kg) and growth (g/day) performance of straightbreds and their crosses.

Breed	Birth Weight	Weaning Weight	Mature Weight	Pre-Wean. Gain
WASH <sup>1</sup>	14.6	107.1	241.3	440
N'dama <sup>1</sup>	14.4	106.7	271.1	440
WASH x N'dama <sup>1</sup>	14.1	107.1	-	443
WASH x Sokoto Gudali <sup>1</sup>	23.0	114.2	324.9	433
WASH x Red Poll <sup>1</sup>	22.0	107.6	345.8	408
N'dama x Jersey <sup>2</sup>	20.0	111.5	-	425
Sokoto Gudali x Jersey <sup>2</sup>	24.2	139.1	-	518
WASH x Friesian <sup>2</sup>	24.1	133.9	-	502
Sokoto Gudali x Friesian <sup>2</sup>	23.9	137.6	-	506
N'dama x Friesian <sup>2</sup>	24.2	138.2	-	520
WASH <sup>3</sup>	19.2	108.5	-	432
WASH x Jersey (F <sub>1</sub> ) <sup>3</sup>	20.4	109.2	-	430
WASH x Jersey (B <sub>1</sub> ) <sup>3</sup>	21.9	109.8	-	428
WASH x Jersey (>B <sub>1</sub> ) <sup>3</sup>	22.5	95.1	-	354
N'dama <sup>4</sup>	19.0	80.6	-	342
N'dama x Red Poll <sup>4</sup>	21.5	99.5	-	433
N'dama x Santa Gertrudis <sup>4</sup>	21.7	97.3	-	419

F<sub>1</sub> and B<sub>1</sub> refer to first cross and backcross with 75 % Jersey, respectively.

Source: (1) Ngere and Cameron (1972); (2) Danboro *et al.* (1991); (3) Ahunu *et al.* (1993); (4) Ahunu *et al.* (1994).

In the present study, this could possibly have resulted from nutritional stress, due to poor milk yield of local dams (as will be seen later), which could not support the pre-weaning growth rate of crosses with high genetic potential. The dramatic drop in average daily gain of crosses with more than 75 % Jersey blood relative to F<sub>1</sub> or backcross calves during the pre-weaning period (Ahunu *et al.*, 1993), may be indicative of decreasing adaptability in the crosses with less than 25 % of West African Shorthorn blood (Table 3.5). This is an indication that the crossbreds performed at genetically sub-optimal levels, during the pre-weaning periods.

After weaning, when the crossbreds no longer depended on the milk of their dams, they were able to outperform the locals to reach a significant higher mature weights than their contemporary locals (Table 3.5). This probably demonstrates the poor maternal ability of local dams, expressed as poor milk yields, which in turn largely influence the pre-weaning growth of crossbred calves.

**Table 3.6:** The effect of supplementary feeding on live weight gains of WASH, N'dama and Santa Gertrudis x WASH cross.

Breed	Type of feed	Growth rate (g/day)
N'dama	Pasture alone	122
	Supplementary + Pasture	92
WASH	Pasture alone	136
	Supplementary + Pasture	166
Santa Gertrudis x WASH	Pasture alone	194
	Supplementary + Pasture	487

Source: Ngere and Cameron (1972).

N'dama, WASH and WASH X Santa Gertrudis calves were each fed by different methods for 18 weeks after weaning. The results show that the crosses responded much more to extra feeding than the other groups (Table 3.6), which demonstrate a greater

potential for growth by these animals on improved pastures. The higher post-weaning growth of crossbreds under good nutritional regimes was a reflection of their capacity to express their genetic potential. Better live weight gains are therefore possible with better feeding. It should, however, be noted that if the pre-weaning growth restriction is too severe, as a result of poor nutrition, animals will be unable to compensate for their growth to reach similar live weights of their non-restricted contemporaries (Allden, 1970).

#### 3.4.4 Reproductive characteristics

Table 3.7 shows the reproductive performance of the breeds of cattle in Ghana. The data show that the reproductive performance of all the breeds presented are poor, with the exception of their performance in calving percentage, which seems reasonably good. The older age at first calving of these breeds means that the age at which they reach puberty is similarly older, which also indicates their late-maturity. Age at first calving is closely related to generation interval and, therefore, influences response to selection.

**Table 3.7:** Reproductive Performance of Different Breeds of Cattle in Ghana

Trait**	WASH	N'dama	Zebu	Friesian
Age at First Calving	44.1	34.5	43.4	32.3
(Months)	34.8-48.1	32.1-39.2	38.6-46.7	30.5-34.1
Calving Interval	16.3	16.0	15.8	16.0
(Months)	839	280	254	45
Gestation Length	13.8-18.3	14.2-18.6	15.5-16.5	9.3-24.8
(Days)	284.7	288.0	290.5	278.4
	121	115	17	30
	283.5-284.7	287.1-288.5	289.7-291.1	265.0-288.0

Table 3.7 continued

Post-partum	6.7	6.8	3.3	5.4
Return to Oestrus	111	154	11	28
(Months)	5.5-9.6	6.0-9.6	1.0-8.6	3.3-8.2
Calving	74.7	73.5	76.0	-
Percentage	208	290	46	-
	66.0-89.0	72.3-85.0	75.1-88.9	-

\*\* = Each column indicates the mean value of trait, number of observations, and range of values in that order.

Adapted from: Monstma (1963); Sada (1968); Ngere and Cameron (1972); Vohradsky and Sada (1978, 1979, & 1984); Kabuga and Agyemang (1984a); Tuah and Danso (1985); Osei and Effah-Baah (1989); Osei *et al.* (1991); Hoste *et al.* (1992); Rege *et al.* (1994b & c); Ahunu *et al.* (1994).

The ability to conceive 75-85 days after parturition (days open) to complete the reproductive cycle in twelve months is of major significance in cattle (Rudder, 1989; Peters, 1984; Short *et al.*, 1995). The calving interval of about sixteen months observed for all these breeds in Ghana means that cows take longer time to become pregnant after parturition. This was reflected in their postpartum return to oestrus which was also too long (Table 3.7). The smaller value of postpartum return to oestrus obtained for Zebu is likely to be unreliable, because of the small number of observations.

The long postpartum return to oestrus in the local breeds may be attributed to long periods of suckling by calves which cause a delay in resumption of oestrus (Short *et al.*, 1972; Thomas *et al.*, 1981; Peters *et al.*, 1981; Peters, 1984; Hopkins, 1986; Rund *et al.*, 1989). Indirect evidence of suckling on postpartum return to oestrus is provided by the work of Gyawu (1988), which showed that cows which lost their calves 1-23 days after parturition were the first to resume cyclic ovarian activity, suggesting that absence of suckling might have enhanced early return to cyclicity in these cows. The proportion of N'dama cows in this study, resuming cyclic ovarian activity by 110 days postpartum

was only 6.8 % in the Sahel region of the Gambia, but was high (48.4 %) in the forest zone of Ghana, which demonstrates that postpartum return to oestrus was a more serious problem in the Sahel zone of the Gambia than in the humid forest zone of Ghana. This is probably related to the nutrition of cows in the different environments.

The short rainy season and the long dry period in the Sahel region of Gambia, during which time cattle have inadequate feed to maintain body weight, may be one of the main reasons for the non-cyclicity after parturition. This is in contrast to the bimodal rainfall pattern of the forest zone of Ghana which ensures an adequate supply of natural pastures almost throughout the year. This compares favourably to the north (which has almost the same climatic conditions as the Sahel region of the Gambia) and south of Ghana.

The effect of nutrition on the successful rebreeding of the cow during the post-partum period has been explored. If a cow is not adequately fed during the last trimester of gestation, she will use her body reserves to nourish the foetus by mobilizing body tissues and depositing it into the foetus. Consequently, she will calve thin and will fail to rebreed (Spitzter, 1986). After calving, nutrients are partitioned for lactation, maintenance, growth and reproduction. Reproduction, especially in conditions of food scarcity, has a relatively low priority for nutrient partitioning, and it will be the first function to suffer with poor nutrition (Gerloff and Morrow, 1986). It can thus be seen that long periods of suckling and in some cases poor nutrition related to management are likely to be responsible for the extended postpartum anoestrus, which is in turn responsible for long calving intervals.

Rege *et al.* (1994b) observed lower mean age at first calving at on-station than on-farm (village conditions), which most likely reflected the effect of poor nutrition in the villages. All data used in the present study originated from on-station, where the farms are managed by research scientists. This means that the reproductive performance of these animals would be very poor on the farmer's own field in Ghana since it is most likely that nutrition in the research stations would be better than that of the village. This has serious implications, especially where sires are being transferred from the research

stations for breeding in the village, because of genotype by environment interactions. It is also most likely that the reproductive performance of cattle in the northern part of Ghana would be worse than their counterparts in the south, because of severe feed shortages in the north, especially during the dry season. The Zebu cattle in the south are also likely to perform poorly than their counterparts in the north, because of serious trypanosomiasis problem in the south. The delay in pregnancy observed in Friesian cattle has been attributed to management problems, related to heat detection (Osei *et al.*, 1991).

**Table 3.8:** Reproductive performance of local breeds and their crosses

Breed	AFC (Months)	CI (Months)	GL (Days)	PPRO (Months)
N'dama <sup>1</sup>	39.2	15.0	288.5	6.0
WASH <sup>1</sup>	34.8	14.6	285.3	5.5
N'dama x Jersey (F <sub>1</sub> ) <sup>1</sup>	29.6	12.9	278.2	3.8
WASH x Jersey (F <sub>1</sub> ) <sup>1</sup>	31.5	12.8	276.4	3.7
WASH	48.1	18.0	-	-
Sokoto Gudali	46.7	15.5	-	-
WASH x Jersey (F <sub>1</sub> ) <sup>2</sup>	40.6	13.6	-	-
WASH x Jersey (B <sub>1</sub> ) <sup>2</sup>	38.0	15.3	-	-
S. Gudali x Jersey (F <sub>1</sub> ) <sup>2</sup>	40.8	14.4	-	-
S. Gudali x Jersey (B <sub>1</sub> ) <sup>2</sup>	40.6	13.2	-	-

F<sub>1</sub> and B<sub>1</sub> refer to first cross and backcross with 75 % Jersey blood, respectively.

Source: (1) Vohradsky and Sada (1978); (2) Rege *et al.* (1994c)

Age at first calving (AFC), calving interval (CI), gestation length (GL) and post-partum return to oestrus (PPRO) all reduced slightly as the level of exotic breeding increased

in crossbreds, showing an improvement in crosses compared to the locals (Table 3.8). However, an other study crossing the White Fulani (Zebu) and WASH (local) resulted in higher age at first calving and an intermediate calving interval, resulting in no significant improvement in calf production (Marchot *et al.*, 1989). This latter result was expected since these two breeds have almost the same reproductive characteristics. Data from Africa, Asia, America and Australia have confirmed the poor reproductive performance of Zebu cattle (Mukasa-Mugerwa, 1989). Data from the neighbouring West African Senegal have also confirmed the poor reproductive performance of N'dama cattle (ILCA, 1982a).

#### 3.4.5 Milk production characteristics

Milk letdown in WASH, N'dama and Zebu is difficult to stimulate, except when calf is at-foot. Milk yield in these breeds has therefore been estimated using the weigh-suckle-weigh method (Monstma, 1960, 1962, 1963; Ngere *et al.*, 1975). With this method, milk yield is measured as the difference between the calf's live weight before and after suckling. Results from various studies reported on milk yield, lactation length, and milk composition are presented in Table 3.9. Total milk yield converted to a 305-day lactation, and daily milk yield of WASH and N'dama were relatively low, when compared to means obtained for the Zebu cattle. Available evidence in the literature shows that the milk yield of the local cattle is too low to support the efficient growth of crossbred calves which have high genetic potential (Kahoun, 1970; Ngere and Cameron, 1972; Ahunu *et al.*, 1993).

Lactation lengths for the local cattle and Zebu were also short, when compared to the normal 305 days lactation period (Table 3.9). Short lactation lengths are typical of tropical cattle. Studies have shown that there is a close association between lactation length and milk yield in tropical cattle, and estimates of repeatability suggest that lactation length is heritable to almost the same extent as milk yield (Syrstad, 1993; Eghobor, 1994). Therefore, where milk production is sought in tropical cattle, lactation length may be included as a trait in the breeding objective.

**Table 3.9:** Milk production characteristics of WASH, N'dama, Zebu and Friesian cattle in Ghana.

Trait**	WASH	N'dama	Zebu	Friesian
Lactation	223	192	179	305
length	38	19	114	22
(days)	110-261	150-252	151-252	-
Daily milk	1.9	2.8	5.4	13.7
yield	155	19	72	145
(kg/day)	1.5-2.9	2.5-3.0	3.2-6.9	8.2-19.4
Total milk over	427.0	549.0	976.0	4178.5
305 lactation	155	19	72	145
days (kg)	165.0-756.9	375.0-756.0	483.2-1738.8	2501.0-5197.0
Total solids (%)	10.6	-	-	11.6
Solid not fat (%)	9.3	-	-	-
Butterfat (%)	3.6	-	-	3.6
Protein (%)	3.2	-	-	3.0
Ash (%)	0.75	-	-	0.59

\*\* = Each column indicates the mean value of trait, number of observations and range of values in that order.

Adapted from: Monstma (1960 & 1962); Ngere *et al.* (1975); Alhassan and Owusu (1980); Sada and Vohradsky (1979 & 1984); Kabuga and Agyemang (1984a); Kabuga and Sarpong (1991); Osei *et al.* (1991); Ahunu *et al.* (1994); Rege *et al.* (1994b & c).

The 305-day lactation milk yield of 4178.5 kg obtained for Friesian cattle in Ghana is below the typical range of 8,000-9,080 kg and 4,500-5,000 reported in temperate and tropical environments, respectively (McDowell *et al.*, 1976; McDowell, 1992). This low performance of Friesian cattle in Ghana has been attributed to an outbreak of

streptothricosis in the herd between 1980-1985 (Osei *et al.*, 1991). According to Gyawu and Agyemang (1977), cited by Osei *et al.* (1991), an earlier evaluation of the foundation stock on the same station produced a total 305-day lactation milk yield of 4,496.0 kg, which is almost within the range reported above for tropical environment.

Improving the level of feeding by the provision of supplementary feed (1.8 kg groundnut cake and maize mixture per day) from late pregnancy through lactation increased the milk yield of local and Zebu cattle (Table 3.10). The level of milk yield attained in Zebu by improving the level of feeding is an indication of the superiority of the milk production potential of Zebu cattle relative to local breeds. This work shows that with proper nutrition, the local cattle may at least be able to produce enough milk for their purebred calves which require about 2.5 kg milk per day (Monstma, 1960; 1963). However, these amounts may not be able to sufficiently raise either Zebu or European breed x local crosses, which have higher requirements. For example, purebred Zebu calves require about 4.5 kg milk per day (Monstma, 1960; 1963) and purebred Jersey and Friesian calves require 4.5-8.0 kg milk per day (Holmes and Wilson, 1987).

**Table 3.10:** Milk yield (kg/day) of cattle fed either on natural pastures or natural pasture plus supplementary feed

Treatment	WASH	N'dama	Zebu
Natural grazing	2.1	2.5	3.2
Plus supplement	4.2	3.9	6.3

Source: Monstma (1963).

