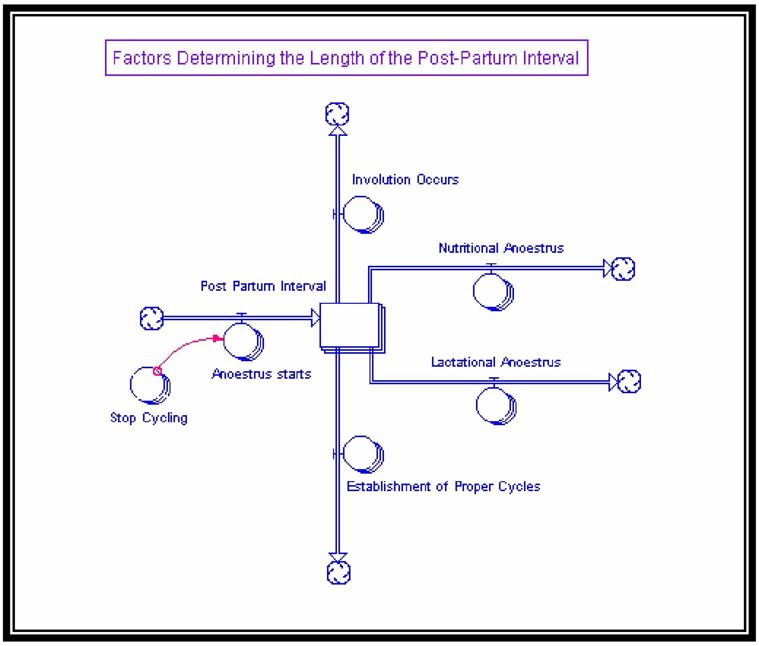
R6359: The Development of Feeding Strategies to Improve Reproductive Performance and Yields of Cows in High Potential Mixed Farming Systems.

A Final Technical Report on a Research Project Funded by the Department for International Development's Livestock Production Research Programme



Executive Summary

A key constraint to the development of smallholder dairy production lies in farmers' lack of access to reliable information on appropriate feeding strategies for the range of conditions that they experience during the course of a year. This can have a variety of consequences that affect the viability of small-scale dairying. In addition to direct effects on levels of milk production, these may results from interactions with other factors that influence such as health and disease status and fertility of both male and female animals.

Poor reproductive performance has been observed in both extensive and intensifying cattle production systems in many environments. It is generally characterised by:

- Long calving intervals. These restrict the lifetime productivity of breeding females and require the maintenance of larger herds for economically viable production levels.
- The development of seasonal calving patterns which limit access to markets and the maintenance of regular incomes. Seasonal calving patterns often result in poor synchronisation between the feed requirements of the herd and feed availability.

These features have serious consequences for productivity in cattle production systems, resulting in low reproductive rates, low overall milk yields and, in some cases, high calf mortality. Apart from reducing the number of animals available for domestic consumption or sale, irregular breeding and extended calving intervals present farmers with a number of practical difficulties in managing their livestock holdings. Replacement strategies are difficult to plan so unnecessarily large herd sizes may have to be maintained. Furthermore, as animals with high productive potential are difficult to detect, there is a risk that, with a more aggressive culling strategy, these good animals might be rejected.

This project attempted to elaborate on some of the relationships between nutrition and reproductive performance in a typical, smallholder dairy system in North-eastern Tanzania (Tanga Region). The results of a longitudinal monitoring study were used to characterise farms in Tanga as a basis for planning more detailed studies to be carried out on-station. A simulation model evaluating the effects of changes in the feed resource base on reproductive performance and, thereby, on herd dynamics was constructed. It was apparent from the characterisation study that farms in the area are highly heterogeneous and that potential interventions targeting reproductive performance, or other performance variables for that matter, would need to take account of this. For example, a key factor influencing the availability of forages on farms appears to be the extent to which labour is hired. However, increases in forage collection due to labour hiring are concentrated at certain times of the year.

Use of the simulation model developed is at an early stage but, mechanically at least, the outputs of the model appear to be responsive to a relatively simple description of the dynamics of forage availability, quality and concentrate use. Not all of the findings of the on-station study have been collated at the time of writing but these will be available in the form of a Ph.D. thesis during 2000.

The project worked closely with the Dutch Government-funded Tanga Dairy Development Project (TDDP). The dissemination of project findings will continue via long-term links between TDDP and the implementing institution in Tanzania (Tanga Livestock Research Institute).

Recommendations

Due to the delays in experienced in executing this project, not all data are available at the time of writing. In particular, progesterone analyses on the samples collected during the on-station experiment are incomplete due to delays in the collaborating institution. Further analysis of data from the longitudinal study and on-station study will be forthcoming by Mid-2000 and will be included and discussed in a Ph.D. thesis to be written by the principal investigator in TLRC.

This project revealed a number of difficulties in executing controlled studies on the scale adopted. The lessons learned are likely to be invaluable but it is suggested that future research should identify more practicable approaches to integrating on-farm and on-station experimentation where issues relating to reproductive performance, that of necessity, requires a long-term approach, need to be identified.

Recommendations on suitable approaches to the dissemination of the project's finding should await the production of the Ph.D. thesis of the Tanzanian principal investigator. It is suggested that there are two main channels for this.

- The existing link with TDDP. The project can feed information into the extension material that is produced routinely by TDDP.
- Project R7431 (Talking Pictures) is developing pictorial extension material for small-scale dairy producers. The projects findings could inform the development of the software required to do this.

Table of Contents

List of Tables

List of Figures

List of Annexes

List of Appendices

Background

Identification of Demand

The potential of small-scale dairy production to contribute to securing the livelihoods of millions of smallholder farm households in developing countries has been widely appreciated (Del Castillo, 1990; De Jong, 1996; ILRI / NARO / MAAIF, 1996). On these farms, hired labourers from poorer households benefit from hand-outs of or payments in kind in milk as well as increased opportunities for earning cash. Marketing of the milk produced by small-scale enterprises allows wider access to cheaper dairy products amongst poorer consumers in both rural and urban areas (MOAC / SUS / ILRI, 1998). Increasingly, there is solid evidence for the long-made assumption that the involvement of community members in small-scale dairying can directly improve infant nutrition and reduce the occurrence of human health problems amongst the young (C. Nicholson, *pers. comm.*)

Researchable Constraints

A key constraint to the development of smallholder dairy production lies in farmers' lack of access to reliable information on appropriate feeding strategies for the range of conditions that they experience during the course of a year (Laurent and Centres, 1990). This can have a variety of consequences that affect the viability of small-scale dairying. In addition to direct effects on levels of milk production, these may results from interactions with other factors that influence such as health and disease status and fertility of both male and female animals.

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These features have serious consequences for productivity in cattle production systems, resulting in low reproductive rates, low overall milk yields and, in some cases, high calf mortality. Apart from reducing the number of animals available for domestic consumption or sale, irregular breeding and extended calving intervals present farmers with a number of practical difficulties in managing their livestock holdings. Replacement strategies are difficult to plan so unnecessarily large herd sizes may have to be maintained. Furthermore, as animals with high productive potential are difficult to detect, there is a risk that, with a more aggressive culling strategy, these good animals might be rejected.

There are strong indications in the literature (see below) that these effects are largely due to nutritional constraints on oestrus resumption after calving. These constraints may be a particular problem in cattle with higher genetic potential for milk yield and, consequently, higher feed requirements. Preliminary field reports suggesting that the reproductive performance of crossbred *Bos taurus* cattle is often poor. However, there is little information available to quantify the extent of the problem and the main causative factors in the field.

This has hampered the development and adoption of improved feeding strategies for dairy cattle which optimise reproductive performance for enhanced, long-term productivity as well as promoting milk production in the shorter term.

Review of Literature

Introduction

The importance of nutrition in determining the reproductive status and performance of ruminant livestock has been well established (Robinson, 1990). In particular, a considerable body of evidence has accumulated to suggest that the ability of female cattle to rebreed successfully may be severely compromised by inadequate nutrition that results in a lengthy *post-partum* interval[1] (PPI) and, in consequence, extended calving interval.

Prolonged PPI has been identified as a major factor influencing the productivity of cattle kept under traditional management systems in Africa (ILCA, 1987). Field observations of cattle suggest that PPIs in excess of 500 days are not uncommon (Pullan, 1979; Ward *et al*, 1988; Mukasa-Mugerwa *et al*, 1989; Osei and Effah-Baah, 1989). However, studies with *Bos indicus* breeds under improved management have demonstrated that they are capable of oestrus resumption within 120 days of calving (Alim, 1960; Swensson *et al*, 1981; Trail and Gregory, 1982). indicating that the genetic potential of these animals is often not being realised.

In addition to the length of calving intervals, the pattern of distribution of calving over the year may also be affected by nutritionally mediated PPIs. In most traditional livestock production systems, access of males to females is unrestricted. However, marked conception peaks are often observed in response to feed flushes at the onset of a rainy season or when crop residues are grazed. As many as 80% of conceptions may take place during seasonal feed flushes resulting in calvings which are clustered when feed supplies for supporting the increased nutritional demands of the dam during early lactation are extremely restricted. This lack of synchronisation between supply of and demands for nutrients adversely affects productivity. Furthermore, the mobilisation of nutrients from body reserves assimilated during periods of relative plenty, may be undesirable as the catabolism of body tissues represents a less efficient path than the direct utilisation of feed nutrients.

The pattern of irregular breeding with extended calving intervals which can occur in breeding females limited by nutrient availability tends to reduce the number of growing animals available for domestic consumption or sale. It will also increase the reluctance of farmers to cull unproductive animals they have, as they are unable to plan replacement strategies for maintaining an acceptable herd size.

This review considers, in the context of some of the livestock production systems adopted in Africa, established knowledge of the relationships between nutritional status of female cattle and their *post-partum* reproductive performance. This information will be of use as a basis for suggesting improved management and feeding practises to allow the supply of nutrients to breeding cattle to correspond more effectively with the different stages of their production cycles.

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[1] - *post-partum* interval is defined as the interval between parturition and the first *post-partum* oestrus.

THE PHYSIOLOGICAL BASIS OF THE *POST-PARTUM* INTERVAL

A number of recent, detailed reviews of the physiological processes which regulate PPI and their relationships with the nutritional status of the *post-partum* cow are available (Nett, 1987; Short and Adams, 1988; Short *et al*, 1990; Lishman and Inskeep, 1991).

Components of the Post-Partum *Interval*

Short *et al* (1990) have identified four principal components - general infertility, uterine involution, short oestrus cycles and *post-partum* anoestrus - which may determine the length of the PPI. General infertility refers to factors such as genetic abnormalities and pathogenic infection which affect reproductive function in general and do not act exclusively on PPI (Peters and Ball, 1987). The other factors all exert functional effects which influence PPI directly.

Uterine Involution

The uterus becomes greatly modified in size and form during pregnancy and, *post-partum*, undergoes the process of uterine involution to return it to the physical condition associated with the non-pregnant animal. During the period between parturition and complete involution, the distorted uterus forms a physical impediment to the movement of spermatozoa towards the ovaries and the implantation of fertilised ova. Thus, time to involution is likely to be a significant component of the PPI during the early *post-partum* period and may represent a final limitation to the reduction of PPI in the absence of other limiting factors.

The time taken for involution of the uterus may be affected by season and the age of the dam but is normally complete within 40 days *post-partum* in *Bos indicus* cattle (Mukasa-Mugerwa, 1989). Eduvie and Oyedipe (1991) quote a range of 16 to 35 days *post-partum* in published values for uterine involution in indigenous West African (*Bos indicus* and *Bos taurus*) cattle. The process is therefore unlikely to be a significant determinant of the lengthy PPIs that may be exhibited by cattle under African conditions.

Post-Partum Anoestrus

Post-partum anoestrus is the interruption in the normally cyclical production of ova which occurs, to varying degrees, in all cattle following parturition. A continuing anoestrus state arises through suppression of the hormonal mechanisms which govern the development and maturation of the follicle. This appears to involve the hypothalamus-pituitary complex, the ovaries and a disruption of the feedback mechanisms between them (Short *et al*, 1990).

The most distinctive characteristics of anoestrus cattle are the low levels of circulating serum progesterone and luteinizing hormone (LH) and an associated decrease in the frequency of the episodic release of the latter (Richards *et al*, 1989; Canfield and Butler, 1990). These conditions imply a dysfunction in the gonadotrophin releasing hormone (GnRH) pulse generator of the pituitary (Foster *et al*, 1989). This is supported by a number of studies conducted with anoestrus cattle in which artificial administration of pulsatile GnRH has initiated a pre-ovulatory LH surge leading to successful ovulation and development of the corpus luteum. However, it seems likely that GnRH pulses are first-limiting only in cattle in relatively shallow anoestrus. During the early *post-partum* period or in animals which are grossly underfed the exogenous administration of GnRH may fail to elicit a response (Rutter and Randel, 1984). Inhibition of LH synthesis by progesterone and oestradiol during pregnancy depletes pituitary LH stores in the *post-partum* animal. Thus, in deeper anoestrus, insufficient LH may be available to stimulate early follicle development even if GnRH pulses are generated artificially (Moss *et al*, 1985). Recovery of LH stores may be slowed by inadequate nutrition due to limited availability of precursors.