Milk yield generally increased in  $F_1$  crossbreds, but decreased with increasing exotic breeding beyond the  $F_1$  (Table 3.11). These findings are also supported from the work of other authors (e.g. Sada and Vohradsky, 1978 & 1982; Ahunu *et al.*, 1993). Sada and Vohradsky (1978) observed that improving local breed with Jersey blood beyond  $F_1$  did not bring about distinct improvement in the morphological shape of the udder and teats. The length of teats in cows beyond the  $F_1$  cross were insufficiently developed and did

not reach on average 5 cm which is the required length of teats for machine milking. The dramatic improvement in the milk production of Friesian x Sokoto Gudali  $F_1$  crosses probably confirm the milk production potential of the Zebu cattle (Table 3.11). The possibility of using such crosses for milk production in Ghana needs further investigation.

**Table 3.11:** Lactation performance of local and crossbred cattle

Genotype**	Lactation Length (days)	Milk Yield	
		kg/day	305 days
WASH	295	2.6	748.6
Sokoto Gudali	167	6.9	629.9
Jersey x WASH ( $F_1$ )	305	6.0	1835.0
Jersey x WASH ( $B_1$ )	305	5.5	1679.0
Friesian x WASH ( $F_1$ )	305	6.2	1893.0
Jersey x S. Gudali ( $F_1$ )	305	6.7	2051.0
Jersey x S. Gudali ( $B_1$ )	277	6.7	1678.3
Friesian x Gudali ( $F_1$ )	327	9.3	3271.8

\*\* =  $F_1$  and  $B_1$  refer to first and backcross (75 % Jersey) respectively.

Adapted from: Ahunu *et al.* (1994).

There are only some limited data available on the milk composition of the breeds of cattle studied. The milk fat content of WASH and Friesian (Table 3.9) are below the typical values from temperate regions, but within the range of values reported for the tropics (McDowell, 1992).

### 3.4.6 Carcass characteristics

The limited information available on the carcass traits of cattle in Ghana is presented in Table 3.12. These results suggest that dressing out percentage of the local cattle compares favourably with that of the Zebu cattle. In some other study, dressing out percentage of the local cattle and their crossbreds were also found to be similar. Pooled data from Red Poll x N'dama and Santa Gertrudis x N'dama crosses gave dressing out values of 50 % as against 51 % for N'dama alone (Ahunu *et al.*, 1994). However, crossbreeding slightly improved the dressing out percentage of Jersey x N'dama F<sub>1</sub> relative to the N'dama (46.3 % vs 50.2 %), respectively (Sada and Vohradsky, 1979). These results are not surprising since heterosis in carcass traits is very minimal (Rae, 1973; Rudder, 1989).

**Table 3.12:** Carcass characteristics of WASH, N'dama and Zebu cattle.

Breed	No. of Records	Live Weight	Slaughter Weight	Dressing %
WASH	52	292.4 <sup>1</sup>	133.0	45.5
	-	221.0 <sup>2</sup>	113.5	51.4
	-	142.0 <sup>2</sup>	67.0	47.2
N'dama	41	223 <sup>3</sup>	113.0	50.7
	13	277.8 <sup>4</sup>	139.4	50.2
Zebu	4	189.5 <sup>5</sup>	87.0	45.9

Source: (1) Sada and Vohradsky (1984); (2) Rege *et al.* (1994b); (3) Ahunu *et al.* (1994); (4) Sada and Vohradsky (1979); (5) Clotey (1972).

Markets for Ghanaian beef have a wide range of specifications, making it impossible to define an ideal animal. Data in the literature about meat quality traits (including fat levels) in Ghana is also lacking.

### 3.5 Livestock development policy in Ghana

The overall objective of the government of Ghana with respect to animal production is to increase meat supply to allow for an increased per capita animal protein consumption by its inhabitants. Achieving this will lead to conservation of foreign exchange that would otherwise have gone into importation of meat and meat products. This is expected to be achieved through the production of livestock from the smallholder farmer in Ghana, who is also expected to derive income from the sale of livestock and livestock products.

Since independence in 1957, there has never been any policy on animal production in Ghana. Agricultural production in Ghana has always been viewed as crop production. There is no wonder, livestock contributes only a meagre 9 % to the agricultural GDP or 4 % of the national GDP. However, the livestock production potential of Ghana, especially that of ruminant livestock, has been recognized (ISNAR, 1991). For the purpose of reviving the entire agricultural system including the livestock subsector, the government of Ghana introduced the Medium Term Agricultural Development Programme (MTADP, 1990).

The MTADP is the agenda for sustained agricultural growth and development over the 1991-2000 period. A blue print on livestock development has been drawn and a National Livestock Development Programme has started running (NLDP, 1991). The National Livestock Development Programme is a joint project instituted between the government of Ghana and the World Bank. The livestock subsector is placing emphasis on ruminant production in view of the fact that it is the least developed within the private sector and also because ruminants do not compete with man for feed resources, notably grain. The objective is to improve the productivity of ruminant livestock through better animal health, nutrition and water supplies, and in the long term breed improvement.

### 3.6 The objective and structure of the cattle industry in Ghana

Traditionally, most farmers in the north bred cattle for socio-religious reasons or to serve in ritual events. Hutchinson (1962) observed three factors of tradition and customs which are presently of great importance to cattle rearing in Ghana: the prestige value of the herd, its value as a self-sustaining investment, and the vital part livestock play in marriage (essentially for the payment of bride price). Livestock may be used as security in cases where inadequate rainfall may fail the subsistence type of crop farming. Livestock may also be sold for the purchase of seed and fertilizer during the cropping season. Large herds therefore can mean security, wealth and prestige.

Ownership of cattle in Ghana may be direct, personal and individual, or in majority of cases, the cattle may belong to an ethnic group of farmers or family or, even a whole village (Monstma, 1960; Hutchinson, 1962; Dalton *et al.*, 1973; Okantah, 1992). Where a large herd is concerned the owning family groups may be several, varying widely in size and in relationship. It frequently occurs that the apparent owner is not the real one. It is therefore likely that it will be difficult for the caretaker to authorize or approve interventions without consulting with the absentee owners. The situation is quite different from the south, where cattle rearing is seen as an economic venture and tends towards ownership by individuals (Monstma, 1960; Hutchinson, 1962; Dalton *et al.*, 1973; Okanatah, 1992). However, the objectives of farmers in the north are changing to be more market-oriented as land deteriorates in fertility and fertilizer prices continue to rise.

In areas of genetic management, only little effort has been made. There has never been any deliberate attempt to plan a national breeding programme designed to improve the productivity of cattle herds in Ghana, until the advent of the recent National Livestock Development Programme. Cattle production is largely uncommercialized and characterized by low inputs. There are basically no nucleus breeding herds, except some few government cattle breeding stations. Unlike the ruminant industries, the monogastric industries (poultry and pigs) are very much developed and have several commercial and nucleus herds. All commercial and nucleus sectors of the poultry and

pig industries are located in the south. Some smallholder dairy herds exist on the Accra plains of the southern grassland ecological zone (Okantah, 1992).

In the northern savanna zone, cattle are kept in small herds (Monstma, 1960; Hutchinson, 1962). In the southern savanna, herds are mostly of larger size and may number up to 800 head. In a survey conducted by Okantah (1992) on the Accra plains of the southern coastal zone of Ghana, average size of herds was 113 with a range of 19-232 (Okantah, 1992). Farmers breed their own replacements, especially females. Males are purchased from other farmers or from government breeding stations. Opportunities for within herd selection are greatly reduced by the prevailing ownership patterns. Mass selection is done by castrating males that are judged substandard. Judgement is by visual appraisal since almost all farmers do not keep records. In one study, a majority of farmers quoted better growth rates, improved calving intervals, good conformation and greater size and price as their reasons for crossing the local cattle to the Zebu (Dalton *et al.*, 1973). These farmers also recognized the adaptability of the local cattle to the harsh environment.

From the foregoing, one realizes that the beef cattle industry in Ghana is unstructured. Under the National Livestock Services Project, the Open Nucleus Breeding Scheme has been proposed, but its implementation is still a matter of concern. The mandate of the national breeding programme is to select more productive cattle, sheep, and goats that are hardy and trypanotolerance (NLDP, 1991; ISNAR, 1991). Priority is accorded to plans for cattle breeding because their current contribution to meat supply is far larger than that of combined production of sheep and goats (38 % vs 20 %) (FAO, 1993b). The objective is to breed more productive (output per unit animal) cattle. Milk production is important since it is essential for calf growth and survival. Despite all these aspirations, breeding objectives for the individual livestock industries have not been defined.

Nucleus herds for livestock breeding have been established in four major climatic zones (Table 3.13). The Pong-Tamale Livestock Breeding Station in the north and the Amrahia Dairy Cattle Breeding Station in the south are the only two nucleus breeding

stations established to produce improved breeding stock for beef and dairy cattle farmers, respectively, throughout the country. These two stations are also to serve as performance testing stations for beef and dairy cattle industries. Private ownership participation in the establishment of nucleus herds for both dairy and beef cattle industries is to be encouraged so as to increase the number of breeding stock that would be made available to farmers.

**Table 3.13:** Establishment of livestock nucleus herds in different ecological zones in Ghana

Station	Breed	Ecological zone
Amrahia	Dairy cattle	Coastal grassland
Pong-Tamale	Beef cattle, sheep, goats & pigs	Northern savanna
Babile	Pigs	Northern savanna
Ejura	Sheep	Transition*
Kintampo	Goats	Transition*
Nungua	Grasscutter, poultry & pigs	Coastal grassland

\* = intermediate vegetation type between northern savanna and southern forest zones

Source: NLDP (1991)

Neglecting dairy cattle production in the hot climates of the north, a separate beef cattle nucleus breeding station needs to be established in the south to cater for farmers in this zone, since the production systems, management of stock, objectives and climatic conditions of the north and south are quite different. The idea of not establishing any nucleus breeding station, especially that of ruminant livestock, in the forest zone probably means that livestock production is not to be encouraged in this zone. This idea is laudable because of the prevalence of trypanosomiasis in this zone. Secondly, intensive ruminant livestock production in the forest zone will mean desertification and deforestation, towards improved animal welfare and increased production quality, with

an emphasis on increased grassland production. Apart from the fact that such a system is not sustainable (Parry, 1994; Spedding, 1995), the Ghanaian staple foods such as plantain and cocoyam, most of which are produced in the forest zone will cease to be productive, since they do not grow well in grasslands.

Livestock research and development is the sole responsibility of the Animal Research Institute, the universities, Veterinary Services Department, Animal Production Department and the Extension Services Department. The last three of these departments are under the umbrella of the government's Ministry of Agriculture, which also has the Crop Services, Agricultural Engineering, Plant Protection and Regulatory services, and Policy Planning, Monitoring and Evaluation departments as its subsidiary departments.

The main functions of the various departments involved in animal health and production are:

- (1) The Animal Research Institute and the universities conduct research in animal health and production, in addition to training of agricultural graduates by the universities.
- (2) The Veterinary Services Department is involved in the health aspects (preventive and curative) of animals on the farmer's field and the training of field staff.
- (3) The Animal Production Department is responsible for the nucleus breeding stations and also for conducting field trials (on-farm and on-station) into improved management practices in association with the universities and the Animal Research Institute
- (4) The Extension Services Department carry messages to farmers.

Before the nineteen nineties, livestock research and development was fragmented, with different aspects being conducted in the Animal Research Institute, the universities and the Ministry of Agriculture. Partly as a result of this uncoordinated effort, there was an imbalance in the research and development programmes and confusion with regard to linkages between research and extension staff and producers (ISNAR, 1991). The amount of extension on livestock used to be very minimal because of the lack of a livestock policy. All these departments and organizations are now expected to coordinate and link together with the farmer to foster the development and conduct of a nationally coordinated livestock improvement programme. Where possible, livestock farmers owning similar cattle in the vicinity of the stations should be induced to

cooperate in the breeding programmes by agreeing to the marking and recording of the production of their animals; thus providing a larger number for selection purposes (NLDP, 1991).

### **3.7 Management and production systems of the cattle industry in Ghana**

Cattle in Ghana are owned by small scale farmers who are predominantly crop farmers. Livestock production in the majority of cases is only a secondary vocation. These smallholders exist as mixed crop-livestock farmers. Cassava (manioc), cocoyam, plantain, coffee, cotton, cowpeas, maize (corn), millet, groundnuts (peanuts), pineapples, rice, sorghum, sugar cane, tobacco, yams, pepper, tomatoes, onions, cabbage, lettuce, and a number of other food crops do well in Ghana. Fruit crops such as oranges, limes, grape fruit, avocado, mango, papaya, shea, banana, cocoa, plantain, coconut, cola and cocoa, oil palm, and baobab are also grown in Ghana. Livestock species reared include chicken, guinea fowl, goats, sheep, cattle, rabbits and pigs.

The main export crops, viz. cocoa (Ghana's largest foreign exchange earner) and coffee are all produced in the south. Whereas agricultural activities go on in the south throughout the year, the rainfall pattern in the north enables it to have only one main cropping cycle. The agriculture in the north is dominated by food crop and produces only grain crops (maize, millet, sorghum, and rice) and legumes (groundnut and cowpeas), together with yam, cassava, cotton and some vegetables. However, the north has the greatest proportion of ruminant livestock; about two-thirds of Ghana's cattle, sheep and goats are located in the north.

Unlike the south, the productivity of crops grown in the north depends heavily on inorganic fertilizers. With the removal of government subsidies on fertilizers in the early part of the nineteen nineties, fertilizer prices have risen and consumption of fertilizers have gone down. For example, the average fertilizer consumption in Ghana went down from 6.5 kg/hectare of arable land in 1979/80 to 2.9 kg/hectare of arable land in 1990/91 (World Bank, 1994). Most farmers, especially those in the north are therefore changing from the production of certain crops (e.g. maize), which require

heavy inputs of fertilizers, to livestock production due to the high cost of fertilizers.

Cattle are bred under conditions which are both extensive and traditional (Hutchinson, 1962; Hoste *et al.*, 1992). Cattle production under traditional management accounts for about 99.2 % of the total cattle population (Hoste *et al.*, 1992). Only 0.8 % of the cattle are raised on ranches or research stations. Most stock are kept under extremely simple management conditions and receive little supplementary feed or health care.

Although, cattle husbandry methods are not advanced, some changes are taking place. Breeding is not controlled, thus calving takes place all year round. Weaning in most cases is natural. In the Tongu district of south-east Ghana, Dalton *et al.* (1973) observed that on average, calf weaning takes place, when calves are at about 13 months of age. Health measures include vaccination against principal epizootic diseases such as rinderpest, contagious bovine pleuro-pneumonia (CBPP), blackleg and anthrax (Veterinary Services Department, pers. comm.). Vaccination charges are free, and it is even compulsory for every farmer to vaccinate his cattle against rinderpest. Antihelminthics and acaricides are used less frequently because of the high cost of drugs. Farmers pay for all service charges and the cost of drugs for activities such as castration, drenching, deticking and wound treatment (Veterinary Services Department, pers. comm.). It must be pointed out that livestock owners, both in the north and south, frequently employ the services of the veterinary staff in Ghana (Hutchinson, 1962; Dalton *et al.*, 1973; Hoste *et al.*, 1992). It is believed that an epidemic of rinderpest that occurred in 1925 almost wiped out the entire cattle population in Ghana (Dalton *et al.*, 1973). Livestock farmers are therefore very much aware of the devastating effect that epizootic diseases can have on their animals. At the moment, cattle diseases are under control in Ghana (Hoste *et al.*, 1992). However, drugs used for the treatment of trypanosomiasis are prohibitively expensive, and most farmers will not treat their animals, even if they are diagnosed as being infected by trypanosomiasis. Losses due to trypanosomiasis can therefore be very high, especially in trypanosusceptible Zebu cattle.