A feedback on the hypothalamus of oestradiol produced by the maturing follicle is responsible, under normal conditions of oestrus cyclicity, for the initiation of the pre-ovulatory LH surge. This feedback is also disrupted in the anoestrus animal. During deep anoestrus, levels of circulating LH are low, restricting follicular development and therefore the release of oestradiol to stimulate pulsatile GnRH secretion by the hypothalamus (Nett, 1987). There is also evidence that the hypothalamus becomes hyper-sensitive to oestradiol resulting in a negative feedback during deep anoestrus (Garcia-Winder *et al*, 1986).

Observations of oestrus behaviour and hormonal profiles in cattle in African livestock production systems suggest that an extended period of *Post-partum* anoestrus is the most important contributor to the length of the PPI (Dawuda *et al*, 1988; Mukasa-Mugerwa *et al*, 1991).

Anomalous Oestrus Cycles

It has been suggested that around 50% of cows returning to oestrus under the relatively intensive management systems of developed countries exhibit the phenomenon of short oestrus cycles (Peters and Ball, 1987). A short cycle is an abnormal first cycle characterised by a less pronounced rise in progesterone than is observed with the normal cycle. Short cycles may be followed by normal ovulations which can even result in fertilisation. However, pregnancy does not result due to the premature regression of the *corpus luteum* (Short *et al*, 1990).

The majority of experimental observations of short cycles have been made in animals fed intensively. Under these conditions, only animals returning to oestrus activity within 40 days of parturition are likely to exhibit them (Short *et al*, 1990). However, silent heats associated with lower than normal rises in progesterone have been observed later than 100 days *post-partum* in cattle under farm conditions in Africa (Oyedipe *et al*, 1988; Mukasa-Mugerwa *et al*, 1991) prior to their return to normal oestrus cycling. It is therefore possible that, in some circumstances, anomalous cycles may be a significant component of extended PPIs.

NUTRITION AND *POST-PARTUM* INTERVALS

Effects of Deficiencies in Specific Nutrients on the Resumption of Oestrus Cycling

The hormonal interactions which determine the anoestrus state have been reasonably well defined. However, the means by which specific nutritional, and other, factors affecting *post-partum* anoestrus exert these effects on the hormonal system are relatively poorly understood. Nevertheless, pronounced effects of shortages of specific nutrients on oestrus resumption are clearly indicated in the literature. Shortages in current dietary intakes of energy and, to a lesser extent, protein and calcium may be compensated for by the mobilisation of body reserves.

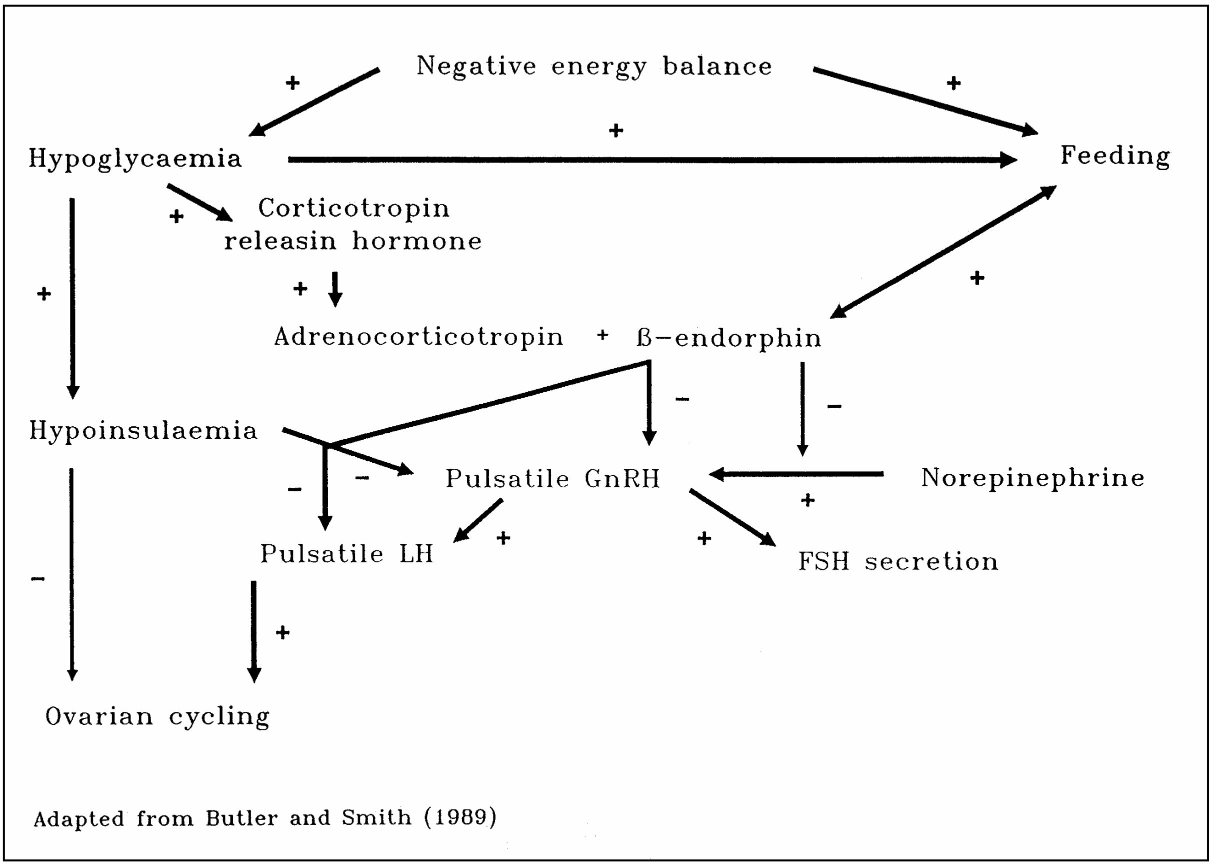
Energy

The relationships between energy balance and *post-partum* reproductive function in dairy cattle have been studied in considerable detail (Butler and Smith, 1989).

High yielding dairy cattle characteristically enter negative energy balance *post-partum* despite being fed to the constraints of their appetite limits. This is due to the sudden increase in their nutrient requirements for milk production which cannot be met adequately from feed intake which gradually increases during the first few weeks of the lactation.

Significant correlations have been observed between the degree of the mean negative energy balance and the length of the PPI. Butler *et al* (1981) estimate an increase of 11 days in the PPI for each 1MJ ME reduction in energy balance. In this study, cattle were observed returning to oestrus while still in negative energy balance and the increases in serum progesterone levels appeared to correspond with the inflexion point at which energy deficit reached a maximum and started to recover. This is supported by Canfield and Butler (1990) who observed a significant positive correlation between the time to this "energy balance

Figure 1: Relationships between negative energy balance and oestrus cycling.



nadir" and PPI. The inflexion point was associated with increases in mean serum LH levels and LH pulse frequency.

Current appreciation of the relationships between energy status in cattle and the hormonal processes of the oestrus cycle is summarised in Figure 1. The metabolism of glucose and insulin which are responsive to changes in energy balance appear to exert an effect on the resumption of oestrus cycling in dairy cattle *post-partum* (Short and Adams, 1988). Inhibition of GnRH secretion mediated by insulin (Harrison and Randel, 1986) and possibly the insulin-like growth factor, IGF-1 (Rutter *et al*, 1989) has been observed in studies with beef cattle. In some studies, these relationships have not been apparent and plasma non esterified fatty acids (NEFA) have appeared more likely to be involved in signalling the initiation of recovery from negative energy balance to the central nervous system (Canfield and Butler, 1990). Alternatively, or possibly in addition, Butler and Smith (1989) observed inhibition of LH release associated with increased levels of the hypothalamic opoid peptides, in particular ß-endorphin, in dairy cattle in negative energy balance. These brain chemicals appear to operate through inhibition of the GnRH pulse generator.

The significance of periods of negative energy balance for the extension of PPIs in traditionally managed animals is difficult to extrapolate from the information derived in more intensively managed animals and detailed studies of energy metabolism in the former do not appear to have been undertaken. It is unlikely that a clearly defined energy balance nadir occurs under extensive conditions and cattle calving during the earlier part of a feed flush may be seen to gain weight suggesting that they are in positive energy balance (Kidner, 1966; Holness *et al*, 1978; Djabakou *et al*, 1991). The fact that animals do not return rapidly to oestrus under these conditions may be due to the well documented inhibitory effects of lactation and suckling on return to oestrus cycling (Loudon, 1987; Williams, 1990).

Protein

The effects of protein nutrition on reproduction in dairy cows has been reviewed by Ferguson and Chalupa (1989). The effects of changes in protein supply appear to be expressed mainly through secondary changes in energy balance. The stimulatory effect of rumen undegradable protein (UDP) on milk yield increases the energy demand of lactation tending to push the animal deeper into negative energy balance with increased body fat mobilisation. Under these circumstances, a limited degree of compensation may take place with the increased dietary UDP stimulating feed and consequently energy intakes (Roffler and Thacker, 1983) but hormonal profiles are generally more consistent with an effect mediated by energy balance (Ferguson and Chalupa, 1989). Excessive rumen degradable protein (RDP) may lead to elevated levels of potentially toxic nitrogenous compounds such as ammonia and urea (Hibbitt, 1984). These do not appear to affect ovarian cycling directly, but might disrupt intermediary metabolism and the development of the *corpus luteum* (Ferguson and Chalupa, 1989) and uterine involution (Robinson, 1990).

The effects discussed above result from excessively wide protein to energy ratios which are unlikely in traditionally managed animals. The proportion of crude protein in their feed intakes during the dry season may be as low as two *per cent*. Effects are therefore more likely to be due to protein limitation but the rôle of protein supply *per se* in mediating PPI in traditionally managed animals has received little attention. Sasser *et al* (1988) observed a tendency towards delayed return to oestrus in beef heifers consuming adequate dietary energy but low protein between 50 days *pre-partum* and 110 days *post-partum*. Wiley *et al* (1991) have demonstrated that supplementary UDP *post-partum* can improve weight gain and reduced PPI in beef heifers irrespective of the plane of nutrition (low *vs* maintenance) *pre-partum*. These authors suggest that, supplying UDP *post-partum* may stimulate pancreatic insulin production, compensating for the adverse effects of low *pre-partum* nutrition on insulin levels, and consequently, return to oestrus. These observations would suggest that, while energy may be the most important factor in governing breeding cycles in traditionally managed animals, the importance of and possible modifying effects of quantity and quality of protein supplied should not be ignored when supplementation strategies are being considered.

Fat

It is difficult to draw conclusions regarding the specific rôle of dietary fat in mediating PPI due to conflicting indications from different studies. There is some evidence that supplementary fat in early lactation may promote less severe negative energy balances but in other studies, cows responded to fat supplementation with increased milk yield and reduced dry matter intake rather than decreases in the length of the PPI (Grummer and Carroll, 1991).

Some components of dietary fats are important precursors of reproductive hormones. Animals supplemented with fat *post-partum* exhibit raised levels of serum cholesterol and progesterone (Grummer and Carroll, 1988) - of which cholesterol is a precursor - and improved follicle growth (Williams, 1989; Hightshoe *et al*, 1991). Linoleic acid appears to stimulate the secretion of prostaglandin $F_{2\alpha}$ (Lucy *et al*, 1990) which is involved in the promotion of follicular development and uterine involution and may therefore, under certain circumstances, affect PPI.

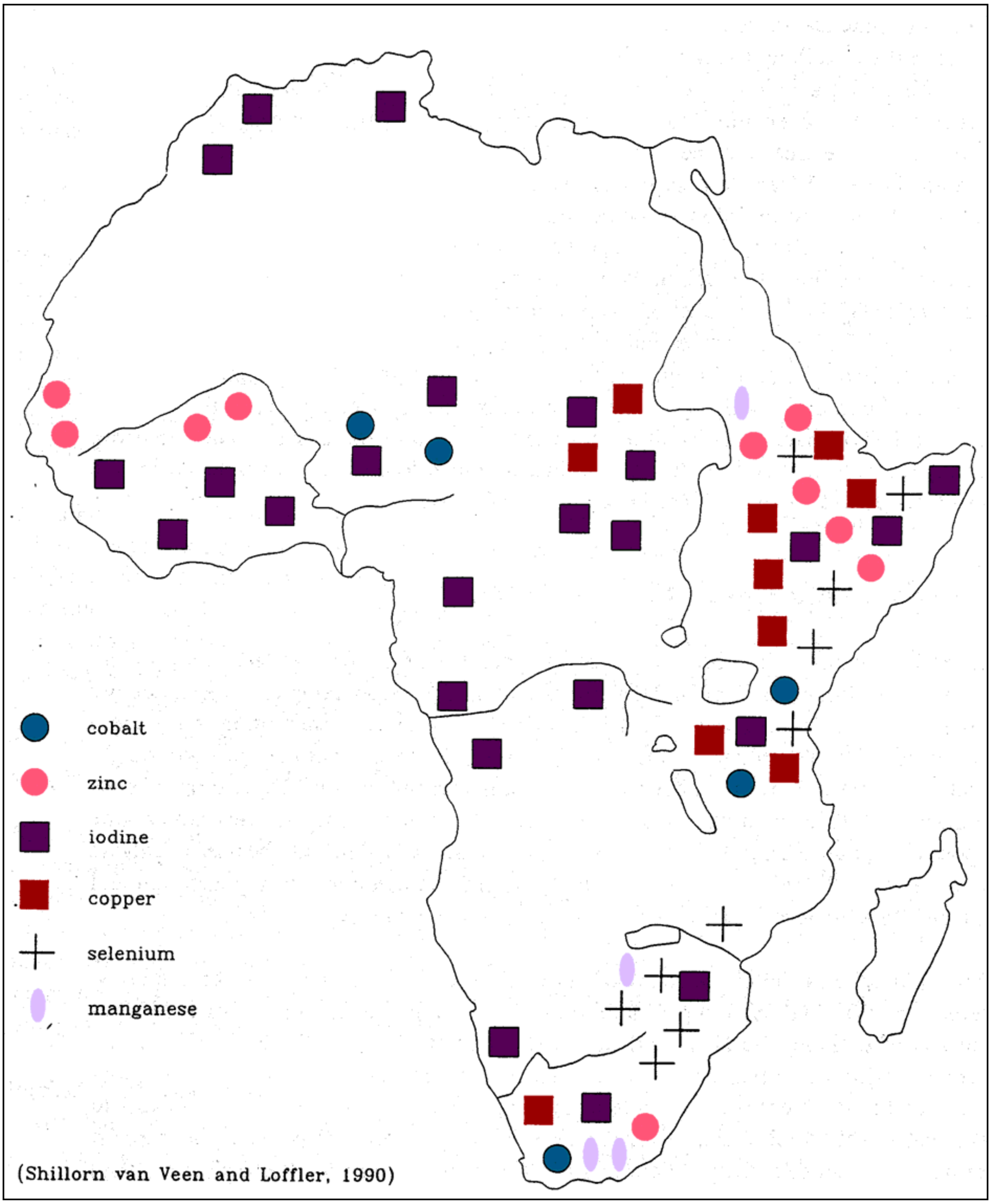
In view of the inconclusive nature of the evidence in this area and the lack of established causal relationships, possible interventions involving the use of fat supplementation to reduce PPIs should be considered with some care.