Grazing of cattle is mostly on communal lands, consisting of native and exotic species.

These plants range from perennial and annual grasses, forbs, trees and shrubs. Grasses have never been regarded as crops to be managed or cultivated for animal feeding, even though the bulk of ruminant livestock feed is from the range. No concerted action by rearers or government has been made to protect and enhance the productivity of this range (Alhassan and Barnes, 1993). Pathetically therefore, very little documentation is available on the production and management of pasture species in the range.

Exploratory studies on some of these native and exotic pasture species (Rose-Innes, 1962; Rose-Innes and Mabey, 1964; Mabey and Rose-Innes, 1964; Asare, 1970, 1974; Barnes and Alhassan, 1993) have provided some guide to successful pasture production and management. These studies have indicated some of the pasture species that are suitable for intensive pasture production in Ghana. It is hoped that a lot more will be achieved in the area of pasture development under the current National Livestock Development Programme. What needs to be done presently is the promulgation of a simple grassland policy to reflect the peculiarities of the various agro-ecological zones. Such a policy should spell out the course of research and the institutional framework to facilitate improved range management and forage production (Alhassan and Barnes, 1993).

Grazing and watering is a major problem in the dry season, especially in the north. During the dry season which last for about 3 months in the south and 5-6 months in the north, cattle trek very long distance in search for feed and water, due mainly to rampant bush burning and drying of ponds and rivers. For example, Dalton *et al.* (1973) found out that the average distance travelled in one direction by cattle in search for water was 6.4 km with a range from 0.4-16.1 km. Though periodic bush burning is undesirable, it is both useful in maintaining the grassland vegetation as well as encouraging regeneration of grasses in the absence of rains.

Indeed, in case of extreme dryness, some herd owners move their stock several kilometres away from the village to the nearest river. They do not return to the village until the wet season sets in or the dry season is over. This intensifies grazing around water supplies, leading to overgrazing. The shortage of feed during the dry season is

worsened by its poor quality (Table 3.14). The performance of animals that subsist solely on range pasture during the dry season, especially in the north reduces drastically. A mean loss of over 11 % of body weight of cattle in three-months dry season in southern Ghana has been reported (Rose-Innes and Mabey, 1964). Supplementary feeding in the dry season is practised only by few enlightened stock-owners, although millions of tons of crop residues (e.g. rice straw, groundnut and cowpea vines, maize, millet and sorghum stovers) are burnt by bush fires and go to waste during the dry season.

**Table 3.14:** Chemical composition of natural grassland in Accra plains.

Season	Dry Matter	Crude Protein	Crude Fibre	Ash
Major Rainy	38.6	11.4	23.5	14.1
Minor Rainy	34.9	8.8	26.2	13.0
Dry	69.3	4.4	29.8	9.8

Adapted from: Rose-Innes and Mabey (1964)

Studies have shown that seasonal effects on animal performance is not of major significance in southern Ghana. The lack of a seasonal effect on the performance of cattle has been observed in Friesians (Kabuga and Agyemang, 1983; Osei *et al.*, 1991), N'dama and WASH (Osei and Effah-Baah, 1989) and in WASH and their Jersey crosses (Ahunu *et al.*, 1993). The effect of season on the performance of cattle depends on the quantity and quality of feed available to animals throughout the year. The bimodal rainfall pattern of the southern ecological zone allows it to have abundant, high quality, feed which grows throughout the year. Apart from some advantages related to management, the lack of a seasonal effect on the performance of cattle indicates no benefit from restricting calving to any season of the year. This would be extremely beneficial to the dairy cattle industry where all year-round calving is essential to maintain a continuous supply of milk.

Animals are herded, together every day, away from and back to the kraal. A kraal is a simple structure built of locally available materials. Calves up to a certain age stay back in the kraal until their dams return from grazing, when they suckle. Cattle are usually grazed by herdsman for about 8-10 hours a day. Four types of herdsman were observed by Dalton *et al.* (1973). These include children (57 %); hired labour (24 %); Fulanis (16 %) and cattle owners (3 %). A large single herd will have one or more herdsman but often a number of small owners will combine their herds and hire a single Fulani herdsman and their responsibility towards him will be shared proportionately. Payment is usually in kind, with the Fulani traditionally being paid in milk or provided a heifer after a number of years service together with free food, clothing and housing. In some places herdsman are paid in cash. Where the herdsman's main, and often his only, remuneration is the right to sell milk from the herd, particularly around the larger towns, it is most likely that calves will receive inadequate milk. The consequence of this could be reduced growth rates and high calf mortality.

The practice of partial milking is practised on the coastal grassland plains of Ghana (Okantah, 1992). This is a system whereby calf and farmer share milk from the cow. It involves careful judgement by the Fulani herdsman who extracts as much milk as possible once daily, but leaves some in the udder on which the calf must survive. Essentially, calves are penned separately from their dams overnight. This prevents suckling and facilitates partial milking the next morning with a calf at-foot for stimulation of milk letdown. The calf is allowed access to residual milk left at the discretion of the milker. Some herdsman milk from the right or left half of the udder only, leaving the other half for the calf.

### **3.8 Marketing of cattle and cattle products in Ghana**

Marketing of livestock in general is not organized in Ghana. The bulk of regular marketing of cattle is carried out in the north. The southern coastal grassland areas are regarded by most dealers as a reservoir to be tapped when the supply from the north is cut off for any reason, such as the ban of movement of livestock from the north to the south, when controlling an outbreak of major epizootic diseases. The principal

demand such that they will consume more meat than the rural communities. Generally, livestock products are priced higher than most agricultural products, due probably to many people chasing few products. This provide the average smallholder livestock farmer with additional and possibly more regular income.

Products of cattle sold in the markets include beef, offals, skin, cowleg and cow head. Thus, apart from the horns, hoofs and blood, every product from cattle is sold and eaten in Ghana. Beef is sold as bone-in and bone-less, the latter is expensive compared to the former. Beef carcasses are generally cut into small cubes and sold in chunks to buyers. This ensures that almost every household budget can afford beef. A value is always added to frozen or chilled meat and this puts the price above most average households. Since the lowest income consumers are the principal buyers of offals, hides, leg and head, the movement of frozen or dressed carcasses would automatically exclude these parts which are within the budget of poorer consumers. Beef is therefore a staple protein source in the Ghanaian diet. Older and tougher meats are entirely acceptable. The only requirement is that the meat is fresh and preferably lean. The primary methods of beef preparation include boiling, frying, roasting, grilling and smoking. Beef is principally used as a stock meat in stew and soup. Dried (smoked) beef is very popular, and this is mainly used for soup preparation.

### **Summary**

Rapid population growth and rising rural-urban migration are leading to increasing demands for meat in Ghana. The present demand for meat far more exceeds local production. Beef is therefore imported to supplement local meat production. Livestock research, extension and development in Ghana has suffered in the past due to the lack of simple livestock production policy. This has been rectified, and the entire livestock industry in Ghana is being restructured through the implementation of a National Livestock Development Project jointly sponsored by the government of Ghana and the World Bank. The objective of the national breeding programme is to select more productive cattle that are hardy and trypanotolerant. Although detailed planning has been done for the implementation and monitoring of the project, breeding objectives for

the various livestock industries have not been defined.

Three main beef breeds of cattle are farmed in Ghana: N'dama and Sorthorn cattle which are traditional or local breeds and the Zebu which is imported. Some limited information on Friesian cattle was included in the study because they can be used to produce beef crosses in the smallholder herds in the future. Classification of traits based on performance indicate that the local breeds of cattle (WASH and N'dama) are late maturing with relatively small body size, poor reproductive and milk production capacity but they are well adapted to the tropical environment (Table 3.15). On the other hand, the Zebus are larger, late maturing types, tending towards lower reproductive rates, medium milk yield, and relatively lower adaptation. Friesians in the Ghanaian environment have a high capacity for milk production, but are limited by the harsh tropical environment to express their genetic potential.

**Table 3.15:** Classification of traits based on performance of different breeds of cattle in Ghana.

Trait	Local	Zebu	Friesian
Survival	High	Low	Low
Reproduction	Low	Low	Low
Growth	Low	High	High
Milk Production	Low	Medium	High
Carcass	Indifferent	Indifferent	-

Crossing the two local breeds has not brought about any significant improvement. Crossing any of the local breeds to the Zebu or European breeds resulted in some improvement. Some scanty information indicates that there were no improvements in reproductive traits with the crossing of a local breed and Zebu. There appeared to be some growth depression at the pre-weaning stage of crosses which have local breeds as mothers. This was probably due to the poorer milking ability of the local dam.

The production systems of the beef cattle industry for the north and the south are entirely different. The objectives, climate, vegetation and constraints to animal production are different for the two regions. Although, the north accounts for almost two-thirds of Ghana's ruminant livestock, information on livestock production in the north is lacking in the literature. This probably results from the fact that all the universities and the Animal Research Institute which conduct research in Ghana on livestock have all existed in the south, until only recently when the University of Development Studies was opened in the north.

The livestock industry used to be unstructured. The Open Nucleus Breeding Scheme has been proposed for the cattle industry under the National Livestock Development Project, but its implementation is still a matter of great concern. Nucleus breeding stations for different livestock species have been established in different ecological zones. These farms were established, based on the assumption that private ownership participation to supplement government efforts is to be encouraged in order to increase the number of animals that will be made available for sale to farmers. These private participants must be guided so that nucleus breeding stations are established for all the different livestock species in each of the ecological zones, because the transfer of an animal from one zone to the other may be fraught with genotype by environment interaction.

The most important limiting factor to increased livestock production in Ghana is trypanosomiasis. The incidence of trypanosomiasis is, however, low in the north compared to the south, which is good because the cattle numbers and the savannah vegetation gives the north a greater potential to increased beef production than the south. However, the objectives of most livestock farmers in the north tend to favour the social needs of the people more than their economic needs. This has the effect of limiting adoption of new technologies and thus decreases production.

## CHAPTER 4

### DEVELOPING THE BREEDING OBJECTIVE

#### 4.1 Introduction

In order to weight traits in the breeding objective, their economic values need to be estimated. The economic values of traits are not only important for selection within a breed, but also for choices of optimum breeding programmes (Harris *et al.*, 1984; Harris and Newman, 1994; Amer, 1994). The objective of this chapter is to develop models that are capable of simulating the life cycle production of a breeding cow and growth performance of her offspring in N'dama and Zebu cattle. The models will apply to the situation in southern Ghana, and parameters originate from a variety of sources in Southern Ghana.

The life cycle model was used to estimate the economic values of the following traits: calving rate, age at first calving, calving interval, survival rate of calves from birth to weaning, survival rate of calves from weaning to maturity, pre-weaning daily gain, post-weaning daily gain and food intake. The estimated economic values should be used to evolve appropriate guidelines that are needed for improving cattle production in Ghana. The method used in this study follows the sequential procedure used by Ponzoni (1986, 1988) and Ponzoni and Newman (1989) for sheep and beef cattle, respectively, in Australia.

#### 4.2 Defining a typical Ghanaian beef cattle breeding, production and marketing system

##### *Breeding system*

It was assumed that farmers purchase bulls from government cattle breeding stations (nucleus herds) but breed their own female replacements. Further, farmers produce virtually all the meat, but depend on government cattle breeding stations for permanent

genetic change. Under such circumstances, the government cattle breeding stations should define their objectives to coincide with that of the farmer. Purebreeding N'dama and Zebu beef production systems were considered.

#### *Production and marketing system*

The generalized flow diagrams for N'dama and Zebu cows and their offspring derived from the average values of all traits are shown in Fig. 4.1 and 4.2 respectively. Five classes of stock were defined: calves, heifers, bullocks, cows and replacement heifers. Two growing stages were distinguished for the calves of cows: (1) from birth to weaning at 6 months, and (2) from weaning to mature age at three years. Table 4.1 shows the weight distribution by sex for age of the classes of animals, from which the growth rates of all classes of cattle were derived. Growth rates at their respective stages of growth (birth to weaning, and weaning to mature weight at 3 years) were assumed to be linear. Most of the data used in the construction of Table 3.3 in chapter three indicated only average weights for both sexes of the different breeds of cattle studied. It therefore became necessary to select those which grouped weights by sex and use them exclusively for developing the models.

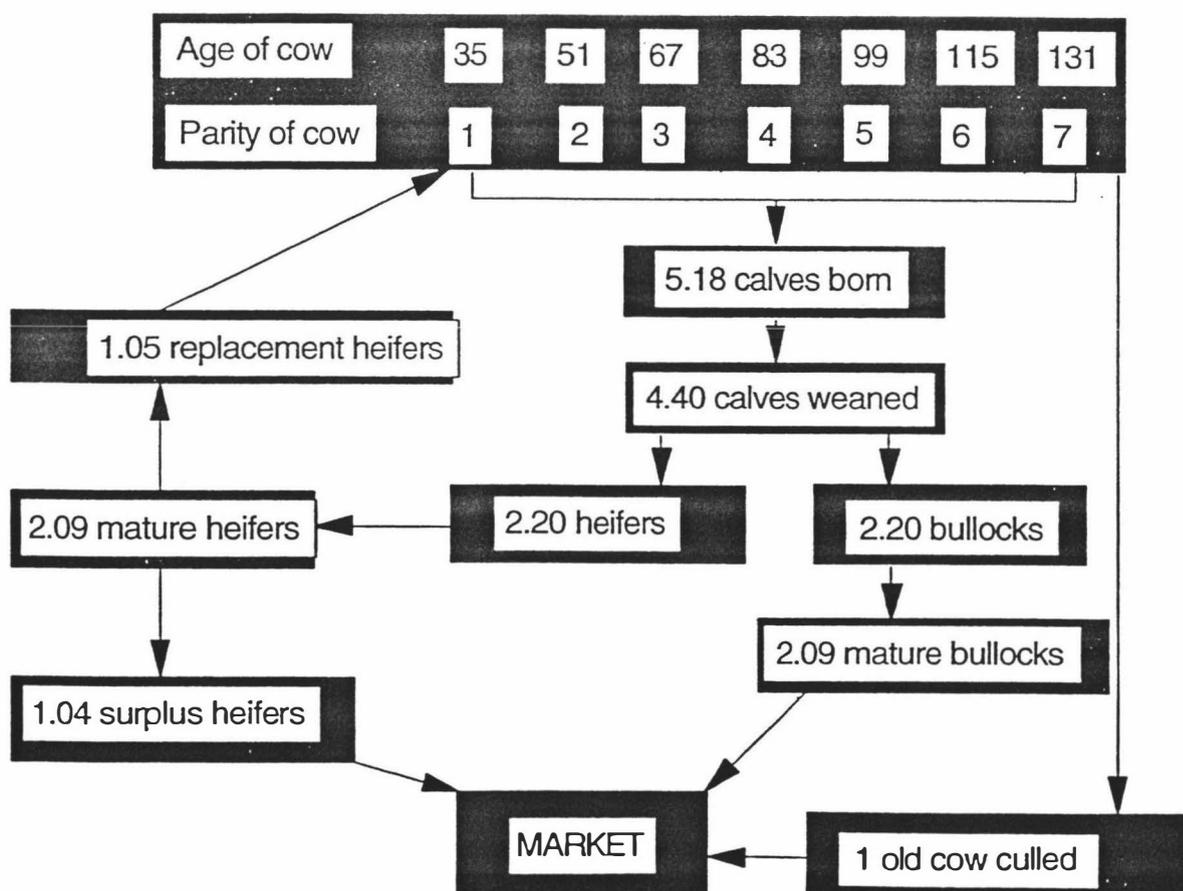
All male calves are castrated after weaning, to avoid the problem of separating males and females into different herds. The castrated male calves shall be referred to as bullocks in the rest of the text. Heifer calves would be kept until culling takes place prior to mating at about 26 and 34 months, respectively, in N'dama and Zebu heifers. Surplus heifers and bullocks would be sold for slaughter at 3 years of age i.e. the time taken for cattle to reach maturity was assumed to be the same for the two breeds. Thus, the weight of heifers and bullocks sold was taken as their expected weight for their age. Culled cows would be disposed off at 90 % of the expected weight of marketed heifers (Wilton *et al.*, 1974), since the dressing percentage is slightly higher for finished cattle than for culled cows (Morris, 1980).