Minerals

The effects of vitamins and minerals on the reproductive performance of dairy cattle have been reviewed by Hurley and Doane (1989). Borderline deficiencies in minerals and vitamins may result in impaired fertility before gross deficiency symptoms are observed. However, specific requirements for optimum reproductive function at different stages of the reproductive cycles of cattle have not been determined. Consequently, information on the effects of specific deficiencies in macro- or trace-minerals on the length of the is limited.

Some studies have reported positive responses in reproductive performance to mineral supplementation (Ca, P, Cu, Fe and I - Surendra Singh and Vadnere, 1987; Mn - Wilson, 1966). In others, similar responses have not been forthcoming (Cu - van Niekerk and van Niekerk, 1990). Minerals may exert adverse effects on *post-partum* interval when consumed in excess (e.g. Phillippo *et al*, 1989). However, this situation is probably unlikely to arise under traditional feeding systems practised in Africa. Mechanisms by which mineral deficiencies exert their effects on reproductive performance are unclear. Decreased serum insulin levels have been observed in hypo-calcaemic dairy cattle (Littledike *et al*, 1968) suggesting possible links with energy mobilisation.

Figure 2: *The geographical distribution of mineral deficiencies in African ruminant livestock.*



Mineral status in breeding livestock is probably related to levels in feeds and consequently in the soils on which they are grown. Published information on the geographical distribution of specific mineral deficiencies in Africa (Figure 2) has been reviewed by Schillhorn van Veen and Loeffler (1990). Deficiencies in phosphorous are widespread throughout the continent with more localised occurrences of deficiencies in other minerals. However, the possibility of predicting reliably from soil mineral contents, instances in which reproductive performance might suffer, may not be easily practicable given the length of the pathway from soil to animal tissue. Attempts to supplement specific mineral deficiencies in the animal which are suggested by soil profiles may also be masked by more critical limitations imposed by other factors such as energy and protein.

Nutritional Status and the Post-Partum Interval

There are numerous practical impediments to measuring energy balance in traditionally managed cattle at different stages of their productive cycles. Therefore, most studies have relied on changes in body weight and body condition score to indicate changes in nutritional status over time. However, the interpretation of these changes as they relate to returns to oestrus may be complicated by the combined effects of a number of different factors. Where feed supply is seasonal, patterns of change in body weight or body condition tend to follow those in feed supply, usually with a lag period of around three to six weeks (Potter, 1985). This general seasonal pattern of changes in body weight and condition score is then modified by the varying demands of the animal for nutrients at different stages of its production cycle. For example, an animal calving during the dry season may lose weight in early lactation in order that nutrient demands for milk production are met adequately. Another animal, of similar initial body weight and condition, calving in the early wet season may be able to maintain these during the early part of its lactation but need to rely on catabolism of body reserves, thereby losing weight and condition, later in lactation as feed supplies dwindle during the post-rains period (Kidner, 1966; Djabakou *et al*, 1991).

Relationships Between Bodyweight and PPI

Strong correlations have been observed in a number of studies between body weight immediately after parturition and the duration of the PPI (Steenkamp *et al*, 1975; Bellows and Short, 1978; Holness *et al*, 1978). Cows which are heavier at parturition return more quickly to oestrus than lighter ones. It seems likely, however, that current body weight would be more important in determining oestrus resumption and this is supported by Rudder *et al* (1985) who observed higher pregnancy rates in comparatively heavy cows exposed to a bull than in light cows. Nevertheless, animals which are heavier at calving are better able to maintain or lose less body weight and condition during lactation and will therefore achieve adequate condition to resume oestrus cycling earlier.

This is a manifestation of the common-sense concept of a target body weight at mating, adopted by Ward (1968) and popularised in a much quoted review by Lamond (1970) as a means of defining the likelihood of successful re-breeding on the basis of past and current nutritional status. The concept specifies that, for animals of a given breed under given conditions, there is a minimum body weight below which re-mating is unlikely to take place. This implies that a certain level of body reserves is necessary to support normal reproductive activity, whatever the level of current nutrition. Richards *et al* (1989) have demonstrated that oestrus cycling is an important component of the target weight concept by feeding normally cycling beef heifers to lose one *per cent* of their body weight per week. After thirty weeks of this regime, 91% of cows ceased cycling having lost approximately 24 *per cent* of their initial bodyweight. With increased feeding to restore bodyweight, oestrus cycling was re-initiated in around 9 weeks. A number of estimated target body weights are shown in Table 1. However, the practical value of these for predicting the likelihood of an individual returning to oestrus is likely to be compromised by the confounding effects of other factors, particularly between-animal variability. (Richardson *et al*, 1975; Holness *et al*, 1978).

Table 1: *Examples of values cited in the literature for target body weights at mating*.

Target bodyweight (kg)	Breed	Reference
220	N'Dama	Agyemang *et al*., 1991
275	Mashona	Ward, 1968
<250	Mashona	Holness *et al*., 1978
318	Boran, East African Zebu and Hereford X	

If the achievement of a target body weight is necessary for successful conception, it might be expected that the length of the PPI would be closely related to the rate of liveweight recovery following parturition. However, information in the literature is contradictory. Agyemang *et al* (1991) reported a study in which only 27.5% of cows which lost weight in the first four months *post-partum* calved again within 21 months compared with 50% of animals which gained weight during this period. Of the cattle which successfully conceived at 21 months, 71% were gaining weight in the three months prior to conception. However, in a number of other studies, cows which lost weight *post-partum* returned more quickly to oestrus (Steenkamp *et al*, 1975; Bellows and Short, 1978; Holness *et al*, 1978).

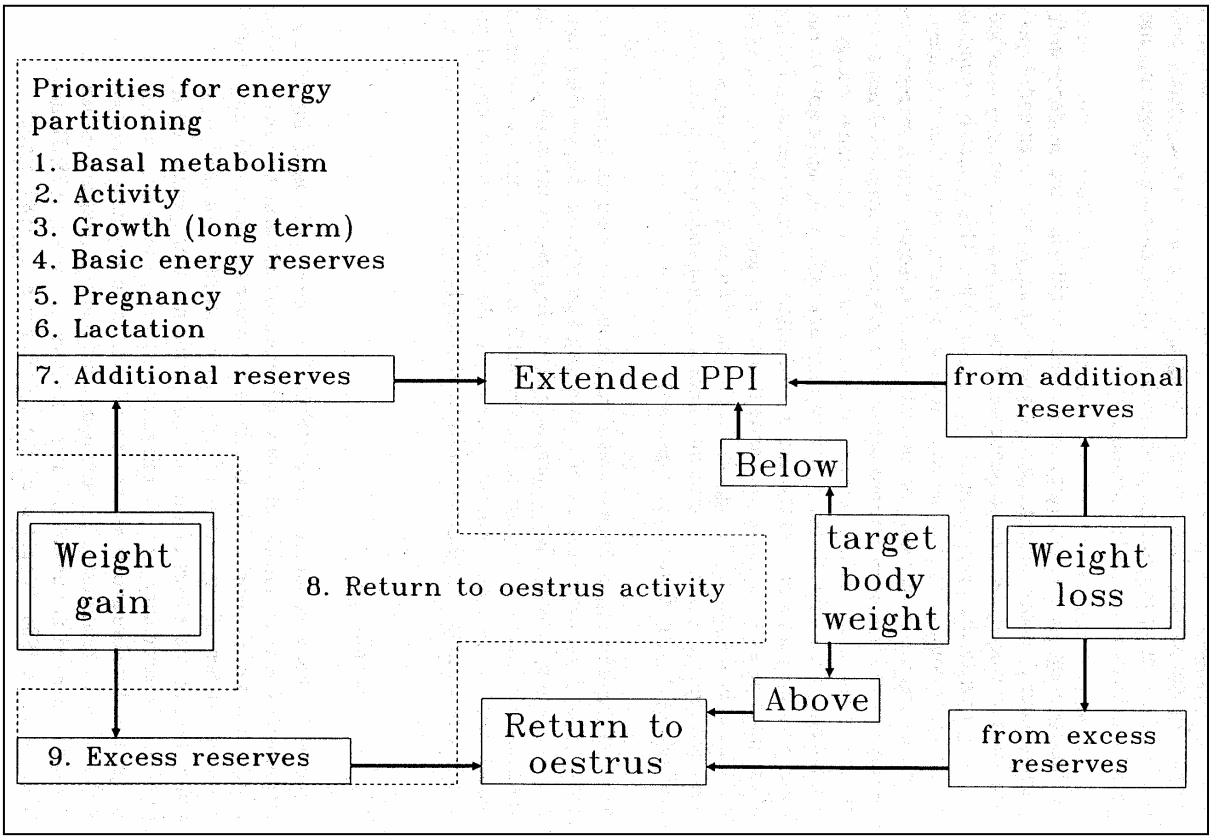
Table 2: *Priorities for the partitioning of nutrients in the post-partum cow (Short et al., 1990)*.

Priority	Nutrient-demanding process
1.	Basal metabolism
2.	Activity
3.	Growth
4.	Basic energy reserves
5.	Pregnancy
6.	Lactation
7.	Additional energy reserves
8.	Oestrus cycles and initiation of pregnancy
9.	Excess reserves

Of some use in resolving these apparent contradictions, is the suggestion of Short *et al* (1990) that there is an approximate order of priorities for nutrient partitioning that may be attached the range of nutrient-demanding activities which the *post-partum* cow must or may potentially undertake (Table 2). The concept of a target weight for conception may be interpreted in terms of this order of priorities as the body weight reached when adequate additional energy reserves (priority seven) have been laid down.

Figure 3 presents a simple model, based on these priorities for nutrient partitioning, of how the same pattern of *post-partum* liveweight change may occur in animals whose nutritional status is adequate *or* inadequate for the resumption of oestrus cycling. For example, animals

Figure 3: *A conceptual model of the possible relationships between energy partitioning and liveweight changes in the* post-partum *cow.*



which are below target weight, but increasing in body weight, may be regarded as laying down additional body reserves and therefore do not have adequate energy reserves to direct towards oestrus resumption. Conversely, an animal above the target weight, may also be losing weight but from excess body reserves and therefore still be able to direct available energy towards the resumption of oestrus cycling.

Perhaps the most important conclusion to be drawn is that *post-partum* body weight changes cannot be considered in isolation from the absolute body weight of the animal. This is underlined by correlations that have been observed between absolute liveweight and *post-partum* body weight change. There is strong evidence that, under extensive management, lighter animals tend to gain weight between parturition and re-breeding in contrast to heavier animals which tend to lose weight during this period (Steenkamp *et al*, 1975; Holness *et al*, 1978; Agyemang *et al*, 1991). Agyemang *et al*, 1991), report that N'Dama cattle which were losing weight in the period before conception tended to be in higher weight class groups, in excess of the 220kg target body weight for conception estimated for this breed.

If this scenario is accepted, it seems likely that *post-partum* body weight changes *per se* are not of particular significance for the length of the PPI unless the animals under consideration are light and need to regain a body weight in excess of the target body weight for conception. Body weight changes during this period merely reflect the combined effects of the nutrient mobilisation and utilisation processes that are taking place in animals in particular metabolic states.

Within the framework of priorities for nutrient partitioning, the incidence, in the *post-partum* animal under traditional management in Africa, of extended periods of anoestrus may be viewed as a consequence of the relatively low priority attached by the breeding cow to the resumption of breeding activity. This is clearly a sound strategy from an evolutionary perspective as the concentration of resources in other activities relating to the mother's own survival and that of current offspring which represent resources already invested is more likely to spread the animal's genetic material. Thus, a cow under nutrient stress after calving remains anoestrus until the additional energy reserves component of the animal's body reserves increases sufficiently to be able to support a concurrent pregnancy or until the demands of lactation cease at weaning. The incidence of extended periods of *post-partum* anoestrus might, therefore, be regarded as part of a breeding animal's general strategy for balancing, as far as possible, both short and long term nutrient requirements (for maintenance, lactation and pregnancy) with the supply available to it (from feed or body reserves).

Much of the difficulty in the interpretation of some earlier studies in this area may have risen partly from too casual use of certain statistical methods for the interpretation of data on factors which affect return to oestrus. In view of the correlations between variables referred to above, relationships derived from multiple regression or least squares models need to be considered most carefully in the terms of the biological processes which may, *or may not be*, represented by the numbers.

Body condition score

Changes in body condition score (BCS) have been little used in studies of the relationships between nutritional status and return to oestrus in African cattle. However, in other parts of the world, BCS at calving has proved a useful indicator of nutritional status in studies of the effects of *pre-partum* nutrition on PPI as it represents a summation of the effects of the animals nutritional management up to the point of calving. It is particularly useful in this respect as it is, to an extent, independent of body weight and therefore avoids some of the problems of interpretation of data discussed above. Clear negative relationships between body condition at calving and the length of the PPI has been observed in numerous studies (Bellows and Short, 1978; Holness *et al*, 1978; Richards *et al*, 1986; Wright *et al*, 1987; Richards *et al*, 1989; Houghton *et al*, 1990; Wright *et al*, 1992). In general, excessively fat animals at calving display a number of reproductive problems including extension of the PPI (Butler and Smith, 1989). This situation is normally seen in high yielding dairy cows and is unlikely to arise in the traditionally managed animal. In thinner animals, changes in body condition score at calving exert a marked negative effect on the length of the PPI. The level of body reserves below which PPI may become extended appears to be represented by BCSs slightly below the mid-point of the scales - between four and five on a scale of one to nine (Dzuik and Bellows, 1983; Richards *et al*, 1986) or 2.25 on a scale of one to five (Wright *et al*, 1987).

In an attempt to quantify the relationships between BCS at calving and the duration of *post-partum* anoestrus, Wright *et al* (1987, 1992) have estimated that, for each one point drop in BCS (on a one to five scale) of beef cattle at calving, there was a corresponding increase of 43 ±20 or 86 ±21.6 days respectively in PPI. In the latter study, the range of body weights was greater but that in body condition score smaller and there is clearly a considerable degree of between animal variability not accounted for by this simple regression approach.

The significance of BCS at calving as an indicator of PPI may be related to the importance of body reserves in maintaining adequate supplies of nutrients for the processes occurring during early lactation. These may often outstrip the nutrient restrictions imposed by limited feed availability of feed intake limitations to meet all the demand for nutrients.

As a general conclusion, it would appear that observations of changes in bodyweight are of little use in determining the likely reproductive path in a *post-partum* animal if the absolute bodyweight in relation to the target weight for conception or some idea of the body condition score is available.

CONSEQUENCES OF NUTRITIONALLY MEDIATED PPI IN TRADITIONAL CATTLE PRODUCTION SYSTEMS

Apart from lengthy PPIs, traditionally managed cattle in Africa usually display markedly seasonal conception peaks (Table 3) which are clearly related to seasonal infertility as males and females are generally kept together throughout the year. It has been suggested in a limited number of studies (Steinbach and Balogun, 1971) that this seasonality may be directly mediated by environmental factors such as temperature or photoperiod. However, in the majority of studies, the environmental stimulus appears to be indirect and expressed through seasonal changes in feed supply with conception peaks brought about by improvements in feed availability and possibly quality.

Timing of the Conception Peak

Commonly, a single conception peak appears to be associated with the onset of the rainy season which stimulates a pasture flush and presumably an associated increase in quantity and quality of feed consumed. In Northern Nigeria, a bimodal conception pattern has been observed (Pullan, 1979; Otchere, 1984) with a second peak coinciding with the locally adopted practice of crop residue grazing following the rainy season. In a study of N'Dama cattle in the Gambia, Jeannin *et al* (1988) observed a pronounced peak, not in response to the rainy season but post rains. This may have been due the fact that the mean body weights of the animals in this study were substantially below the target weight for the breed before the onset of the rains and therefore required the entire rainy season to regain adequate body weight.

Relationship Between PPI and Season of Calving

In some studies (Oyedipe *et al*, 1982; Mrode and Akinokun, 1986), there is little evidence of differences between the PPIs of cows which calve in the wet season in comparison with dry season calvers. This would appear to be due to the adoption of improved dry season feeding practices such as supplementation with oilseed cakes and forage conservation. In studies where feeding is restricted to grazing of pasture and crop residues, dry season calvers exhibit markedly longer PPIs than cows calving in the wet season. This is consistent with the observed negative correlation between body weight at calving and the length of the PPI in traditionally managed cattle which tend to be at their lowest body weights during the rainy season (Richardson *et al*, 1975; Fall *et al*, 1982; Wilson, 1986; Jeannin *et al*, 1988). With conceptions concentrated during the early to mid rainy season, the majority of calvings will be during the dry season so there is likely to be a self-reinforcing tendency towards long calving intervals.

Apart from poor productivity arising in this way, the concentration of calvings during the dry season has another disadvantage. The clustering of calvings during the dry season means that the accumulated nutrient demands of the herd, in which a majority of the mature females are at their peak in terms of demand for nutrients, coincide with the time at which feed supplies are at their most limited. Lactating cattle will therefore be reliant on the catabolism of any body reserves which may have been built up during the previous rainy season to support their lactations. In this situation, problems may arise from deficiencies in specific nutrients which are not readily mobilised from body reserves. Furthermore, the use of nutrients from body reserves represents a less efficient path than the utilisation of nutrients directly from feed.

From the preceding, it would appear that, in principle, efficiency of feed utilisation might be greatly improved if reproductive cycles could be manipulated for the calving peak to coincide with the rainy season. Wilson (1986) observed that cattle calving during and immediately after the rainy season had the highest body weight at calving and therefore the highest level of body reserves to support lactation. These animals would also have access to a relatively abundant feed supply. Their comparatively high body weights at calving would also predispose them to a relatively early return to oestrus promoting improved overall herd productivity.

Table 3: *Observations of Post-partum Intervals and the Seasonality Associated with Them*.

Breed	Agro-ecological Zone / rainfall distribution	Timing of conception peak	Percentage of conceptions during peak	Conception peak associated with...	*Post-partum* interval for cows calving in:			Feed management system	Reference
					wet	dry	mean		
Fulani	Sub-humid Mar - Nov	a) Jun - Aug	a) 31	a) Forage flush in rainy season	439	585	475	Daytime grazing. Crop residues available from Dec - Apr.	Otchere (1984)
		b) Dec - Feb	b) 48	b) Crop residue grazing					
Fulani	Sub-humid Apr - Oct	a) Jun - Aug	a) 46	a) Forage flush in rainy season	-	-	542	Rainy season grazing. Crop residues in dec.	Pullan (1979; 1980)
		b) Jan - Feb	b) 28	b) Crop residue grazing					
Fulani	Sub-humid Oct - Apr	-	-	-	169	147	157	Grazing during rains. Hay/silage & crop residues in dry	Oyedipe *et al* (1982)

Fulani	Sub-humid May - Oct	Mar - Jun	51	Body reserves built up from feeding crop residues	-	-	450	Grazing. Crop residues fed from Dec - Mar.	Voh and Otchere (1989)
Fulani	Semi-arid Jul - Sep	Jul-Sep	56	Forage flush in rainy season	-	-	383	Grazing. Limited crop residues available.	Wilson (1986)
Fulani	Sub-humid Mar - Oct	-	-	-	147	129	139	Grazing. Supplemented with oilseed residues during dry season.	Mrode and Akinokun (1986)
Various Zebu types	Semi-arid Jun - Sep	Jul - Oct	74	Forage flush in rainy season	-	-	a) 279	a) Transhumant	Wilson and Clarke (1975; 1976)
							b) 633	b) Grazing with supplementation	
N'Dama	Sub-humid Jul - Sep	Nov - Mar	86	Feeding of crop residues	-	-	448	Grazing from Jul to Sep. Crop residues in early dry season.	Jeannin *et al* (1988)
N'Dama	Sub-humid Jul - Oct	Oct - Mar	80	Feeding of crop residues	364	317	620	Daytime grazing on natural pasture	Agyemang *et al* (1991)
N'Dama	Sub-humid Jul - Oct	Jul - Oct	48	Forage flush in rainy season	129	283	213	Grazing. Supplemented with crop and oilseed residues during dry.	Fall *et al* (1982)

N'Dama	Sub-humid Apr - Nov	Mar - Jun & Nov	46	Forage flush in rainy season	-	-	220	Grazing. Supplemented with brewers grains during dry season.	Tuah and Danso (1985)
N'Dama	Sub-humid Apr - Nov	-	-	-	248	334	284	Grazing. Supplemented with brewers grains during dry season.	Osei and Effah-Baah (1988)
N'Dama	Sub-humid Mar - Nov	Dec - Jul	51	Changes in photoperiod	-	-	-	Grazing of improved and unimproved pasture.	Steinbach and Balogun (1971)
West African Shorthorn	Sub-humid Apr - Nov	Mar - Jun & Nov	43	Forage flush in rainy season	-	-	181	Grazing. Supplemented with brewers grains during dry season.	Tuah and Danso (1985)
West African Shorthorn	Sub-humid Apr - Nov	-	-	-	265	351	284	Grazing. Supplemented with brewers grains during dry season.	Osei and Effah-Baah (1988)
Nguni	Highland Oct – Apr	Dec - Mar	58	Forage flush in late rains	-	-	-	Grazing. Crop residues after harvest.	Butterworth (1983)

Project Purpose

The project was designed to contribute to output 1.4 of the Livestock Production Programme's High Potential Production System. Its purpose may therefore be stated as:

> *Improved strategies for animal husbandry and nutrition in the intensive livestock production system and in crop/livestock systems in high potential and peri-urban areas* developed *and* promoted.

This project has improved our knowledge base of the relationships between nutritional status and reproductive performance. Nutrition has been identified as a widely occurring constraint on the reproductive performance of smallholder dairy cattle. Therefore, the results of on-station research carried out by the project are likely to be of widespread strategic applicability. They are expected to be directly usable by applied researchers wishing to develop feeding strategies for optimum reproductive performance in dairy cattle kept under local conditions.

The knowledge generated is now being used to support the development of practical feeding strategies for maximising milk production in the short and longer terms (by reducing *post-partum* anoestrus intervals) in a typical East African smallholder dairying system (in Tanga, Tanzania). Therefore, the ultimate beneficiaries of the project will be smallholder dairy farmers in East Africa. A number of farmers in the project area are expected to benefit directly through participation in on-farm studies. The project's dissemination activities via the Dutch-funded Tanga Dairy Development Project (TDDP), with which it is directly associated, are intended to provide a model for encouraging the uptake of similar innovations, based on the project's more strategic outputs, in the smallholder dairy sector at other locations.

Research Activities

Implementing the Project

During its lifetime, this project experienced a number of quite major difficulties beyond the control of project staff:

- Unusual weather conditions in east Africa during the course of the project's main experimental study. Drought conditions over two, consecutive years led to considerable difficulties in maintaining feed supplies to animals participating in the study and ultimately required its extension for a period of more than 12 months.
- Death of a key member of the project's support staff during the local project leader's absence in the UK;
- Managerial and financial difficulties in the collaborating institution;
- Difficulties experienced by a collaborating institution in meeting targets for sample analysis.

These have affected the outcomes – in particular, progress along uptake pathways has been less than originally intended. However, because of the projects strong direct link with TDDP – a link, incidentally, which was fortified considerably by the project's activities – it is anticipated that the intended outcomes will, ultimately be achievable.

On-Farm Monitoring

A major component of the project was an on-farm monitoring study. This was conducted in two phases:

- An initial characterisation of selected farms by a broad-based, informal interview and the recording of specific information conducted during the course of an initial visit;
- Longitudinal monitoring of feed resources utilisation, milk production and reproductive events over a two year period.

The principal objective of this monitoring was to identify target groups of farmers and the main constraints and opportunities that they experience in the nutritional and reproductive management of their dairy cattle. This would then be used as a basis for the modelling and on station studies that would underpin the development of management recommendations.

Study Area

The township of Tanga (population 187,000) is situated in the north-eastern corner of Tanzania. The mean, maximum temperature from December to March is 32°C and the mean minimum mean temperature (between June and October) is 20°C. Relative humidity ranges from 55 - 85% with an average of 65%. The mean, bimodally-distributed, annual rainfall ranges from 1200 to 1400mm falling in two peaks during the long (masika) and short (vult) rains. Soils vary from drained sandy and red loams to clay soil. These soils generally have low water retention capacity and are reported to be deficient in phosphorus, nitrogen, copper, organic matter and cation exchange capacity (TIRDEP 1985). Following the establishement of the Tanga Smalholder Dairy Development Programme (TSDDP) in 1985, the smallholder dairy sector in the study area and other parts of Tanga region has developed rapidly.

Farm Selection for Monitoring Studies.