**Table 4.1:** Distribution of weights (kg) by age for male and female N'dama and Zebu cattle.

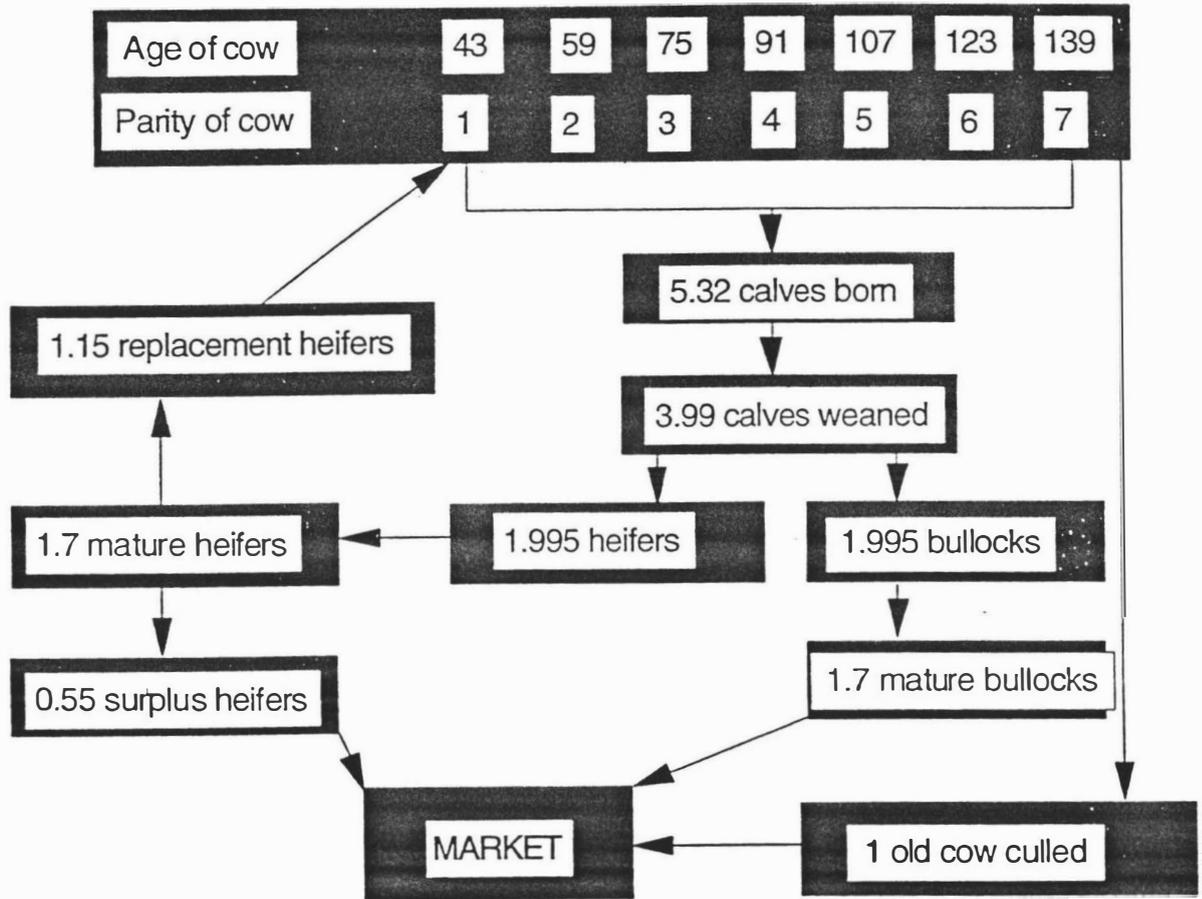
Trait	N'dama		Zebu	
	Male	Female	Male	Female
Birth weight	19	18	24	23
6 months weight	94	85	131	120
Mature weight	239	221	380	323

Adapted from: Montsma (1963); Sada and Vohradsky (1979); Tuah and Danso (1985); Rege *et al.* (1994b).

**Fig. 4.1:** Generalized flow diagram for N'dama cow and her offspring derived from the average values of all traits.



**Fig. 4.2:** Generalized flow diagram for Zebu cow and her offspring derived from the average values of all traits.



Most economic evaluations of breeding objectives have been undertaken based on the volume of product per animal (carcass weight) (e.g. Ponzoni and Newman, 1989; Newman *et al.*, 1992). This approach was not used in the present study because of the necessity of comparing traits of two different breeds which differ markedly in size. Under such circumstances, it is sometimes useful to express carcass weight as the product of the mean weight of animals and the production per unit weight (dressing out percentage) (Weller, 1994). In the present study, the mean weight of mature heifers and bullocks was expressed as:

**Mature Weight = Birth Weight + (Pre-weaning daily gain x Days from birth to weaning) + (Post-weaning daily gain x Days from weaning to maturity)**

This represents the true state of affairs in Ghana, since marketing of cattle in Ghana is presently based on per kilogram live weight basis, in which case carcass composition (meat yield and quality) has no effect on the farmers' income. However, it must be pointed out that this may change in the future. Dressing out percentage for N'dama and Zebu were taken to be 50 and 46 % respectively. These were assumed to be the same for different classes of cattle of the same breed. It was also assumed that the saleable price of beef carcass of the different classes and breeds of cattle are the same on per kilogram basis.

N'dama and Zebu heifers were assumed to be mated at 26 and 34 months of age to calve for the first time at 35 and 43 months of age, respectively. Mating was not restricted to any season of the year. A calving rate of 74 % and 76 % was assumed for N'dama and Zebu, respectively, with calving taking place throughout the year. Rebreeding occurred 7 months after calving i.e. one month after weaning.

There is a lack of information in the literature on the length of the productive life of the breeds of cattle studied. However, the productive life of N'dama cow in neighbouring Senegal has been found to be about 7.5 years (ILCA, 1982a). Data from several sources also revealed that the useful life of Zebu cattle in the tropics varies from 4.5 to 8.5 years (Mukasa-Mugerwa, 1989). An average productive life of 8 years (96 months) was assumed for both N'dama and Zebu cows in this study. When their respective age at first calving (see above) was added to their individual productive life, the average cow on completion of productive life would be 10.9 years or 131 months (N'dama) and 11.6 or 139 months (Zebu). Considering a calving interval of 16 months for each breed, each cow in both breeds will reach its seventh parity before being culled, when the complete replacement of the cow takes place. However, it was also assumed that a cow rears its seventh parity calf for 6 months (when the calf is weaned) and stays in the herd for an additional one month for reconditioning before it is sold off completely. The cow was then assumed to be replaced by one heifer.

Calf mortality up to weaning was assumed to be 15 and 25 % for N'dama and Zebu respectively. From weaning until slaughter in heifers and bullocks, mortality was assumed to reduce to 5 and 15 % in N'dama and Zebu respectively. Mortality in the breeding cow was also assumed to be 5 and 15 % for N'dama and Zebu respectively. This assumption is particularly reasonable, when a cow herd of size  $n$  is considered. Although cow mortality was accounted for by replacement heifers (Fig. 4.1 and 4.2), a dead cow was assumed to have no value (Newman *et al.*, 1992).

The feeding regime assumed was that of cattle grazing unimproved natural pastures. It was assumed that feed was available throughout the year for grazing, and no supplementary feed was provided. It was also assumed that seasonal effects had no influence on quality and quantity of natural pastures. This means that seasonal effects had no influence on animal performance. Although, there is presently no cost associated with natural grazing pastures, because farmers do not cultivate or improve these pastures. Food cost was assumed in this work because it is anticipated that in future farmers would have to cultivate pastures, and/or improve the natural grazing pastures.

Labour was provided by the Fulani herdsman, whose main duty is to graze cattle, build the kraal and assist in handling animals in case of any veterinary interventions. Housing was not costed as kraal is built of cheap locally available materials mobilized by the Fulani herdsman. The labour cost of the Fulani herdsman was considered fixed, since it was assumed that he is paid cash, equivalent to the value of one marketed heifer each year, whether he works or not. Vaccination of cattle and some veterinary assistance against for example traumatic injury and minor diseases were assumed to take place. All of these represented variable cost, with the exception of vaccination which is free in Ghana. The costs associated with the marketing of cattle were also assumed to be born by the farmer. These include transportation, loading fees, local levies and taxes involved in meat inspection. Information on these were provided by the Animal Production Department (APD), Ministry of Agriculture, Ghana.

### 4.3 Identification of the sources of income and expense in production system

Here, the profit (P) in the smallholder herd was expressed as a function of income (I) and cost (C):

$$P = I - C \dots\dots\dots(4.1)$$

Income is derived from the sum of products of number of sale animals in each class of cattle (bullocks, heifers and culled cows) and the values per individual as follows:

bullocks x value per individual  
surplus heifers x value per individual  
culled cow x value per cow

Expenses are derived from food, husbandry, marketing and fixed costs as follows:

heifers' food intake x cost per kg  
bullocks' food intake x cost per kg  
cows' food intake x cost per kg  
heifers' husbandry cost  
bullocks' husbandry cost  
cows' husbandry cost  
bullocks' x marketing cost per individual  
surplus heifers' x marketing cost per individual  
culled cow's x marketing cost per individual  
labour cost  
initial cost for establishment of business  
interest on investment

The last three items are termed as fixed costs, because they are independent of the level of output. All other costs are known as variable costs because they change with the level of output. Husbandry costs included castration, drenching, deticking and wound

treatment. Information on husbandry costs were provided by the Veterinary Services Department (VSD), Ministry of Agriculture, Ghana (Table 4.2). The susceptibility of Zebu cattle to trypanosomiasis requires that the husbandry cost of the Zebu cattle would be more than that of N'dama. The husbandry cost of Zebu cattle was therefore assumed to be double that of the N'dama.

**Table 4.2:** Value of expenses (Cedis) for production systems

Expense**	Heifers	Bullocks	Cows
Feed (Cedis/kgDM)	11	11	11
Husbandry (per head per year)	5100 (10200)	5500 (11000)	6000 (12000)
Marketing (per head)	4500 (6500)	5000 (7500)	4000 (6000)

\*\* = Figures in brackets and open represent values for N'dama and Zebu respectively.

The price of beef was assumed at 2600 Cedis per kilogramme for all classes of stock. This information was provided by the Animal Production Department (APD), Ministry of Agriculture, Ghana, and represented the average prices of beef from nine major markets in Accra. The Cedis is unit of the Ghanaian currency, and about 1200 Cedis is equivalent to 1 US dollar (GRi, 1995). The value of expenses for the production systems are presented in Table 4.2. Marketing cost was based on mature saleable weight, assumed to be about 20 Cedis per kilogramme live weight for all breeds. Food costs for all classes of cattle were assumed to be the same. This was calculated from information provided by APD, Ghana on current cost of establishing and maintaining pasture, and dry matter yields of several grass and legume species in Ghana. The latter were obtained from the literature (Asare, 1970; 1974). Daily dry matter (DM) feed requirements were calculated for the different classes and breeds based on values obtained from ARC (1980). The dry matter intake of N'dama and Zebu (figures in

brackets) were assumed at 4.7 (5.2); 5.0 (5.5); 6.3 (7.1) kg/day for heifers, bullocks and cows respectively. It was assumed that the feed requirements of the breeding cow covered those needed for maintenance, growth, reproduction and lactation.

The feed intake of heifers and bullocks included that occurring between birth to weaning and weaning to maturity. Intake given above covers the post-weaning period, and the pre-weaning intake was assumed to be equal to half of the post-weaning food intake. Intake of the breeding cow was also assumed to include the pre-cow (from birth to first calving) intake and the active productive life intake. The pre-weaning feed intake of calves was assumed to begin actively in 61 days (2 months) after birth (ILCA, 1982b), since very young calves consume insignificant quantities of forage as they cannot digest a greater intake. The pre-weaning husbandry and feed requirements assumed that animals which died did so at the end of the pre-weaning period. Similarly, animals which died at the post-weaning period were counted at the end of this period.

#### **4.4 Determination of biological traits influencing income and expense**

The biological traits assumed to have influence on profit are presented in Table 4.3. The meanings of the symbols used in table three are given in Appendix I.1. Below is the reasoning behind the choice of these traits. A balanced breeding programme demands that a cow in a herd should be in calf at a planned time each year, and producing a life calf which thrives until weaning. This provides enormous contribution to the profitability of the beef cattle industry (N.Z.S.A.P, 1972). Calving rate and calf survival rate are therefore considered to be important traits in beef cattle, because they also contribute to higher net calf crop (number of calves weaned per cow joined), the latter being considered the most important reproductive trait in beef cattle in many temperate regions (Baker, 1973; Morris, 1979; Morris, 1981). If calving and calf survival rates are low, less calves will be weaned, and selection intensity would be reduced and generation length increased to maintain numbers. If a cow should rear a calf each year, then, calving interval becomes important, especially in the tropics where the calving interval often exceeds one year.

In addition, survival is a trait of major importance in the tropics because the cost of production is largely influenced by the ability of animals to cope with the prevailing environmental conditions (e.g. heat, diseases, etc) (Franklin, 1986; Rudder, 1989; Baker and Rege, 1994). Baker and Rege (1994) have noted that the most appropriate option for developing breeding objectives in the tropics is to attempt both a biological and genetic understanding of adaptation and its inter-relationships with production, and so develop breeding systems that improve both adaptation and production. This approach also leads to a better understanding and exploitation of genotype by environment interactions which are commonly encountered in the tropics.

**Table 4.3:** Biological traits influencing income and expense

Product or activity	Class of cattle	Traits in breeding objective
Income		
Surplus progeny	Bullocks	CR, AFC, CI, SBW, SWM, bPRDG, bPODG
Surplus progeny	Heifers	CR, AFC, CI, SBW, SWM, hPRDG, hPODG
Culled cow	Cow	hPRDG, hPODG
Expenses		
Food intake	Bullocks	CR, AFC, CI, bPRFI, bPOFI, SBW
	Heifers	CR, AFC, CI, hPRFI, hPOFI, SBW
	Cow	hPRFI, hPOFI, cFI, AFC
Husbandry	Bullocks	CR, AFC, CI, SBW
	Heifers	CR, AFC, CI, SBW
	Cow	AFC
Marketing	Bullocks	CR, AFC, CI, SBW, SWM
	Heifers	CR, AFC, CI, SBW, SWM

The age cattle reach a given market weight depends on the growth rate from birth to

desired slaughter weight. Gain to market is therefore the trait of highest economic importance in slaughter cattle, at least in temperate regions of the world (Baker, 1973; Rae and Barton, 1970). However, Baker and Rege (1994) have contended that in the tropics, survival is much more important than growth rate. Unfortunately, for most domestic animals reared in the tropics for slaughter, the main trait under selection is growth rate, because it is highly correlated with feed efficiency. Growth rate is also heritable (Table 2.1), and within-breed selection is easy and cheap to implement. In addition, higher growth rates can lead to a decrease in the number of days required to achieve a constant slaughter weight and thus reduce the annual maintenance costs. Both pre-weaning and post-weaning growth rates were therefore included in the breeding objective in order to find out their relative magnitude to survival in the tropics.