The number of farmers selected to participate in the on-farm monitoring was, necessarily, a compromise between maximising numbers and the resources available. It was judged that enumerators would be able to assess around three farmers in a working day. Therefore, to accommodate a monthly visit schedule, 60 farmers were selected and agreed to participate in the study. These were stratified according to their location in relation to Tanga with farmers from three sites, Tanga itself (urban), Mafuriko (sub-urban at a distance of 5 km from Tanga) and Pongwe (peri-urban at a distance of 10km from Tanga). Using an existing database relating to farmers participating in the Dutch Government-funded, Tanga Smallholder Dairy Development Project (TSDDP, now renamed Tanga Dairy Development Project; TDDP), 22, 23 and 15 farmers were selected at Pongwe, Mafuriko and Tanga respectively. These were intended to represent, “best”, “worst” and “average” management conditions as indicated by average calving intervals and milk yields. These farmers then participated in both the initial characterisation and the longitudinal monitoring studies.

Initial Characterisation Study

The survey for the initial characterisation study was conducted using an interactive method led by a structured questionnaire to collect information on demographic data, available resources related to livestock enterprise operations and other related family activities. The checklist presented at Annexe 1 was used as an *aide-memoire* for enumerators. Available forage and offered supplements were measured on the day of visit while average milk production and fertility of animals were obtained from the TSDDP database. The information collected was collated and analysed using the REML procedure provided by Genstat 5 (NAG 1997).

Longitudinal Monitoring

The two year, on-farm longitudinal study was established in September 1995 immediately following the initial charaterisation study. Data describing feed utilisation and animal performance on the 60 participating farms were collected.

Monitoring Visits

Data were collected from the farms at the three locations (Pongwe, Mafuriko and Tanga Urban) by enumerator visit based at each site. Each farm received a monitoring visit at intervals of approximately 14 days giving a total of 48 sequential observations for each variable from each of the participating farms. During the course of each visit, a complete record was made of feeding patterns for the day, of changes in the structure of the livestock holding since the previous visit and of the bodyweights and productive outputs of individual animals.

Livestock Holding Structures and Estimation of Bodyweight

Changes in the structure of ruminant livestock holdings were recorded throughout the study and checked against TDDP data records. These included sales and purchases, births and deaths and temporary exits and entries. Data recording concentrated on dairy cattle as other species formed only a small part of holdings and shared few common feed resources with ruminant livestock

Estimates of the bodyweights of large ruminants (buffalo, and cattle) were made by measurements of heart girth, taken during each visit, based on the equation:

$$Bodyweight = (0.1416 \times Heart\ girth - 5.0564)^2$$

This was derived from a correlation study conducted on animals of a similar genotype in the TLRC herd.

Cut-and-carry Feeds

The main focus of the study was on the utilisation of feeds that were cut-and-carried in a system based on stall feeding. The data collected to describe these cut-and-carry feeds included quantitative estimates of feed utilisation and basic indicators of nutritive value - dry matter (DM) and crude protein (CP) contents.

Feed Offers

Recording of feed utilisation was based on the total allocations of forage and concentrates occurring during the monitoring visits. In order to avoid farmers increasing this on the monitoring day only, visits were unannounced. Forages were weighed in bundles and the identities of the animals to which the total quantity of forage was offered recorded. Feeding of concentrates was normally carried out on an individual basis so quantities assigend to individual animals were recorded separately.

Statistical Analyses

All statistical analyses were conducted using the standard directives and library procedures provided by Genstat 5, release 3.2 (NAG, 1995).

The effects of the main factors and their interactions on the values of the measured and derived variables in the data set were evaluated using a variance components analysis executed with Genstat's REML directive. This allowed the effects of unbalanced factors to be evaluated within a multi-factorial framework, and variances within and amongst farms to be compared.

With the exception of the data describing herd structures, categorical data (e.g. counts of the different feeds observed in use) were treated in the same way as ordinal variables. The large number of observations in the study allowed the assumption that the distribution of these variables would not differ significantly from normality. Application of the more powerful tests indicated that this was the case. Factor effects within the herd data were evaluated using χ^2 tests for independent samples.

Simulation Modelling

Part of the project's activities focussed on the use of simulation modelling techniques to evaluate the consequences of different patterns of nutrient availability for reproductive performance and, consequently, herd dynamics.

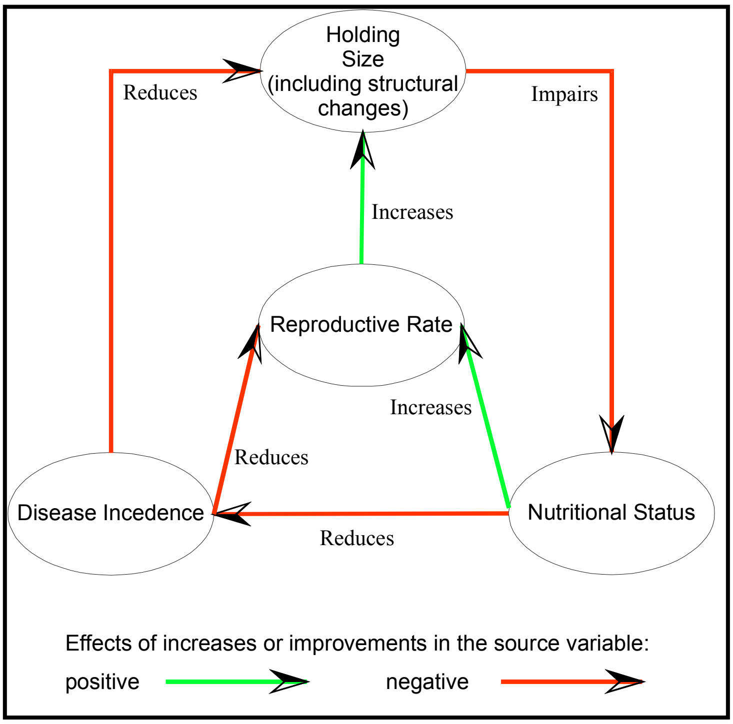
Core Structure of the Model

A stochastic, deterministic model was constructed using the Stella V graphical modelling environment. The model's structure is shown in the figures contained in Appendix 1. The main components of the model include treatments for:

- Assessing the nutritional characteristics of different feed availability profiles;
- Generating reproductive events in response to nutritional and other influences;
- Predicting the impacts of variation in *post-partum* intervals on overall herd dynamics.

In outline, the model uses an assessment of the seasonal availability and quality of feeds to modify the reproductive and other processes that determine herd dynamics. The general interactions that underlie this are outlined in Figure 4.

Figure 4: *The principal interactions associated with the dynamics of livestock holdings*.



Minimum Input Dataset

Initial Herd State

These variables are used, for the array of individual animals that comprises the herd, to set up a starting point for a simulation run:

- Age (years)
- Bodyweight (kg)
- Pregnant (y / n)
- Lactating (y / n)

Breed Specific Variables

These variables allow the impacts of different genotypic effects to be assessed:

- Mean age at puberty (months)
- Standard deviation of mean age at puberty (months)
- Mean cycle length (days)
- Standard deviation of cycle length (days)
- Mean gestation period (days)
- Standard deviation of gestation period (days)
- Maximum daily liveweight change (grammes)

Production System Specific Variables

Describe some key characteristics of the production system to be simulated:

- Mean condition score over the simulation period (on a 1 – 5 scale)
- Mean monthly forage availability (kg)
- Mean monthly supplement allocations (kg)
- Monthly assessments of forage quality (on a five point, qualitative scale)
- Lactation lengths

Input data are set up for the model directly for simple variables or in Microsoft Excel tables for the dynamic variables – for example those that describe the monthly changes in feed availability and quality.

Operation of the Model

The driving force in the model relates to the probability of oestrus events *occurring post partum*. The key factors here are the impacts of lactational and nutritional anoestrus. Effectively, the time after parturition and the intensity (in both duration and extent) of nutritional deficits increase or reduce the probability of oestrus occuring and cycling re-establishing itself. These factors effects a basis for the simulation of herd dynamics with other modifying factors such as disease and culling / marketing policies resulting in further modification.

Nutritional impacts on the establishment of oestrus cycling are based on quite crude assessments of energy balance on a monthly basis resulting from a monthly forage and supplement budget and qualitative assessment of fodder quality (Thorne, 1998). This simplistic approach was taken to allow the model to form a basis for practical management tools that might be developed in future.

System Requirements

The model requires an IBM PC or compatible system and STELLA 5 Research ® systems modelling software[2]. STELLA 5 Research ® requires:

- a PC Windows operating system (3.1 or 95)
- an 80486 processor (running in 386 enhanced mode if the installation is under windows 3.x)
- 8 MB RAM

A full installation of the model (including STELLA 5 Runtime) requires approximately 8 MB of free hard disc space.

On-station Experimentation

This long-term experiment used the findings of the longitudinal field monitoring which started in August 1995 to examine the impacts of different concentrate allocation strategies on milk production and reproductive performance; specifically on *post-partum anoestrus* intervals. The monitoring study indicated that, smallholder dairying in Tanga region is characterised by continuous resource limitations, particularly feed availability. Generally, those feeds that are available are limited in their capacity to supply both energy and protein.

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[2] - the STELLA 5 Research ® software can be obtained from:

HPS (High Performance Systems, Inc.), Hanover, NH 03755, New Hampshire, USA. FAX: 603-643-9502. E-mail: support@hps-inc.com

or in the United Kingdom from:

Cognitus Ltd, 1 Park View, Harrogate, N. Yorks HG1 5LY. FAX 01423 567916. E-mail: info@congnitus.co.uk

Often farmers regard the practice of supplementation as a means of keeping lactating cows standing to be milked rather than part of a strategic approach to feeding for optimised production. Late weaning is normally practised to encourage milk letdown from the dams. Therefore a combination of poor feeding and extended suckling are suspected as being amongst the major factors causing long calving intervals in the study area. It was hypothesised that short-term "tactical" supplementary feeding and early weaning of calves might be used to improve returns to oestrus under these conditions and still be acceptable to farmers as they would not require large investments in additional supplement purchases.

Experimental design.

The experiment used cross-bred cows (a minimum of 18 for each of the five treatments) from the Tanga Livestock Research Centre's (TLRC's) herd. All experimental animal were transferred from the main herd to the experimental stall-feeding facility approximately ten days before calving. During this period they were supplied with napier grass (*Pennistum purpureum*) and other fodder grass at a calculated rate of one and a half times their maintenance ME requirement.

The cows were blocked for:

- Genotype (two levels; 50 and 62 - 87% of *Bos taurus* blood);
- Lactation number
- Body condition score at calving (see Annexe 3).

The effects of five experimental treatments (Table 4) were examined in the experiment.

Table 4: *Experimental Treatments Adopted for the On-Station Experiment*.

Treatment	Description	Total concentrate (kg)
1	3.5kg concentrate day^{-1}, No spike	588
2	2.5kg concentrate day^{-1}, spiked to 7 kg day^{-1}from week 10 for 5 weeks	577.5
3	3.5kg concentrate day^{-1}, spiked to 7 kg day^{-1}from week 10 for 5 weeks	710.5
4	3.5kg concentrate day^{-1}, spiked to 7 kg day^{-1}from week 8 for 5 weeks	710.5
5	3.5kg concentrate day^{-1}, spiked to 6 kg day^{-1}from week 8 for 7 weeks	710.5

Feeding.

Forage.

Three types of basal forage (roadside grasses, napier grass and hay) were fed interchangeably to reflect farmers' practices. These were sourced on-farm when available or from reputable merchants during the periods of feed shortage that occurred durign the course of the experiment.

Concentrate.

The concentrate supplement used was based on maize bran (hominy meal), coconut cake and dried leucaena leaf meal. Additional bone meal was used as a source of calcium and phosphorus. The relative proportions of each ingredient were adjusted to make good estimated energy deficits from the basal forages.

Feeding regime.

Cows were offered fresh forage three times a day (08.00 - 09.00; around 13.00; around 18.00). Supplements were fed during each of the two milking sessions at 06.00 and 15.00. Calves were offered green forages plus 0. 5 kg / day concentrate from 3 week of age until weaning at 12 weeks.

Measurements.

Feed sampling and analyses.

Forages were sampled, oven dried and their dry matter contents estiamted on daily basis. Weekly dried samples were bulked and a small representative sub-sarnple was ground and packed in sample bottles before carried for more detailed nutritional analysis. Forage refusals were be treated in a similar way. Samples of each concentrate formulation were also sampled for future analysis. All bulked feed samples were analysed for in-vitro dry matter digestibility and crude protein content. Crude protein analyses were carried out according to the procedures described by AOAC (1985). In-vitro dry matter digestibility was assessed using the method of Tilley and Terry (1963).

Milk sampling and analyses.

Morning milk samples were collected on the 21st day *post-partum* and twice weekly thereafter. During the spike-feeding period for each period, milk sampling was carried out three times a week. Milk samples were treated and stored at O°C ready for progesterone radio-inununoassay (RIA) to indicate the time of ovulation.

Body condition score and weight measurements.

Cows were weighed initially on the day after calving and thereafter on a weekly basis and, additionally, on the day on which the feeding regime was changed or the calf weaned. All weighings were made early in the morning after millking but before feeding. Body condition scores were recorded on the same days as weighing as described in appendix 1.

Milk yield.

Milk yield was measured and recorded (separately as morning and afternoon yields) volumetrically (in litres) at each milking session.

Other activities.

Calf rearing and performance records.

Calves were weighed at birth and weekly thereafter. No body condition scoring was carried out on the calves. For the first forty eight hours after calving, calves were allowed to suckle colostrum and to stay with their dams. Before weaning, calves were allowed to suckle for 30 minutes following a milking session.

All disease preventative measures and treatments followed the existing routine used by TLRC.

Detection of oestrus.

A penile deviated bull was allowed to walk in the cow shed twice a day (morning and evening) to detect any cow which might be on heat. Oestrus detection dates based on these observations were compared with the RIA results as a confirmatory sign of the occurrence of *oestrus*.

Outputs

On-Farm Monitoring

Initial Characterisation Study

The demographic survey revealed that an average family had 6.7 ± 0.3 people with a range of between 2- 15 people per household. No differences were observed in household sizes ($p > 0.05$) amongst sites. Family was the central labour resource. The cost of hiring labour ranged from T.Sh. 4,000 to 10,000 per month with an average of T.Sh. 6731 ± 974 per month (At the time of the study 1 USD = T.Sh. 670.00).

Site Characterisations

The three locations were selected according to distance from Tanga urban centre. This was reflected in a number of the socio-economic variables recorded in the initial study (Figure 4). In general, farmers operating closer to the Tanga urban centre were more likely to have reached a higher educational level and to engage in activities that were complementary to farming; in the form of formal employment for example. The lesser prioritisation of farming activities by household heads and other family members was reflected in the much greater use of hired labour on the farms in the Tanga urban and Mafuriko locations when compared to the peri-urban Pongwe site.

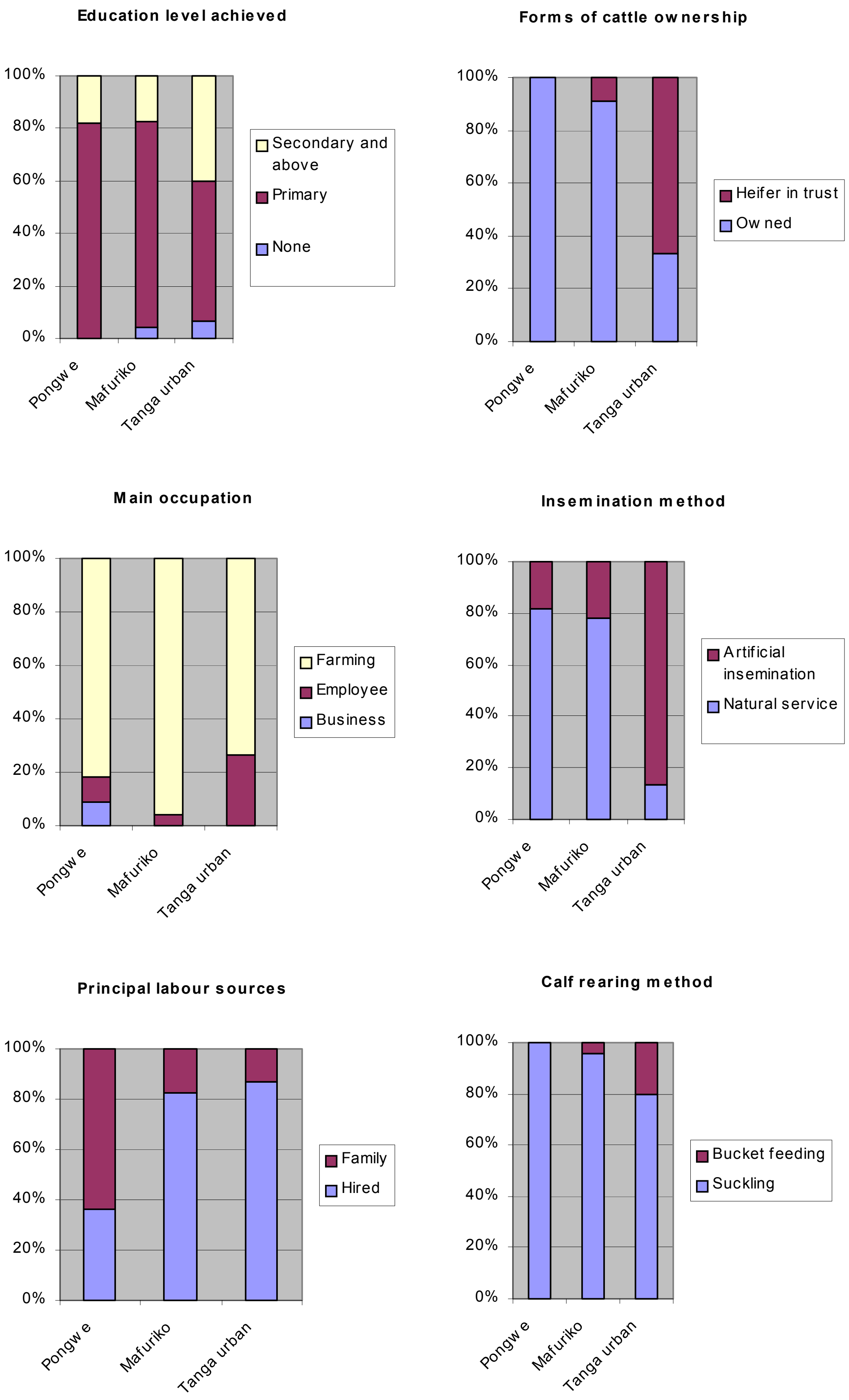
Although, farmers in the urban and sub-urban locations may have devoted their efforts less exclusively to farming, they appeared to be more susceptible to the penetration of technical innovations and managerial innovations. The highest percentages of farmers adopting the bucket feeding of calves, artificial insemination of dams promoted by TDDP and participating in the project's heifer in trust scheme were all observed amongst the group of Tanga urban farmers studied.

Impacts on Management and Production

Management and production factors were studies in more detail during the longitudinal study. However, some interesting, initial observations were obtained from the preliminary study.

The preliminary assessment of feed use by location conducted during the initial characterisation study revealed that feeding depended mostly on natural pastures collected from fallow and communal lands (including roadside verges) although all farmers interviewed claimed that they were growing napier grass (*Penisetum purpureum*). Average forage available on the visiting day was 93 kg/ Livestock unit (LU) and the amount increased with increased with increasing distance from the town centre (Table 5) although the difference was not statistically significant ($p > 0.05$). Supplements were based on maize bran and in some cases included leucaena leaf meal, coconut cakes, sunflower cakes, cottonseed cakes and bone meal. On average 4.2 ± 0.3 kg of a mixed ration or maize bran alone was offered to a milking cow. The amount of supplement offered increased ($p < 0.05$) with increasing distance from the town centre. Average milk yield and calving intervals (CI) were affected significantly by location ($p > 0.05$) with the sub-urban farms of Mafuriko apparently performing most

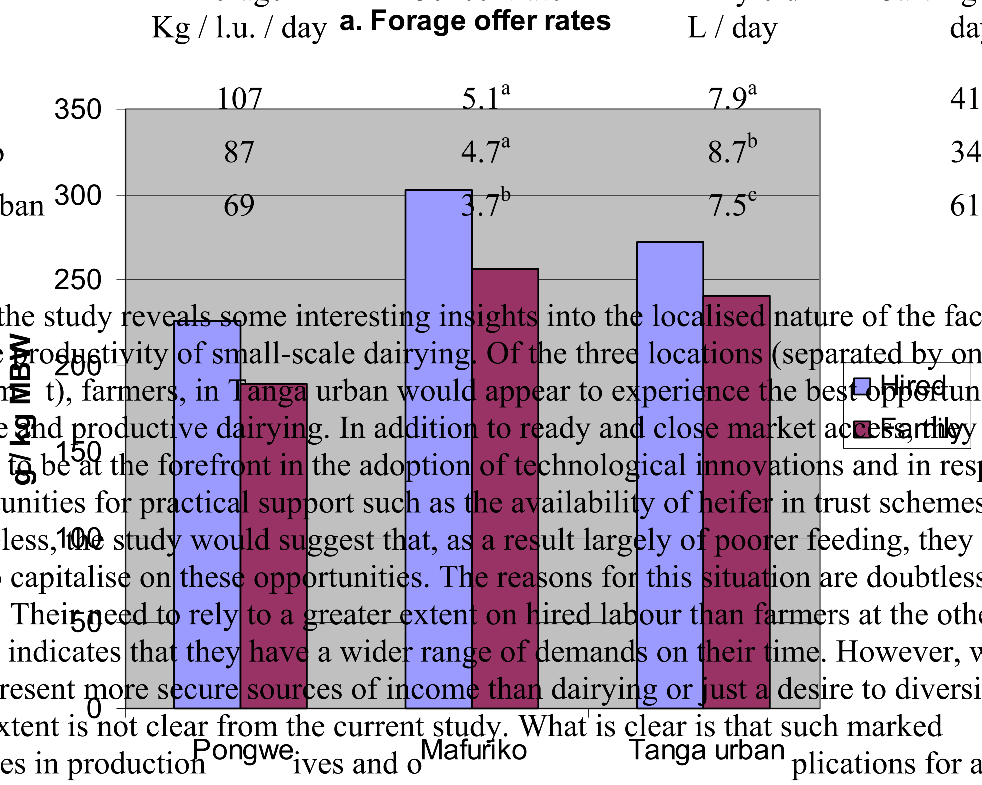
Figure 5: *Effects of farm location on a number of key socio-economic variables related to small scale dairying in Tanga Region.*



effectively and cattle on farms in Tanga urban least so. In addition to the seasonal nature of feed availability, farmers reported animal diseases, low milk prices, unreliable insemination services, cattle rustling and water shortage as being the main problems faced at the three study locations.

Table 5: *Feed use and performance of small holder dairy cows at different locations in Tanga Region.*

	Forage Kg / l.u. / day	Concentrate	Milk yield L / day	Calving interval days
Pongwe	107	5.1[a]	7.9[a]	419[a]
Mafuriko	87	4.7[a]	8.7[b]	349[a]
Tanga urban	69	3.7[b]	7.5[c]	617[b]



Overall, the study reveals some interesting insights into the localised nature of the factors that affect the productivity of small-scale dairying. Of the three locations (separated by only 10 miles at most), farmers, in Tanga urban would appear to experience the best opportunities for profitable and productive dairying. In addition to ready and close market access, they also appeared to be at the forefront in the adoption of technological innovations and in responding to opportunities for practical support such as the availability of heifer in trust schemes. Nevertheless, the study would suggest that, as a result largely of poorer feeding, they do not appear to capitalise on these opportunities. The reasons for this situation are doubtless complex. Their need to rely to a greater extent on hired labour than farmers at the other locations indicates that they have a wider range of demands on their time. However, whether these represent more secure sources of income than dairying or just a desire to diversify to a greater extent is not clear from the current study. What is clear is that such marked differences in production[illegible]ives and o[illegible]plications for a need to target future innovations in small-scale dairying at a very local level.

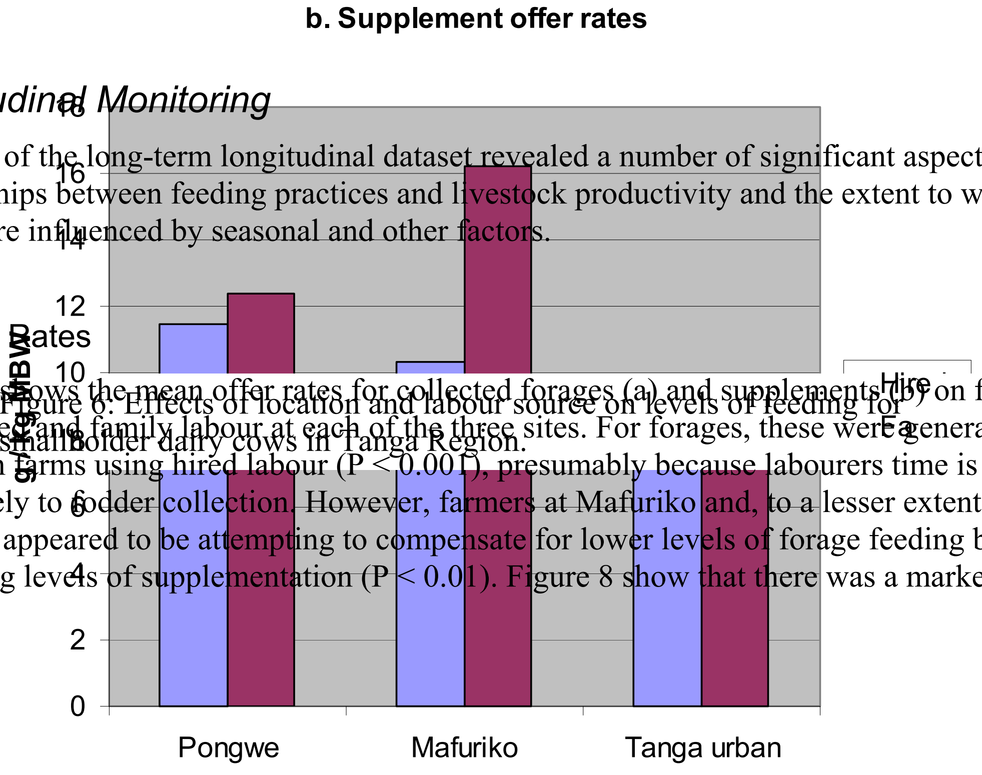


Figure 6: Effects of location and labour source on levels of feeding for smallholder dairy cows in Tanga Region.