Selection for high growth rate may produce cows that require heavier weights to achieve puberty. This can prolong the age at first calving, and compound the already existing problem of older age at first calving. The major mechanism for increasing the ability for an animal to grow fast is to increase its mature size. Maintenance costs, which are a function of mature weight, typically account for 50-60 % of the total costs in a cow calf operation (Morris, 1980; Boggs, 1993). Therefore, selection decisions which increase mature size have a significant impact on feed requirements.

Calving rate, age at first calving, calving interval, survival rates of calves from birth to weaning, survival rates of calves from weaning to maturity, pre-weaning daily gain, post-weaning daily gain, and food intake were therefore the traits chosen to be included in the breeding objective (Table 4.3).

#### **4.5 Derivation of the economic value for each trait.**

A method of deriving economic values is to utilise profit equations. It involves combining income and expense as a function of profit, where profit is derived from the difference between income and expense. The economic value of a trait is the extra profit per cow per year from a unit increase in a trait, under the condition that performance levels of all other traits are held constant, at their mean values. This is

known as the partial budgeting approach (Upton *et al.*, 1988; Barwick, 1992; Barwick and Fucsh, 1994). It is done in a budgeting framework by considering only those parts or items of the budget that change. The budgeting process involves identifying and costing all activities carried out on each class of animal from birth to sale. When the increment in the trait is small, the partial budgeting gives the same result as the partial derivative approach (Upton *et al.*, 1988).

In general, profit (P in Cedis) can be expressed as a function of m traits in the breeding objective as follows:

$$P = \sum_{i=1}^m ni(Vi - Ci)Xi - K \dots \dots \dots 4.2$$

where, n is the number of expressions for trait i, V and C, the value and cost per unit for trait X respectively, and K are the fixed costs. The profit equation is expressed by grouping terms by classes of cattle and calculating returns and expenses in one-year yields:

$$P = (P_{\text{bullocks}} + P_{\text{heifers}} + P_{\text{cow}}) - \text{Fixed cost} \dots \dots \dots (4.3),$$

where  $P_{\text{bullocks}}$ ,  $P_{\text{heifers}}$  and  $P_{\text{cows}}$  are the profits from bullocks, heifers and cows respectively in the complete life cycle of the breeding cow. Fixed costs were ignored, since I and C were combined as a difference, and do not include the items of the budget that change. It should be noted that when I and C are combined as a ratio (efficiency) (e.g. Brascamp *et al.*, 1985), an estimate of fixed cost would be required. However, Ponzoni (1988) found the way in which I and C are combined has only a small effect on economic values derived in this way.

Each of these profits were expressed as a function of traits in the breeding objective (see Appendix II.1, II.2 and II.3). The combined life cycle profit was scaled from a life time profit to a per cow-year basis by dividing profit by the total number of years in which a cow completes its entire life cycle: 11.5 and 12.2 for N'dama and Zebu cows

respectively (Appendix II.4). Calculating profit in one-year yields allows for frequency of expression of traits (Ponzoni and Newman, 1989; Newman *et al.*, 1992). The marginal profit resulting from 1 % increase in each trait was calculated by subtracting the total profit accruing from average levels of values for all traits from total profit resulting from 1 % increase in the level of each trait (Appendix II.4). All costs and returns were expressed as an Annualized Present Value (APV), taking into account the time preference for consumption (Smith, 1978). Three discount rates (0, 10 and 20 %) were used in order to find a suitable discount factor that is capable of adjusting net profit to allow for a decrease in value of the future net returns. The wide range of discount rates chosen is because of the high inflation and lending rates in Ghana which currently stand at 21.5 and 31.5 % respectively (GRI, 1995).

## CHAPTER 5

### RESULTS AND DISCUSSIONS

#### 5.1 The main elements of returns and costs

The main elements of returns and costs, including profit from the breeding cow, heifers and bullocks are presented in Appendix III. From Appendix III, the marginal profit in Cedis resulting from the change in the level of any trait can be calculated. For example, the marginal profit derived from the complete life cycle of the cow (12,526.30), resulting from a 1 % increase in calving rate in N'dama cattle, is the difference between the combined profit from bullocks (482,475.56), heifers (147,530.22), and the breeding cow (-78,393.30) for average level of all traits and the combined profits from bullocks (488,995.50), heifers (153,536.58) and the cow (-78,393.30) resulting from change in the level of calving rate, whilst holding the average levels of all other traits constant. Thus, the total enterprise marginal profit divided by the life time of the cow in years gives the marginal profit per cow per year, and hence undiscounted economic value of calving rate (1,089.24).

Whilst the food and husbandry cost of heifers and bullocks were always comparable, the returns and marketing cost of bullocks were always much higher than that of heifers. This difference resulted from replacing heifers for the culled and dead cows, respectively (Fig. 4.1 and 4.2). The replacement heifers did not contribute to the returns and marketing cost of heifers, although they had previously contributed to the food and husbandry costs of heifers before reaching maturity. However, the opportunity cost and returns associated with the replacement policy are the marketing cost and returns accruing from the sale of the salvage cow.

Changes in the level of reproductive traits (CR, AFC and CI) resulted in changes in all costs and returns, hence profit, in both bullocks and heifers (note that changes were made in AFC and CI by decreasing the average level of these traits by 1 %). These were expected, because inspection of Table 4.4 and Appendix II.1 and II.2

reveals that these traits affect marketing, food and husbandry cost, and returns. This same effect was also observed in the survival traits, except in the case of food and husbandry cost, which did not change, as a result of change in SWM. The food and husbandry costs of bullocks and heifers remained the same as the average values of all traits because animals which died during the post-weaning phase were assumed to have done so at the end of the period. Therefore, the same number of animals that reached the end of the pre-weaning stage were carried to the end of the post-weaning stage.

Changes in pre- and post-weaning growth rates affected returns but not costs. Similarly, changes in pre- and post-weaning food intake affected only food cost but not either marketing and husbandry cost, nor returns. The reasons advanced for these are the same as those given above for reproductive traits. In fact, one of the lapses in these simple models is the failure to define growth rate as a function of food intake. An increase in growth rate should result in an increase in food costs, because larger animals produced at a constant age may require more feed (Koch, *et al.*, 1963; Greeff *et al.*, 1995). Alternatively, an increase in food intake may result in an increase in growth rate, especially where animals are underfed. It was assumed in the examples examined here that growth rate had no connection with food intake, which is rarely true. This was equally true of the breeding cow whose body weight at different stages of the life cycle was not taken into consideration in the models, because of the lack of data on cow size in relation to different stages of growth in the literature. Beef cow weights are always expected to rise as correlated response to selection for high growth rates in growing stock. This is a cost in terms of food for heavier cows, and a benefit in terms of extra returns derived from the sale of heavier culled cows. More sophisticated models which differentially value growth rate as a function of food intake are required to predict these changes.

However, it must be remembered that if increase in growth rate leads to a consequential increase in food intake, costs of production will rise and profit will shrink (Koch *et al.*, 1963; Taylor and Young, 1966; Morris, 1980). Nevertheless, increases in food intake due to increases in growth rate are not proportional. As an

example, an attempt was made to predict changes in costs, assuming that changes in growth rate lead to consequential changes in food intake. Assuming that there are increases in food intake in faster growing cattle slaughtered at the same age, and recognizing that these increases are only about 40 % of what would be a proportional increase in intake (Koch *et al.*, 1963; Taylor and Young, 1966), the marginal cost resulting from these changes were calculated for the different levels of growth traits. Table 5.1 shows the marginal cost resulting from an increase in food cost as a result of 1 % change in the level of pre-weaning (PRW) and post-weaning (POW) growth rates. Thus, marginal profits, and hence economic values are expected to be reduced by these amounts (Table 5.6).

**Table 5.1:** Marginal cost (Cedis) associated with defining growth rate as a function of food intake at various discount rates.

Trait	0 %		10 %		20 %	
	N'dama	Zebu	N'dama	Zebu	N'dama	Zebu
Bullocks' PRW	34.76	35.70	23.74	24.38	16.77	17.21
Heifers' PRW	34.76	35.70	23.74	24.39	16.77	17.22
Bullocks' POW	443.16	401.60	304.13	274.29	215.68	193.67
Heifers' POW	443.16	401.59	304.14	274.29	215.68	193.67
Cow's Heifer	208.01	261.69	180.29	212.49	158.24	190.21

As expected, the marketing cost of the cow was constant at the average level and at all sensitive levels of each trait, because none of the traits had an influence on the marketing cost of the cow (Table 4.4 or Appendix II.3). Whereas AFC, hPRFI, hPOFI and cFI affected the food cost of the cow, hPRDG and hPODG affected returns from the breeding cow. There was also an increase in husbandry cost of the cow as a result of decrease in AFC, because of the corresponding increase in the reproductive life of the cow.

Cow's food cost accounted for 54 and 57 % of total enterprise food cost of N'dama

and Zebu respectively (Table 5.2). This is consistent with the reports in the literature. It has been reported that about 50-70 % of the total herd food intake is required by the breeding cow herd (Morris, 1979, 1980; Boggs, 1993).

**Table 5.2:** Cow's food cost as a percentage of total enterprise food cost at the different levels of traits.

Trait	N'dama	Zebu
Average	53.49	57.26
CR	53.16	56.94
AFC	53.43	57.18
CI	53.28	57.05
SBW	53.22	56.96
SWM	53.49	57.26
bPRDG	53.49	57.26
hPRDG	53.49	57.26
bPODG	53.49	57.26
hPODG	53.49	57.26
bPRFI	53.48	57.25
hPRFI	53.49	57.25
bPOFI	53.37	57.14
hPOFI	53.42	57.20
cFI	53.69	57.45

When the difference between returns and costs was used as an indicator of economic evaluation, the N'dama production system produced more profit per cow per year

than Zebu (Table 5.3). The profit per cow per year for N'dama was on average 17 % more than that for the Zebu production system. When the price of feed was set to zero ( $F = 0$ ), profit per cow per year was almost doubled for both breeds (Table 5.3). However, profit per cow per year for the N'dama production system was only about 7 % more than that of the Zebu, with the removal of food intake from the objective. This probably explains why farmers in Ghana prefer the Zebu to the local cattle, although it will be seen later that adaptation (survival), which is higher in the local cattle, contributes enormously to the overall profitability of the beef cattle enterprise in Ghana. Presently, most farmers in Ghana do not cultivate pasture, but depend on free natural grazing pastures which are not even maintained i.e. if feed costs is ignored, Zebu cattle appears to look similar to N'dama for profit.

In terms of economic efficiency, defined as total returns divided by enterprise cost, the N'dama production system was more efficient than that of the Zebu. For the average levels of all traits, the economic efficiency for N'dama and Zebu were 31 and 24 % respectively. This supports the argument above that the N'dama performs better in economic terms than the Zebu.

Biological efficiency, defined as the ratio of product output (kg) to feed input (kg) was just 1 % for both N'dama and Zebu. This shows the poor efficiency with which ruminants convert forage into meat. However, it should be recognized that this forage cannot otherwise be used by humans. The validity of biological efficiency as an indicator of efficiency in animal production has recently been questioned.

Morris *et al.* (1994) demonstrated that marked differences between systems in the value of the carcass produced and/or feed consumed can lead to poor correlation between the efficiency of ranking systems by biological and economic criteria. In most cases, biological efficiency is reduced when expressed per unit of a breeding population, (as done here) since the feed required to support breeding females have to be included and for the whole time, not merely when they are being productive (Dickerson, 1982; Spedding, 1988). This has been demonstrated in sheep in South Africa. The results of studies conducted by Greeff *et al.* (1995) illustrated the huge

cost (at least 81 to 94 % of total food intake depending on reproductive rate of the different genotypes used) of maintaining a ewe flock and indicated that the efficiency of food utilization of lamb was relatively unimportant when the total amount of food consumed by the ewe-lamb unit is considered.

**Table 5.3:** Profit per cow per year (Cedis) for N'dama and Zebu cattle production systems at 0 % discount rate.

Level of Trait	N'dama when		Zebu when	
	N'dama	F = 0	Zebu	F = 0
Average	47966.30	91303.64	39844.40	84708.42
CR	49055.55	92665.26	40959.74	86076.08
AFC	48199.57	91616.23	40142.09	85102.20
CI	48664.17	92176.02	40578.30	85608.35
SBW	48945.87	92503.09	41026.30	86125.13
SWM	49092.90	92430.23	41196.40	86060.42
bPRDG	48150.78	91488.12	39877.88	84741.90
hPRDG	48270.72	91608.06	39980.45	84844.47
bPODG	48643.42	91980.75	39930.93	84794.95
hPODG	48541.85	91879.19	39888.76	84752.78
bPRFI	47958.75	91303.64	39836.35	84708.42
hPRFI	47956.46	91303.64	39833.93	84708.42
bPOFI	47869.96	91303.64	39753.88	84708.42
hPOFI	47835.98	91303.64	39705.90	84708.42
cFI	47776.99	91303.64	39643.29	84708.42

In addition to the reasons given above, assessment of the efficiency with which feed

is used by the animal population has to take into account the feed used to produce replacement breeding stock and losses of animals due to diseases. All of these lead to reduction in efficiency. Even, where efficiency is used as the basis for assessing breeding objectives, Dickerson (1970, 1982) and Harris (1970) have warned that although the effect of genetic changes in performance on biological efficiency can be used as the basis, the breeding objectives must be determined finally by effects on economic efficiency.

Biological efficiency was again evaluated based on the amount of body weight of offspring sold, generated by the breeding cow. It was assumed that the average body weight of the breeding cow was equal to that of a mature heifer. On average, the N'dama and Zebu cows were capable of generating only about 0.4 and 0.3, respectively, of their body weight in progeny each year. These figures are low compared to the 0.7 calculated from data reported by Spedding (1979). This reflects the results of relatively low reproduction and survival rates, and the conversion of grass to meat (calf) with the loss of energy at each stage of the process (Everitt, 1972). Measures of biological efficiency which relate meat production to dam live weight assumes a constant relationship between dam live weight and input costs, of which the most important are commonly feed costs. Biological efficiency measured in this way is therefore known not to be useful when comparisons are made across species, and may also be questionable when comparisons are made between systems within species (Morris *et al.*, 1994).

## **5.2 Economic Values of traits in the breeding objective**

The economic values of traits resulting from 1 % increase or decrease (in the case of AFC and CI) in the average value of each trait are presented in Table 5.4 (N'dama) and Table 5.5 (Zebu). The predicted economic values for individual traits regressed towards zero for non-discounted marginal returns compared to discounted marginal returns. The regression increased as the discount rate increased.