Longitudinal Monitoring

Analysis of the long-term longitudinal dataset revealed a number of significant aspects of the relationships between feeding practices and livestock productivity and the extent to which these were influenced by seasonal and other factors.

Feeding Rates

Figure 7 shows the mean offer rates for collected forages (a) and supplements (b) on farms using hired and family labour at each of the three sites. For forages, these were generally higher on farms using hired labour ($P < 0.001$), presumably because labourers time is devoted exclusively to fodder collection. However, farmers at Mafuriko and, to a lesser extent Pongwe, appeared to be attempting to compensate for lower levels of forage feeding by increasing levels of supplementation ($P < 0.01$). Figure 8 show that there was a marked seasonal distribution of the differences in forage offer rates between farms hiring labour and those using family labour. There was evidence that these different feeding practices adopted at the different sites and on family and hired labour farms were also reflected in production parameters.

Figure 7: *Seasonal distributions of the differences in forage offers between farms using hired and family labour.*

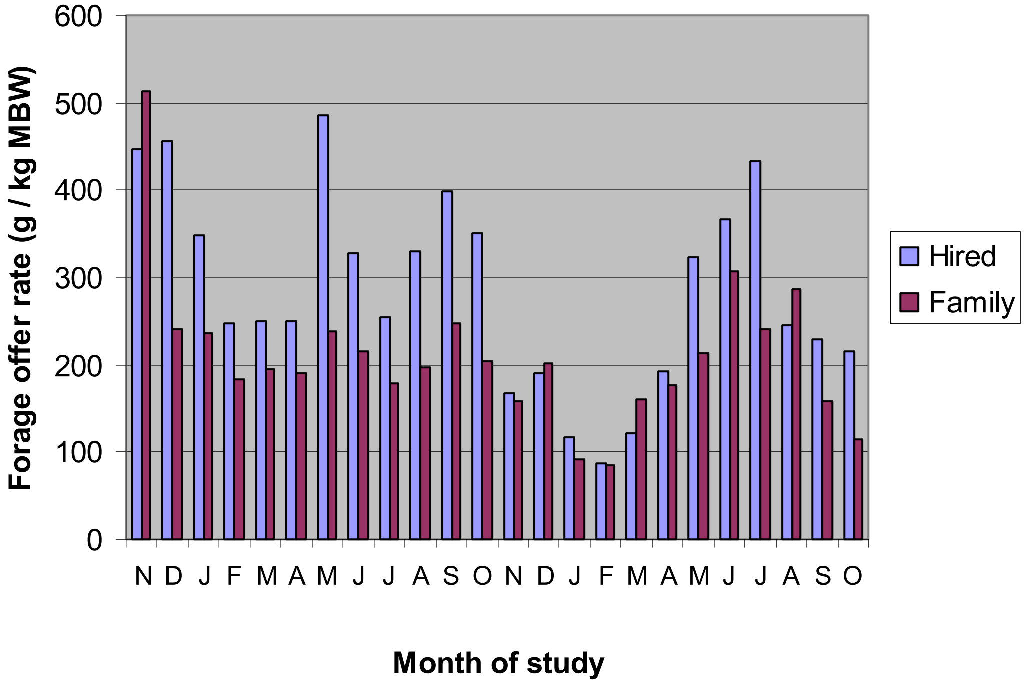
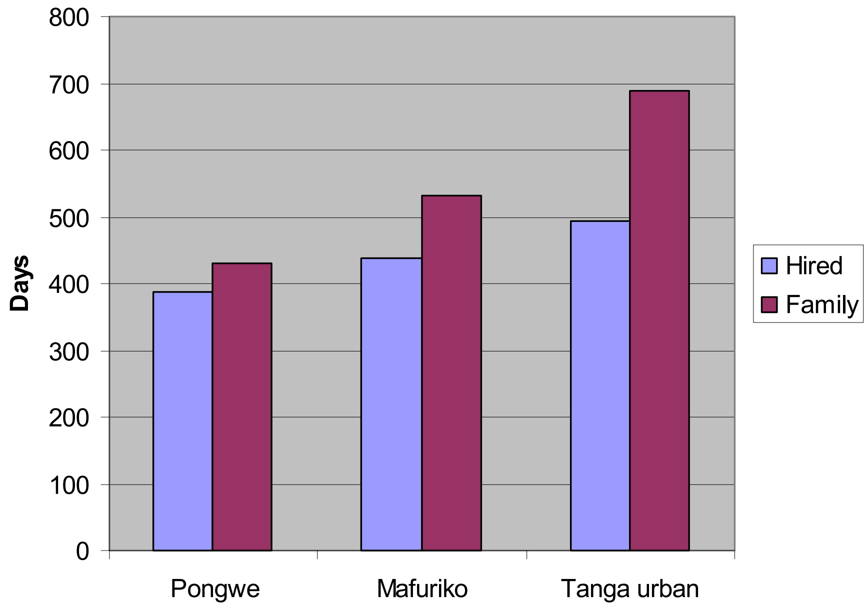


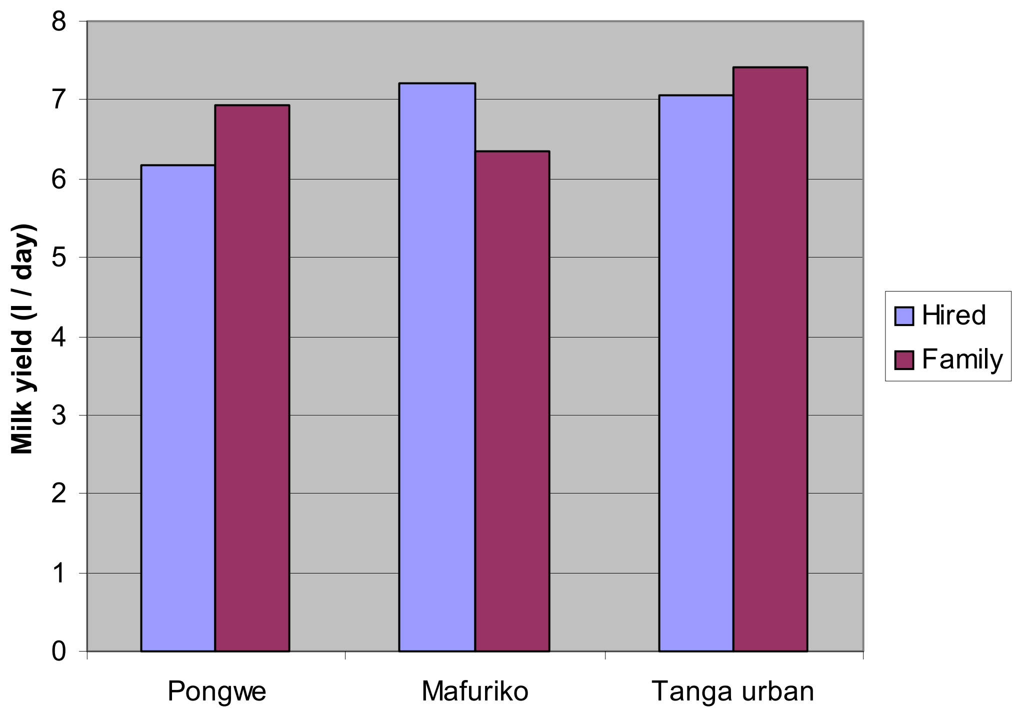
Figure 8: *Effects of location and labour source on calving intervals smallholder dairy cows in Tanga Region.*



Calving Intervals and Milk Yields

Calving intervals (Figure 8) appeared to be inversely correlated with the distance of the location from the Tanga Urban centre ($P < 0.001$). At each village, cattle on farms that relied on hired labour exhibited consistently shorter calving intervals than those on farms on which the family was the main labour source ($P < 0.001$). Trends in mean daily milk yields were less consistent although farms at Tanga urban appeared to have the highest yielding cows on a daily basis. The reasons for this are unclear although bucket feeding has penetrated more widely amongst this group of farmers. More detailed analysis of the dataset for the productionof future dissemination outputs will explore this issue further.

Figure 9: *Effects of location and labour source on mean daily milk yields of smallholder dairy cows in Tanga Region.*

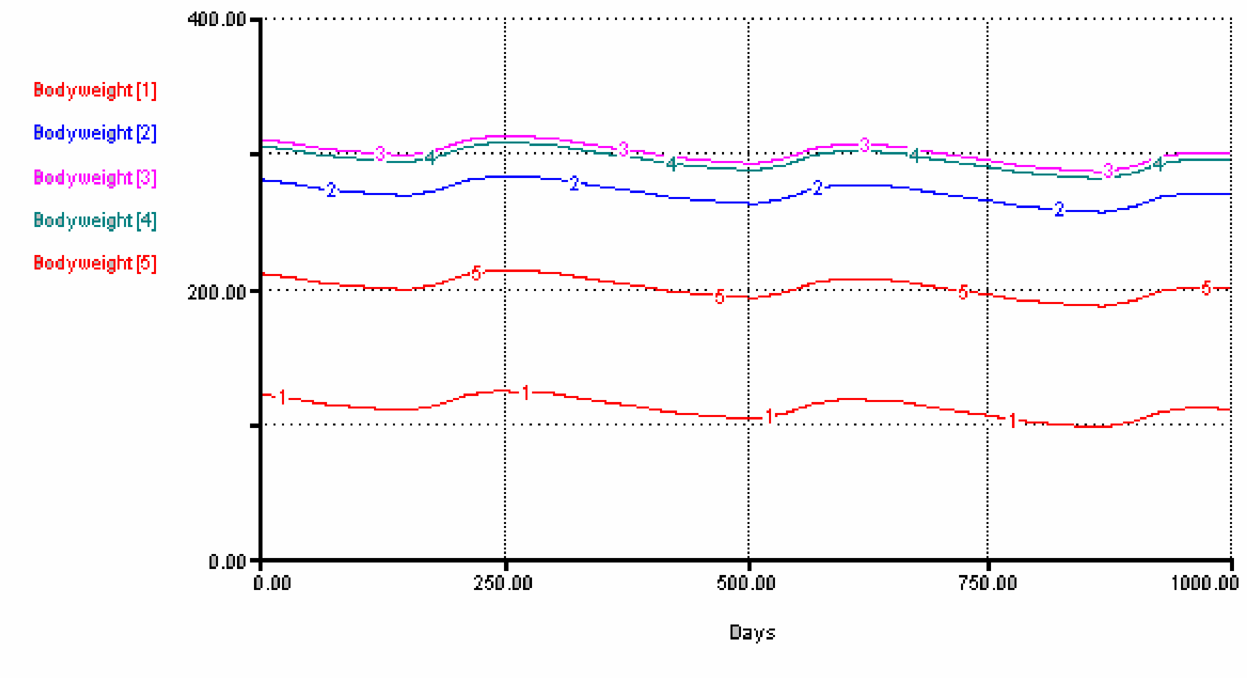


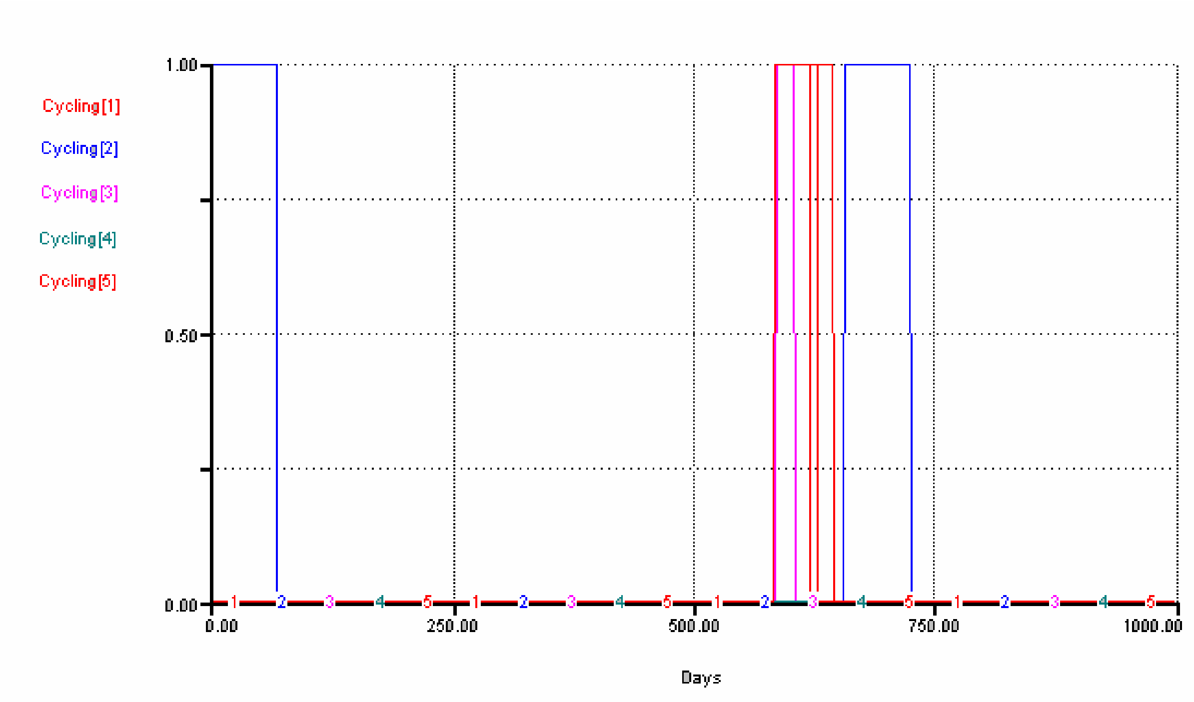
Simulation Modelling

Due to delays experienced in generating the data from the on-station experiment and processing and evaluating the data from the longitudinal study, the modelling component of the project has received only limited testing to date. However, preliminary indications are that it is effective in simulating the impacts of changes in the feed resources base, as described by the models quantitative input data, at least within a limited range of situations. Some problems leading to failure of the model or the generation of implausible results have been experienced with simulations conducted with input scenarios outside this limited range.