**Table 5.4:** Economic values of traits (Cedis) in the breeding objective at different discount rates for N'dama production system

Trait	0 %	10 %	20 %
CR	1089.24	747.59	530.19
AFC	233.27	170.31	132.30
CI	697.87	478.97	339.69
SBW	979.57	672.26	476.73
SWM	1126.59	773.15	545.14
bPRDG	184.48	126.60	86.44
hPRDG	304.42	159.23	96.81
bPODG	677.11	464.69	326.39
hPODG	575.55	301.04	183.03
bPRFI	-7.56	-5.16	-3.64
hPRFI	-9.84	-7.23	-5.51
bPOFI	-96.34	-66.12	-46.89
hPOFI	-130.32	-96.62	-74.32
cFI	-189.31	-126.26	-87.23

The regression of economic values towards zero was more pronounced in hPRDG and hPODG than in other traits, because these traits affected the returns from the culled cow (Table 4.3 and Appendix II.3) and are expressed later in life than all the other traits. This observation has been made by other workers. For example, Ponzoni and Newman (1989) observed that relative to taking all income and expenses per year, discounting increased the importance of traits expressed early in the life of animals, e.g. carcass weight of calves, whereas the opposite was true for traits expressed late in life, e.g. carcass weight of cows. In this study, the change was greater the greater the discount rate applied.

**Table 5.5:** Economic values of traits (Cedis) in the breeding objective at different discount rates for Zebu production system

Trait	0 %	10 %	20 %
CR	1115.34	732.68	499.06
AFC	297.69	215.29	161.79
CI	733.90	482.11	328.39
SBW	1181.90	777.75	530.64
SWM	1352.00	879.41	617.30
bPRDG	33.48	22.22	15.29
hPRDG	136.05	60.56	32.61
bPODG	86.53	57.43	39.51
hPODG	44.36	19.75	10.63
bPRFI	-8.05	-5.50	-3.88
hPRFI	-10.47	-7.62	-5.75
bPOFI	-90.52	-61.83	-43.66
hPOFI	-138.50	-103.24	-79.73
cFI	-201.11	-127.88	-84.59

Among the reproductive traits, calving rate was the most important trait. This was followed by calving interval, with age at first calving ranking the least important. It was surprising to note that age at first calving ranked the least important amongst the reproductive traits, although the age at first calving of these breeds are quite late. This is probably a reflection of how a change of 1 % relates to the phenotypic standard deviation.

Survival from weaning to maturity was more important than survival from birth to weaning. Mortality from birth to weaning was higher than that from weaning to

maturity in the assumptions made earlier in this study. This means that calves are more vulnerable than their adult counterparts. It was therefore expected that survival at the pre-weaning stage would have been more important than survival at the post-weaning stage. This result is difficult to explain, although a simple reason that could possibly account for this is that the pre-weaning stage of growth is short, compared to post-weaning stage. End points are always determined by passage of time.

In both N'dama and Zebu cattle, the economic value of hPRDG was higher than that of bPRDG, whereas the reverse occurred at the post-weaning stage of growth. In the former, the heifer stage of the breeding cow contributed to the economic values (Table 4.3 and Appendix II.3). Whereas in the latter, returns from heifers relative to that of bullocks was reduced because some heifers were used to replace the culled cow. In general, the economic values for growth from birth to weaning were small compared with those for later growth, except in the case of the Zebu, where the value of hPRDG was higher than hPODG. This same effect was observed by MacNeil *et al.* (1994). This is because growth early in life is short compared to growth at the post-weaning stage. The cost associated with the pre-weaning stage is therefore low. Rapid growth early in life does not increase the amount of product produced, as slow growth later in life would do, because endpoints are completely determined by passage of time.

The economic values of growth rate resulting from expressing growth rate as a function of food intake (see Section 5.1) are presented in Table 5.6. There were decreases in the magnitude of the economic values (Table 5.4 and 5.5) of growth rates because increased in food cost resulting from increase in growth rate led to decreases in marginal profit (Table 5.1). However, trends in economic values still remained the same. The negative value obtained for hPODG in the Zebu cattle probably emphasizes the important point that growth rate *per se* is not critical issue for cattle in Ghana where survival and reproductive rate assume greater importance (Table 5.4 and 5.5).

**Table 5.6:** Economic values of growth rate assuming increase in growth rate leads to corresponding increase in food intake.

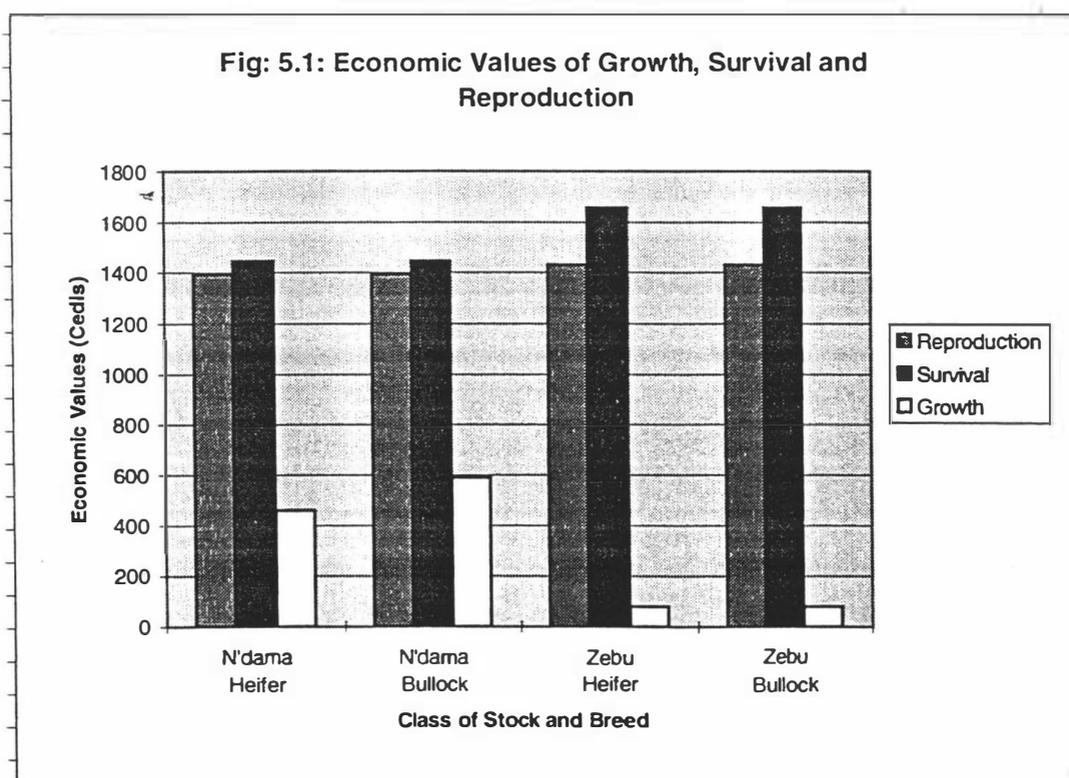
		bPRDG	hPRDG	bPODG	hPODG
N'dama	0 %	181.46	300.23	638.58	520.09
	10 %	124.54	151.15	438.24	259.93
	20 %	88.32	94.47	310.78	151.41
Zebu	0 %	30.55	132.02	53.61	-8.91
	10 %	20.22	57.63	34.95	-19.96
	20 %	13.88	30.40	23.63	-20.03

The economic values of food intake had negative values because increasing food intake had the effect of increasing cost and decreasing marginal profit. cFI had the highest negative economic value relative to the values of heifers and bullocks for food intake. This same effect was reported by Ponzoni and Newman (1989). They observed that the cow's food intake made the greatest negative contribution to total gain in terms of economic units. Since more feed is required to maintain the breeding cow, increasing food cost of the cow has a pronounced effect of decreasing marginal returns in the cow, compared to the same effects in bullocks and heifers.

The economic values of food intake of heifers had larger negative values than that of bullocks at both the pre- and post-weaning stages because the food intake of the cow's heifer stage contributed to the economic value of heifers' food intake. The economic values of food intake of both heifers and bullocks at the pre-weaning stage had lower negative values than that of the same class of stock at the post-weaning stage. Morris (1980) has given an explanation for this. The marginal food cost of higher weaner calf production is likely to be relatively small because of major importance of cow herd overhead costs. However, the marginal costs of growing and fattening one more steer per 100 steers from weaning to slaughter are likely to be in proportion to existing costs and cattle numbers. An alternative explanation is that

growth is a function of number of days in the pre- and post-weaning stages.

Combining pre- and post-weaning characters for either a heifer or a bullock, survival appeared to be the most important trait in both breeds (Fig. 5.1). This was followed by reproduction, with growth rate ranking the least important. It is important to note that while the economic values of survival traits in Zebu cattle were slightly higher than their values in N'dama cattle, the economic values of growth rates were much lower in the Zebu cattle, compared to the N'dama. This suggests that survival is more important in the Zebu than the N'dama, because the latter is better adapted to its environment than the former. Additionally, growth rate is more important in N'dama cattle than the Zebu, because the latter has good growth rates and is larger in size than the former. These suggest that the emphasis on traits in the breeding objective for two different breeds in the same environment may be different.



### 5.3 The effect of removal of food intake from the objectives on the economic values of traits.

Removing food intake from the objective by setting the price of feed to zero is equivalent to setting its economic value equal to zero. This was investigated because most farmers in Ghana depend on free natural grazing pastures, although there is still an opportunity cost associated with this kind of practice. The economic values of all reproductive traits and survival from birth to weaning increased, when food intake was removed from the objective, although the trends in economic values still remained almost the same (Table 5.7 and 5.8). The most significant change was that SBW ranked first among all the traits in the Zebu production system, whilst calving rate ranked first in the N'dama production system.

**Table 5.7:** Effect of removal of food intake from the objective on the economic values of traits in N'dama cattle production system

Trait	0 %	10 %	20 %
€R	1361.32	934.45	662.66
AFC	312.59	217.15	156.07
CI	872.38	598.69	424.56
SBW	1199.45	823.16	583.74
SWM	1126.59	773.15	545.14
bPRDG	184.48	126.60	86.44
hPRDG	304.42	156.91	96.81
bPODG	677.11	464.69	326.39
hPODG	575.55	301.04	183.03

These changes were expected because examination of Table 4.4 and Equations 4.4 and 4.5 indicates that the traits through which the cost of food intake is multiplied

were CR, AFC, CI and SBW. Newman *et al.* (1992) defined a breeding objective in which food intake (expense) was assumed to be affected by the number of calves weaned per cow joined. When food cost was set to zero, the response to selection for number of calves weaned per cow joined increased. This increase was presumed to be due to an increase in the economic value of number of calves weaned per cow joined.

**Table 5.8:** Effect of removal of food intake from the objective on the economic values of traits in Zebu production system

Trait	0 %	10 %	20 %
CR	1367.66	905.02	620.74
AFC	393.78	266.92	187.92
CI	899.93	595.51	408.45
SBW	1416.71	938.13	643.88
SWM	1352.00	879.41	617.30
bPRDG	33.48	22.22	15.29
hPRDG	136.05	60.56	32.61
bPODG	86.53	57.43	39.51
hPODG	44.36	19.75	10.63

Changes in the economic values of some traits relative to others mean that there is some justification for the description of breeding objectives to include food intake as an input of the production system. However, it must be pointed out that the technology involved in the measurement may be too expensive, especially for a developing country like Ghana, to justify its inclusion in the objective or its measurement as a selection criterion. Nevertheless, it is important to have food intake in the breeding objective even if it is not assessed as a selection criterion. Otherwise, traits incurring a feed cost will receive too much selection pressure. The

cost effectiveness of recording food intake is therefore worth investigating in future.

#### 5.4 Implications of the results in the tropics

Although the findings of the present study are, of course dependent on the assumptions made during the development of the model, it may be worthwhile speculating about some of the main results. Under most circumstances, combined data from a bullock or a heifer indicated that survival was the most trait that made the greatest positive contribution to profit, in terms of economic units (Fig. 5.1). This was followed by reproductive traits, with growth rate making the lowest positive contribution. Breeding of cattle in the tropics has always focused attention in the improvements of growth traits. Surprisingly, this work has demonstrated that growth rate *per se* is not important, compared to survival and reproductive traits.

Recently, Baker and Rege (1994) pointed out that in many subsistence tropical farming systems, survival in the face of multiple stresses (heat, diseases, etc.) is one of the most important economic traits, while increasing growth rate is of less economic value. This statement traces back to the work of Upton (1985) which evaluated the returns from small ruminant (sheep and goats) production in South West Nigeria. The results of that work are quite similar to the present study. Analysis done by Upton (1985) suggested that the most critical area, where improvements were most needed, was that of reducing mortality i.e. increasing survival. Variation in growth rate had only a relatively small impact. The second most influential factor on overall economic performance was reproduction rate (litter size and parturition interval). This is supported by work done recently in South Africa to determine biological efficiency of meat and wool production of seven sheep genotypes (Greeff *et al.*, 1995). The results of this latter work also emphasizes the importance of high reproductive and survival rates to increased efficiency of lamb production in the tropics.

Conflicting results to the present study were obtained in Canada. McNeil *et al.* (1994) observed that the economic values for male fertility, female fertility and calf

survival were small compared to the economic values of growth rates. In their studies, post-weaning growth rate was the trait with the highest economic value. This emphasizes the important point that breeding objectives in temperate regions may be very different from those in the tropics (Davis, 1993; Baker and Rege, 1994), and that European animal husbandry models should be adopted by developing countries with extreme caution (Jasiorowski, 1991).

The most important environmental factor that contributes to survival or adaptation are diseases, of which trypanosomiasis is the most important in tropical Africa. Diseases in animals cost farmers and consumers millions in monetary units each year (Cundiff *et al.*, 1982). These monetary losses arise from mortality losses, subclinical infection, and veterinary and drug costs. In addition, infection and/or diseases in a herd can reduce genetic progress from selection for production traits, especially in cattle where only a small number of progeny are weaned per dam.

It has been advocated that breeding programmes in the tropics should aim to attempt both a biological and genetic understanding of adaptation and its inter-relationships with production, and so develop breeding systems that improve both adaptation and production (e.g. Franklin, 1986; Davis, 1993; Baker and Rege, 1994). This means that disease traits must be included in the selection objective of breeding programmes in the tropics. However, there are greater difficulties in adopting this option because selecting for disease resistance and immunological responsiveness is not an easy task to accomplish (Baker, 1991; Rothschild, 1991).

First, the breeder must determine that improving the resistance of animals to disease is a worthwhile trait to include in a selection objective. Whereas production traits such as growth rate impact economic returns through income, disease traits usually impact returns through their effects on expenditure for control, or their effects on production if left untreated. Much of production losses from diseases occur from subclinical cases and the benefits from control may therefore be difficult or impossible to quantify. In addition, the future cost of disease control may be very different from current values.

Other difficulties arise in part when constructing the selection index equation, because determination of parameters of disease traits is a difficult task. A clear understanding of disease and the animals's defence mechanism is required. The onset of disease is often the result of the interaction between an individual animal's genotype and the environment to which the animal is exposed, or it may be entirely environmental. Genetic resistance to diseases is therefore extremely complex in nature. Fortunately, the biological components of survival, which includes disease resistance, are moderately heritable. However, variation in estimates of parameters between breeds in different environments suggest that caution is required when choosing values to include in the index (e.g. Cundiff *et al.*, 1982; Davis, 1993). Apart from the above difficulties, the largest problem with selection for disease resistance is to determine the selection criterion that can be measured and used to assess the genetic merit of individual animals. In many cases, the lack of an identifiable character is a reflection of poor level of understanding of the animals physiological and/or immunological response to disease. A further problem in finding a character to measure for disease traits is that not all animals contract the disease and the incidence of disease can vary widely between years and/or locations.

Nevertheless, Packed Red Cell Volume (PCV) has been found to be an indicator of the extent of anaemia in cattle due to trypanosomiasis infection (Trail *et al.*, 1991). The repeatability and heritability of PCV are reasonably high and there are positive genetic correlations of PCV with production traits. Cattle with improved resistance to the effects of trypanosomiasis can be identified and selection based on PCV could be used to improve both productivity and disease resistance (e.g. Mackinnon *et al.*, 1991).

There is also considerable interest presently throughout the world to integrate molecular genetics with traditional methods of artificial selection on phenotypes by applying Marker Assisted Selection to improve the rate of genetic progress (e.g. Lande and Thompson, 1990; Weller *et al.*, 1990). This technology is currently being used in some African countries to identify genetic markers for trypanotolerance. For example, there is a major research programme at the International Laboratory for

Research on Animal Diseases in Nairobi, Kenya, to identify genetic markers for trypanotolerance in  $F_2$  families generated by crossing N'dama (tolerant) and Boran (susceptible) cattle (Teale, 1993). Such a programme could be used to increase selection intensity and reduce generation intervals, especially when used in conjunction with reproductive technologies (e.g. artificial insemination and embryo transfer) and well-defined breeding structures.

It is clear from the foregoing that it is not easy to improve survival in tropical cattle, net of all cost. Therefore, it is concluded in this work that consideration should be given to the use of trypanotolerant livestock breeds in tsetse infested areas in Africa, whilst research efforts in the selection of exotic breeds for trypanotolerance resistance continue. This observation compares favourably with the findings of Davis (1993) in Australia. According to Davis (1993), the predominance of tropical breeds of cattle is the future for Northern Australia beef production. He noted that these breeds have a greater ability than temperate breeds to grow and reproduce in the conditions of high ambient temperatures, poor feed quality and high incidence of pathogens that typify tropical Australia. The indigenous breeds of most African countries, have evolved over centuries in diverse, often stressful, tropical environment, and have unique adaptive traits which enable them to survive and produce in these conditions. The challenge is to use the genetic diversity of the indigenous breeds more effectively than has been done so far. It is therefore reasonable to suggest that serious efforts should be made to conserve these breeds, most of which are endangered (Hodges, 1986; Ngere, 1990).

### **5.5 Implications of the results to the genetic improvement of cattle in Ghana.**

The productivity of a beef herd is a function of survival, reproduction and growth rates as well as carcass acceptability. In the tropics, costs of production are largely influenced by the ability of animals to cope with prevailing environmental conditions (Franklin, 1986; Rudder, 1989; Baker and Rege, 1994). Genetic improvement of beef cattle herds can be achieved by employing crossbreeding or selection within the existing breed or a combination of both techniques. The choice depends on the

merits of the existing breeds in the environment where they are raised.

There are two broad options for genetic improvement of production and adaptation in tropical livestock (Franklin, 1986). The first is to concentrate only on breeding for production traits and let adaptation be maintained by forces of natural selection. The second is to attempt both a biological and genetic understanding of adaptation and its inter-relationships with production and so develop breeding systems that improve both adaptation and production. Despite greater difficulties in adopting the second option, especially with regards to selecting for disease resistance, this is the option of choice, as suggested by Baker and Rege (1994). However, this needs to be resolved through additional research.

The feasibility of making significant progress by within breed selection is governed by survival and reproductive rates. If these rates are low, selection intensity will be reduced and generation length increased to maintain numbers. When the existing breed is also poorly adapted to the environment, crossbreeding to develop a better genotype offers the potential for large gains in productivity due to rapid changes in gene frequencies.

The local breeds of cattle in Ghana are well adapted but have low productive and reproductive rates. This environmental adaptation is particularly important in respect of resistance to trypanosomiasis and the ability to withstand heat stress. The local breeds of cattle population have one other advantage. They are available in large numbers and therefore any genetic improvement programme must be based on these breeds. Obviously, improvements via within breed selection for high reproductive rates will be too slow. In this situation, crossbreeding will be the preferred approach. The decision whether to use crossbreeding or within breed selection is however more difficult because of the absence of comparative field data to support basic principles. All data used in this study were sourced from research stations where conditions are more or less optimal for cattle production. Selection of cattle should be made under normal commercial or smallholder conditions, but not under artificial conditions. Even with genotype by environment interactions, gains under controlled conditions

may be better than those achieved by smallholder.

The decision whether to develop a new genotype by *inter se* mating or to opt for continual crossbreeding system needs to be considered. Feasibility of crossbreeding will depend upon evolving a breed that will possibly combine resistance to trypanosomiasis and other local diseases with those for high growth rate, better milk yield of the dam, and early maturing when an improved environment is provided. The question of selection within local breeds need to be considered in relation to producing animals that can perform adequately to offset the high cost of developing improved pastures. Currently, there is no cost associated with pasture establishment, but in future, farmers may have to cultivate pastures and plant new grass or legume species.

## **5.6 Guidelines for improvement of the beef cattle industry in Ghana**

Two principal changes must be sought in the Ghanaian beef cattle production systems in order to increase profitability: (1) the need to improve the reproductive capacity and milk production for calf growth in the local breeds of cattle, and (2) the need to improve reproductive capacity and adaptation (survival) in Zebu or other exotic breeds of cattle. With respect to the above, the following recommendations can be made.

### *5.6.1 Improving the local breeds*

Smallholder cattle producers should be encouraged to raise local breeds, since adaptation in these breeds is high. In this regard, increasing milk production may not be very necessary, since it was found in this study that the milk yield of the local cow can rear their own calves successfully. What needs to be done then to improve the productivity of the local breeds is to enhance their reproductive capacity. Reproductive traits have low heritabilities and are affected mostly by the environment. Improvements via within breed selection will therefore be too slow. The best option would then be to improve the environment and/or management (for

example, improvement of nutrition of the cow, culling of cows which fail to wean calves in one breeding season in the stud herd). Farmers need to be aware of management alternatives that affect puberty of heifers and fertility in both heifers and cows. An excellent review of this topic has recently been made by Short *et al.* (1995).

Evidence for some of these interventions which have been made to show improvements in reproductive rates are available in the literature. Feed supplementation to N'dama heifers grazing natural pastures in the Gambia during the dry season approximately trebled the proportion of animals calving within two years. This increase was eight-fold in animals that received supplementary feeding during both the dry and wet seasons (Tanner *et al.*, 1995). It was concluded by the authors that such intervention could reduce the usually late observed age at first calving of N'dama heifers in village herds by 12 months. Feed supplementation during the dry season in the Gambia also produced significant increases in milk production in N'dama cows and growth rates of suckling calves, and significantly decreased losses of maternal live weight during these feeding periods (Little *et al.*, 1991a). Post-partum resumption of reproductive activity was also significantly improved in this experiment. This shows that improvement in the environment will not only improve the reproductive capacity of these animals, but will also allow these animals to achieve a greater proportion of their potential for growth (e.g. Ngere and Cameron, 1972; Little *et al.*, 1991b).

Although the local breeds of cattle are adapted to their environment, mortalities observed in studies of the production systems are still too high. These may be due to other factors apart from diseases (e.g. nutrition), since these breeds are asserted to be resistant to various diseases. There is therefore the need to conduct studies to quantify factors causing mortality in the local cattle. Such studies can provide appropriate strategies for improving the environment and/or management.

Local cattle which are naturally resistant to the effects of trypanosome infection should be identified and used widely in the population. This would provide an

alternative and very potential sustainable control option (Trail *et al.*, 1986). Multiplication and improvement of trypanotolerant cattle breeds would be greatly facilitated by identification of genetic markers of the trait, and ultimately, by identification and isolation of the controlling genes (Teale, 1993). Currently, a joint project between the International Laboratory for Research into Animal Diseases (ILRI) in Kenya and Wageningen Institute of Animal Sciences (WIAS) in the Netherlands is going to take place to develop optimum schemes for introgression of trypanotolerance genes into trypanosusceptible cattle breeds (Brascamp and Teale, 1996).

#### *5.6.2 Improving the Zebu or other exotic cattle*

There is the need to intensify research into the use of Zebu or other exotic breeds of cattle in Ghana. The feasibility of developing trypanotolerant Zebu breed needs to be investigated. Fortunately, research has already been initiated on the use of Packed Red Cell Volume for the evaluation of trypanotolerance in cattle at the Animal Research Institute in Ghana (E.K. Adu, pers. comm.). This work will throw more light on the possibility of developing trypanotolerant Zebu breeds. Marker assisted selection may also be exploited to find trypanotolerant animals.

Improvements in disease resistance in Zebu cattle should be concurrent with improvements in the environment as proposed above for the local breeds, in order to improve their reproductive capacity. This will mean that the smallholder cattle producers should also improve their environment, in an attempt to avoid severe genotype by environment interactions, when cattle are transferred from nucleus herds to smallholder herds. An alternative to increasing the survival of exotic cattle is to clean the environment or treat animals against trypanosomiasis or other diseases. However, these may not be cost effective because drugs for these purposes are prohibitory expensive.

### 5.6.3 Genetic improvement using crossbreeding

Improvements in survival, milk production, and reproduction can be achieved through crossbreeding. This can be achieved by crossing the local breeds with the Zebu, which is exactly what is happening in many smallholder herds in Ghana. This may even bring about some improvement in growth rate. However, there are likely to be some problems. Farmers should be made aware of the dangers involved in raising  $F_1$  offspring for sale when the local cattle is the dam of the  $F_1$ . Lower milk yields of local dams may depress growth and survival of  $F_1$  offspring. Evidence for this comes from the Pong-Tamale Livestock Breeding Station in the north of Ghana, which recorded annual calf mortality rates of more than 30 % for this type of crossing between 1990 and 1993 (APD, 1990-1993). Pathetically, the crossbred types (Sanga), which are becoming progressively more important in the smallholder herds in terms of the association of crop cultivation with animal breeding, have been the subject of virtually no genetic or zootechnic studies.

One appropriate solution is to use  $F_1$  crosses as dams in the smallholder herds, because it is most likely that crossbreeding may improve milk production (e.g. Letenneur, 1978). In this regard, both breeders and farmers must be aware that decreased survival in  $F_1$  offspring, due to poor milk yield of local dams, will decrease selection intensity and may increase generation length to maintain numbers. The overall effect is that the annual rate of genetic gain is reduced. Using crosses as dams will also require that milk production should be included as a trait in the breeding objective. This is consistent with the practice of some farmers in Ghana, who share milking with calves. This was neglected in the present study, because of the paucity of data on this aspect.

An alternative solution is to reciprocally cross between these breeds (Zebu cow x N'dama male) in order to take advantage of the moderate milk yield of the Zebu cow to raise  $F_1$  calves. However, a reciprocal cross is not possible, because under natural mating conditions, the height of the Zebu cow may not permit a successful copulation between the Zebu cow and a local male. This can only be achieved through artificial

insemination, which may also not be possible to implement, because the beef cattle industry in Ghana is not structured. It should be remembered that most FAO programmes involving the use of embryo transfer and artificial insemination in several developing countries have failed, because the cattle industries in these countries were unstructured (Brumby, 1973; Jasiorowski, 1973, 1991). There is the need to conduct research into the possibility of using rotational crossing between local and Zebu cattle.

It is of some concern that no significant improvement in the reproductive performance of Zebu and local cattle crosses will be forthcoming, because of the existing poor reproductive performance of both breeds. Some scanty results given in the literature (e.g. Marchot *et al.*, 1989) give clue to this. It is therefore reasonable to suggest that some other exotic breeds with good reproductive performance should be exploited for within breed selection for disease resistance, instead of using the Zebu. If such breeds are proved to be resistant to diseases, especially trypanosomiasis, they would be more useful for crossing the local cattle than the Zebu.

The recommendations given above will require that adequate performance recording and evaluation procedures are put in place, and there should also be justification in economic terms for the use of any reproductive technology. A careful evaluation of the cost effectiveness of running any breeding programme to breed disease resistant animals needs to be done before the programme is undertaken.

## 5.7 Conclusions

The present study shows that survival and reproductive rates are the most important traits contributing towards improved profitability of the beef cattle industry in Southern Ghana, whereas growth rate seems to be less important. The most important single factor contributing to survival is the incidence of trypanosomiasis in cattle. Fortunately, the local N'dama and WASH are trypanotolerant, although they are smaller in size and have poorer reproductive and maternal ability. Increasing

the numbers and performance of cattle which are naturally resistant to the effects of trypanosome infection would provide an alternative and sustainable potential control option for trypanosomiasis. This is consistent with the view of some proponents that breeding programmes in the tropics will only be successful when stresses are controlled (e.g. Franklin, 1986; Trail *et al.*, 1986; Baker and Rege, 1994).

The performance of local breeds can also be enhanced by improving the environment and/or management. Because of the small size of the local breeds, improvements in their reproductive and maternal characteristics will increase their efficiency. Small cows with low maintenance requirements, high reproductive rate and good milking ability should comprise an efficient beef production system. There is also the possibility of using crossbreeding to effect changes in genotype. However, more research effort is needed to find the maximum amount of exotic blood that needs to be combined with local breeds in order to find animals that combine good adaptation with good production characteristics. These points lead to the conclusion that it is necessary to organize and control, to a certain degree, the high incidence of crossbreeding that is currently taking place in the smallholder herds, and to underline the urgency of undertaking measures for the preservation of the local cattle breeds.

## **5.8 Suggestions for further work**

The following suggestions are made for future research:

- (1) Packed Cell Volume (PCV) should be used as a selection criterion in order to construct a selection index for evaluating cattle in Ghana.
- (2) In constructing the selection index equation, data on beef cattle in Ghana and that from the literature should be combined to calculate the required genetic and phenotypic parameters. This requires that adequate recording is carried out in the smallholder herds in Ghana.
- (3) Milk production should be included as a character in the breeding objective.
- (4) It is essential to develop a separate breeding objective for beef cattle production in Northern Ghana.

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## APPENDIX I

### I.1 List of symbols used in the models

CR	= Calving rate
LP	= Length of life cycle of cow (months)
AFC	= Age at first calving (months)
CI	= Calving interval (months)
SBW	= Survival rate from birth to weaning
SWM	= Survival rate from weaning to maturity
bBWT	= Birth weight of bull calves (kg)
hBWT	= Birth weight of heifer calves (kg)
bWWT	= Weaning weight of bull calves (kg)
hWWT	= Weaning weight of heifer calves (kg)
bMWT	= Mature weight of bullocks (kg)
hMWT	= Mature weight of heifers (kg)
DBW	= Days from birth to weaning
DWM	= Days from weaning to maturity
bPRDG	= Pre-weaning daily gain of bull calves (kg/day)
hPRDG	= Pre-weaning daily gain of heifer calves (kg/day)
bPODG	= Post-weaning daily gain of bullocks (kg/day)
hPODG	= Post-weaning daily gain of heifers (kg/day)
MH	= Number of matured heifers
RH	= Number of replacement heifers
DOP	= Dressing out percentage of beef carcass
p <sub>cwt</sub>	= Price per kilogramme of beef (Cedis)
m <sub>M</sub>	= Marketing cost per head of bullocks (Cedis)
m <sub>H</sub>	= Marketing cost per head of heifers (Cedis)
m <sub>C</sub>	= Marketing cost per head of cow (Cedis)
h <sub>M</sub>	= Husbandry cost per year per bullock (Cedis)
h <sub>H</sub>	= Husbandry cost per year per heifer (Cedis)
h <sub>C</sub>	= Husbandry cost per year per cow (Cedis)

- F = Cost of kilogramme dry matter of pasture (Cedis)
- bPRFI = Bullocks' pre-weaning daily dry matter intake of pasture (kg/day)
- hPRFI = Heifers' pre-weaning daily dry matter intake of pasture (kg/day)
- bPOFI = Bullocks' post-weaning daily dry matter intake of pasture (kg/day)
- hPOFI = Heifers' post-weaning daily dry matter intake of pasture (kg/day)
- cFI = Cow's daily dry matter intake of pasture (kg/day)
- DBFI = Days from birth to start of measurement of food intake (kg/day)
- MLCC = Number of months from last calving to culling of cow
- DOM = Average number of days in a month
- t = Average number of years of expression of a characteristic
- DF = Discount rate

## **I.2 List of acronyms used in essential equations**

- MarkBull = Marketing cost of bullocks
- MarkHeif = Marketing cost of heifers
- MarkCow = Marketing cost of cow
- FoodBullPRW = Pre-weaning food cost of bullocks
- FoodHeifPRW = Pre-weaning food cost of heifers
- FoodHeifC = Pre-cow (from birth to first calving) food cost of cow
- FoodBullPOW = Post-weaning food cost of bullocks
- FoodHeifPOW = Post-weaning food cost of heifers
- FoodCow = Food cost of cow from first calving to culling
- HusBullPRW = Pre-weaning husbandry cost of bullocks
- HusHeifPRW = Pre-weaning husbandry cost of heifers
- HusHeifC = Pre-cow (from birth to first calving) husbandry cost of cow
- HusBullPOW = Post-weaning husbandry cost of bullocks
- HusHeifPOW = Post-weaning husbandry cost of heifers
- HusCow = Husbandry cost of cow from first calving to culling
- RetBull = Returns from bullocks
- RetHeif = Returns from heifers
- RetCow = Returns from culled cow

- $\text{ProfitBull}$  = Profit from bullocks  
 $\text{ProfitHeif}$  = Profit from heifers  
 $\text{ProfitCow}$  = Profit from cow  
 $\text{ProfitTotal}$  = Total profit from the entire life of cow due to average values of all traits  
 $\text{ProfitTotalT}^*$  = Total profit from entire life of cow due to 1 % change in the level of trait  
 $\text{ProfitCowYr}$  = Profit per cow per year due to average levels of all traits  
 $\text{ProfitCowYrT}^*$  = Profit per cow per year due to 1 % change in the level of trait  
 $\text{ProfitMCowT}^*$  = Marginal profit per cow per year due to change in the level of trait  
 $^*$  = Any of the traits in the breeding objective

## APPENDIX II

### Essential equations in the life cycle simulation model

#### I.1 Bullocks costs and returns

- $\text{MarkBull}$  =  $0.5 * CR * (((LP - AFC) / CI) + 1) * SBW * SWM * bM$   
 $\text{FoodBullPRW}$  =  $0.5 * CR * (((LP - AFC) / CI) + 1) * (DBW - DBFI) * bPRFI * F$   
 $\text{FoodBullPOW}$  =  $0.5 * CR * (((LP - AFC) / CI) + 1) * SBW * DWM * bPOFI * F$   
 $\text{HusBullPRW}$  =  $0.5 * CR * (((LP - AFC) / CI) + 1) * (bH / 2)$   
 $\text{HusBullPOW}$  =  $0.5 * CR * (((LP - AFC) / CI) + 1) * SBW * 2.5 * bH$   
 $\text{RetBull}$  =  $0.5 * CR * (((LP - AFC) / CI) + 1) * SBW * SWM * (bBWT + (bPRDG * DBW) + (bPODG * DWM)) * DOP * Pcwt$   
 $\text{ProfitBull}$  =  $\text{RetBull} - \text{MarkBull} - \text{FoodBullPRW} - \text{FoodBullPOW} - \text{HusBullPRW} - \text{HusBullPOW}$

## I.2 Heifer costs and returns

$$\text{MarkHeif} = 0.5 * \text{CR} * (((\text{LP}-\text{AFC})/\text{CI})+1) * \text{SBW} * \text{SWM} * (1-(\text{RH}/\text{MH})) * \text{hM}$$

$$\text{FoodHeifPRW} = 0.5 * \text{CR} * (((\text{LP}-\text{AFC})/\text{CI})+1) * (\text{DBW}-\text{DBFI}) * \text{hPRFI} * \text{F}$$

$$\text{FoodHeifPOW} = 0.5 * \text{CR} * (((\text{LP}-\text{AFC})/\text{CI})+1) * \text{SBW} * \text{DWM} * \text{hPOFI} * \text{F}$$

$$\text{HusHeifPRW} = 0.5 * \text{CR} * (((\text{LP}-\text{AFC})/\text{CI})+1) * (\text{hH}/2)$$

$$\text{HusHeifPOW} = 0.5 * \text{CR} * (((\text{LP}-\text{AFC})/\text{CI})+1) * \text{SBW} * 2.5 * \text{hH}$$

$$\text{RetHeif} = 0.5 * \text{CR} * (((\text{LP}-\text{AFC})/\text{CI})+1) * \text{SBW} * \text{SWM} * (1-(\text{RH}/\text{MH})) * \\ (\text{hBWT}+(\text{hPRDG} * \text{DBW})+(\text{hPODG} * \text{DWM})) * \text{DOP} * \text{Pcwt}$$

$$\text{ProfitHeif} = \text{RetHeif} - \text{MarkHeif} - \text{FoodHeifPRW} - \text{FoodHeifPOW} - \text{HusHeifPRW} - \\ \text{HusHeifPOW}$$

## I.3 Cow costs and returns

$$\text{MarkCow} = \text{cM}$$

$$\text{FoodHeifC} = ((\text{hPRFI} * (\text{DBW}-\text{DBFI})) + (\text{hPOFI} * ((\text{AFC} * \text{DOM}) - \text{DBW}))) * \text{F}$$

$$\text{FoodCow} = (((\text{LP}-\text{AFC}) + \text{MLCC}) * \text{DOM} * \text{cFI} * \text{F}$$

$$\text{HusHeifC} = (\text{AFC}/12) * \text{hH}$$

$$\text{HusCow} = ((\text{LP}-\text{AFC}) + \text{MLCC})/12 * \text{cH}$$

$$\text{RetCow} = (\text{hBWT}+(\text{hPRDG} * \text{DBW})+(\text{hPODG} * \text{DWM})) * 0.9 * \text{DOP} * \text{Pcwt}$$

$$\text{ProfitCow} = \text{RetCow} - \text{MarkCow} - \text{FoodHeifC} - \text{FoodCow} - \text{HusHeifC} - \text{HusCow}$$

## II.4 Calculations of marginal, and discounted costs and returns

$$\text{ProfitTotal} = \text{ProfitBull} + \text{ProfitHeif} + \text{ProfitCow} \text{ (from average values of all traits)}$$

$$\text{ProfitTotal}^* = \text{ProfitBull} + \text{ProfitHeif} + \text{ProfitCow} \text{ (when there is 1 \% change in a trait)}$$

$$\text{ProfitCowYr} = \text{ProfitTotal} / ((\text{LP} + \text{MLCC})/12)$$

$$\text{ProfitCowYr}^* = \text{ProfitTotal}^* / ((\text{LP} + \text{MLCC})/12)$$

$$\text{ProfitMCow}^* = \text{ProfitCowYr}^* - \text{ProfitCowYr}$$

$$\text{Discount Rate} = 1/(1+\text{DF})^t \text{ (Applied to all costs and returns)}$$

## APPENDIX III

**Costs, returns and profit from different classes of stock at various levels of traits in the breeding objective**

**Table III.1:** N'dama bullocks (0 % Discount Rate)

Level of Trait**	Marketing Cost	Food Cost	Husbandry Cost	Returns	Profit
Average	10457.13	119479.94	37393.13	649805.75	482475.56
CR	10598.44	121094.54	37898.44	658586.91	488995.50
AFC	10489.80	119853.31	37509.98	651836.39	483983.30
CI	10547.66	120514.39	37716.88	655431.77	486652.84
SBW	10580.15	120783.36	37749.25	657450.52	488337.77
SWM	10567.20	119479.94	37393.13	656645.81	489205.55
bPRDG	10457.13	119479.94	37393.13	651927.27	484597.08
hPRDG	10457.13	119479.94	37393.13	649805.75	482475.56
bPODG	10457.13	119479.94	37393.13	657592.54	490262.35
hPODG	10457.13	119479.94	37393.13	649805.75	482475.56
bPRFI	10457.13	119566.83	37393.13	649805.75	482388.67
hPRFI	10457.13	119479.94	37393.13	649805.75	482388.67
bPOFI	10457.13	120587.84	37393.13	649805.75	481367.66
hPOFI	10457.13	119479.94	37393.13	649805.75	482475.56
cFI	10457.13	119479.94	37393.13	649805.75	482475.56

\* = Average level of each trait and 1 % change in the level of trait. This applies to the rest of tables in appendix III.

**able III.2:** Zebu Bullocks (0 % Discount Rate)

Level of Trait	Marketing Cost	Food Cost	Husbandry Cost	Returns	Profit
Average	12718.13	120254.94	69492.50	770684.46	568218.89
CR	12885.47	121837.25	70406.88	780825.05	575695.46
AFC	12766.95	120716.64	69759.30	773643.34	570400.45
CI	12828.24	121296.11	70094.17	777357.05	573138.54
SBW	12887.70	121727.45	70224.00	780960.25	576121.10
SWM	12867.75	120254.94	69492.50	779751.34	577136.14
bPRDG	12718.13	120254.94	69492.50	771092.92	568627.36
hPRDG	12718.13	120254.94	69492.50	770684.46	568218.89
bPODG	12718.13	120254.94	69492.50	771740.09	569274.53
hPODG	12718.13	120254.94	69492.50	770684.46	568218.89
bPRFI	12718.13	120353.11	69492.50	770684.46	568120.73
hPRFI	12718.13	120254.94	69492.50	770684.46	568218.89
bPOFI	12718.13	121359.32	69492.50	770684.46	567114.51
hPOFI	12718.13	120254.94	69492.50	770684.46	568218.89
cFI	12718.13	120254.94	69492.50	770684.46	568218.89

**ble III.3:** N'dama Heifers (0 % Discount Rate)

Level of Trait	Marketing Cost	Food Cost	Husbandry Cost	Returns	Profit
Average	4911.41	112311.14	34673.63	313566.40	161670.22
CR	5038.59	113828.86	35142.19	321686.22	167676.58
AFC	4940.82	112662.12	34781.98	315444.11	163059.19
CI	4992.90	113283.53	34973.83	318768.71	165518.45
SBW	5022.14	113536.35	35003.85	320635.42	167073.08
SWM	5010.48	112311.14	34673.63	319891.31	167896.07
bPRDG	4911.41	112311.14	34673.63	313566.40	161670.22
hPRDG	4911.41	112311.14	34673.63	315534.49	163638.31
bPODG	4911.41	112311.14	34673.63	313566.40	161670.22
hPODG	4911.41	112311.14	34673.63	317287.34	165391.16
bPRFI	4911.41	112311.14	34673.63	313566.40	161670.22
hPRFI	4911.41	112392.82	34673.63	313566.40	161588.54
bPOFI	4911.41	112311.14	34673.63	313566.40	161670.22
hPOFI	4911.41	113352.57	34673.63	313566.40	160628.79
cFI	4911.41	112311.14	34673.63	313566.40	161670.22

**Table III.4:** Zebu Heifers (0 % Discount Rate)

Level of Trait	Marketing Cost	Food Cost	Husbandry Cost	Returns	Profit
Average	4522.38	113695.58	64438.50	268773.79	86117.33
CR	4667.41	115191.57	65286.38	277393.29	92247.93
AFC	4564.69	114132.10	64685.89	271288.84	87906.15
CI	4617.81	114680.46	64996.40	274445.49	90151.32
SBW	4669.34	115087.77	65116.80	277508.21	92634.30
SWM	4652.05	113695.58	64438.50	276480.64	93694.50
bPRDG	4522.38	113695.58	64438.50	268773.79	86117.33
hPRDG	4522.38	113695.58	64438.50	269572.54	86916.08
bPODG	4522.38	113695.58	64438.50	268773.79	86117.33
hPODG	4522.38	113695.58	64438.50	269034.24	86377.79
bPRFI	4522.38	113695.58	64438.50	268773.79	86117.33
hPRFI	4522.38	113788.39	64438.50	268773.79	86024.52
bPOFI	4522.38	113695.58	64438.50	268773.79	86117.33
hPOFI	4522.38	114739.72	64438.50	268773.79	85073.19
cFI	4522.38	113695.58	64438.50	268773.79	86117.33

**Table III.5:** N'dama Cow (0 % Discount Rate)

Level of Trait	Marketing Cost	Food Cost	Husbandry Cost	Returns	Profit
Average	4000	266588.30	66375.00	258570.00	-78393.30
CR	4000	266588.30	66375.00	258570.00	-78393.30
AFC	4000	266776.18	66401.25	258570.00	-78607.43
CI	4000	266588.30	66375.00	258570.00	-78393.30
SBW	4000	266588.30	66375.00	258570.00	-78393.30
SWM	4000	266588.30	66375.00	258570.00	-78393.30
bPRDG	4000	266588.30	66375.00	258570.00	-78393.30
hPRDG	4000	266588.30	66375.00	260192.91	-76770.39
bPODG	4000	266588.30	66375.00	258570.00	-78393.30
hPODG	4000	266588.30	66375.00	261638.83	-75324.98
bPRFI	4000	266588.30	66375.00	258570.00	-78393.30
hPRFI	4000	266619.84	66375.00	258570.00	-78424.84
bPOFI	4000	266588.30	66375.00	258570.00	-78393.30
hPOFI	4000	267045.59	66375.00	258570.00	-78850.59
cFI	4000	268765.36	66375.00	258570.00	-80570.36

**Table III.6:** Zebu Cow (0 % Discount Rate)

Level of Trait	Marketing Cost	Food Cost	Husbandry Cost	Returns	Profit
Average	6000	313390.55	139550.00	347677.20	-111263.35
CR	6000	313390.55	139550.00	347677.20	-111263.35
AFC	6000	313664.65	139614.50	347677.20	-111601.95
CI	6000	313390.55	139550.00	347677.20	-111263.35
SBW	6000	313390.55	139550.00	347677.20	-111263.35
SWM	6000	313390.55	139550.00	347677.20	-111263.35
bPRDG	6000	313390.55	139550.00	347677.20	-111263.35
hPRDG	6000	313390.55	139550.00	348710.44	-110230.11
bPODG	6000	313390.55	139550.00	347677.20	-111263.35
hPODG	6000	313390.55	139550.00	348014.11	-110926.44
bPRFI *	6000	313390.55	139550.00	347677.20	-111263.35
hPRFI	6000	313425.44	139550.00	347667.20	-111298.24
bPOFI	6000	313390.55	139550.00	347667.20	-111263.35
hPOFI	6000	314036.05	139550.00	347667.20	-111908.85
cFI	6000	315844.06	139550.00	347667.20	-113716.86