Figure 10 illustrates some of the outputs generated by single runs of the model. As the model is largely stochastic in nature, it is more properly used over a number of replications to construct simulation experiments. A simple example of such an experiment is presented below.

Figure 10: *Examples of outputs from single simulation runs of the nutrition - reproduction model.*





A Simple Example of Simulated Impacts of Nutritional Status on Herd Dynamics

This example examines the impact of increasing the level of supplementation during periods of relative feed shortage on nutritional status and reproductive performance. Initial state data for the five cow herd used in the simulation are presented in Table 6 and data describing the two treatments studied in the simulated experiment are shown in Table 7.

Table 6 : *Initial state data for the example simulation.*

Animal	Age	Weight	Pregnant	Lactating
1	1.5	120	✗	✗
2	5.1	280	✗	✗
3	6.3	310	✓	✗
4	9.6	305	✗	✓
5	2.5	210	✓	✗

Table 7: *Forage availability and supplement allocation treatments for the simulated experiment.*

Month	Treatment 1		Treatment 2	
	Forage	Supplement	Forage	Supplement
1	20	4	20	6
2	22.5	4	22.5	6
3	26.25	4	26.25	6
4	37.5	4	37.5	4
5	35	4	35	4
6	28.75	4	28.75	4
7	22.5	4	22.5	6
8	25	4	25	6
9	23.75	4	23.75	6
10	26.25	4	26.25	6
11	28.75	4	28.75	4
12	37.5	4	37.5	4

The model was run ten times over an experimental period of 1000 days[3] for each treatment and produced the results shown in Table 8.

Table 8: *Simulated outcomes in parameters describing nutritional status and reproductive performance of extra feed supplementation during periods of feed shortage*.

	Treatment 1 (n = 10)	Treatment 2 (n = 10)
Post partum weight loss (kg)	22.7 ± 0.83	20.8 ± 0.84
Days in negative energy balance	35.7 ± 1.5	25.8 ± 1.1
Post partum anoestrus interval (days)	42 ± 3.9	38 ± 3.7
Calving interval (days)	366 ± 13.1	361 ± 13.0

At present, it is difficult to provide a broad assessment of the performance of the model without reference to a validation data set. However, it is possible to draw a number of conclusions from these observations.

- The model appears to be relatively insensitive to changes in nutritional inputs at least in terms of their impacts on weight changes and reproductive parameters. An increase of 30 *per cent* in the allocation of supplement in treatment 2 resulted in a reduction of only 10 *per cent* in weight loss post-partum even though days in negative energy balance were reduced by 28 *per cent*. A similar level of improvement in the *post-partum* intervals was also predicted.
- Changes in the *post-partum anoestrus* period appear to be the only component of differences in calving intervals. This is unlikely to reflect the "real-life situation" where other factors are likely to lead to variation in returns to service etc.

On-station Experimentation

At the time of writing, a detailed analysis is not yet available as the delays in implementing the study referred to above have resulted in a number of laggards still participating in the experiment. The information presented below is based on a partial interpretation of results for the first 22 cows to complete the study (Table 9). A more detailed description of the results will be available in a Ph.D. thesis to be completed during 2000.

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[3] - Note: the current version of the model does not allow for the simulation of inter-year effects so the patterns of feed availability effectively repeat from year to year in the simulation.

Table 9: *Summary of means for the performance parameters onserved during each of the three periods of the experiment.*

Parameter	Period	Treatments				
		1	2	3	4	5
	p1	8.26	7.62	8.23	7.51	8.05
Dry matter intake (kg/day)	p2	8.58	11.61	10.71	10.00	10.38
	p3	9.09	8.73	8.24	8.34	9.05
	p1	4.56	5.39	6.06	4.8	4.18
Daily milk yield (litres)	p2	4.13	4.63	5.01	4.17	3.87
	p3	4.87	4.61	5.04	4.51	3.77
	p1	321	336	382	263	232
Total milk yield (litres)	p2	145	163	181	150	193
	p3	360	314	354	323	190
	p1	-35.3	-19.5	-15.2	-10.8	-17.3
Liveweight changes(kg)	p2	-2.2	-10.3	-13.6	-4.0	-2.8
	p3	1.1	-7.6	7.2	1.2	-11.6
	p1	-0.75	-0.38	-0.50	-0.38	-0.25
Change in body condition	p2	0.25	0.25	0.13	0.00	0.25
	p3	0.00	0.00	0.00	0.13	0.17

Dry matter intake.

Higher dry matter intakes during the *spike* feeding period for treatment 2-5 obviously reflected the higher allocations of concentrates (Fig 11). However, there was also some evidence that the increased concentrate feeding on the Spiked treatments also stimulated increased intakes of forages.

Figure 11 : *Record of mean daily dry matter intakes of animals on the five experimental treatments.*

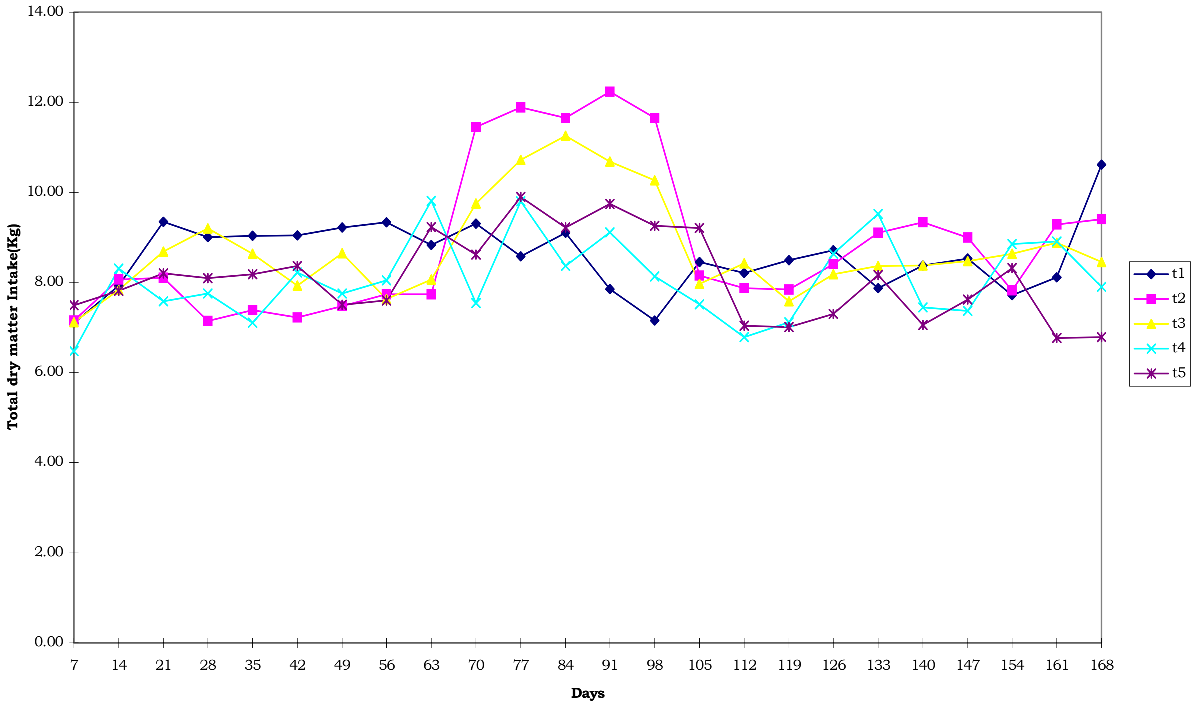


Figure 12: *Record of mean body condition scores of animals on the five experimental treatments.*

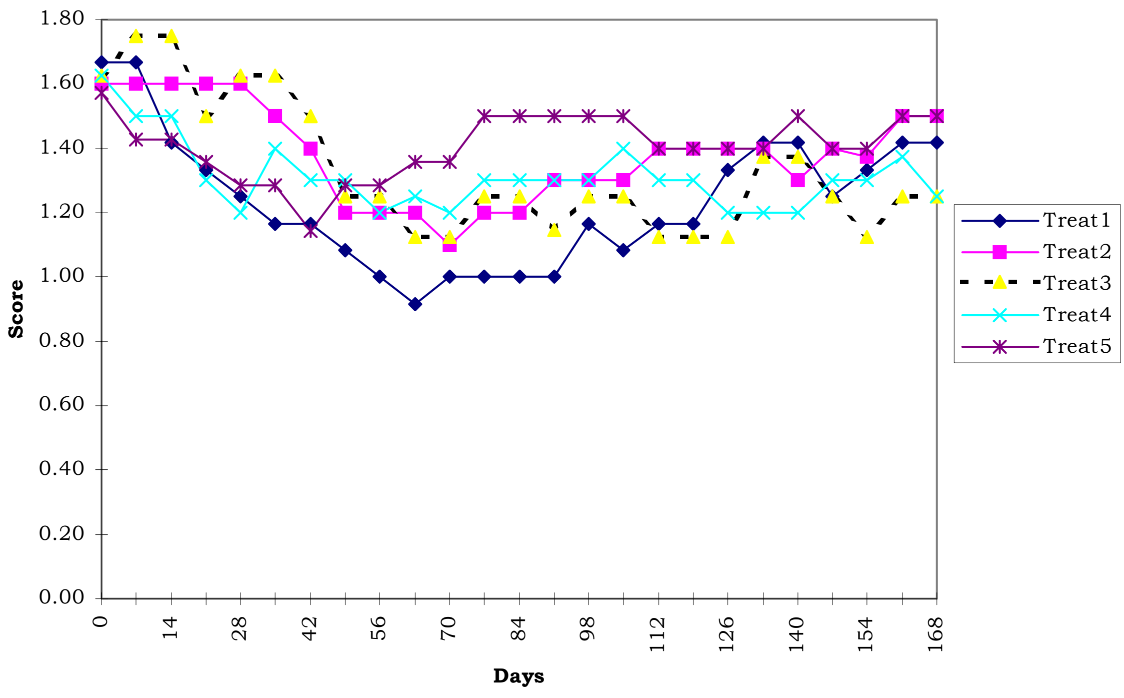


Figure 13: *Record of mean body weights of animals on the five experimental treatments.*

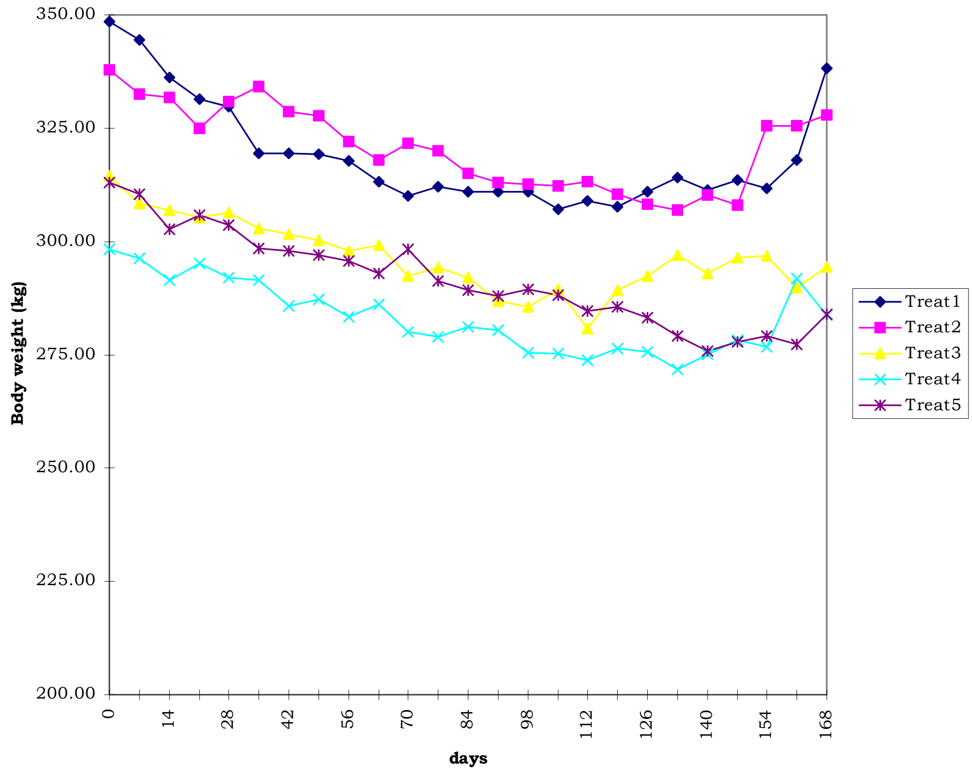
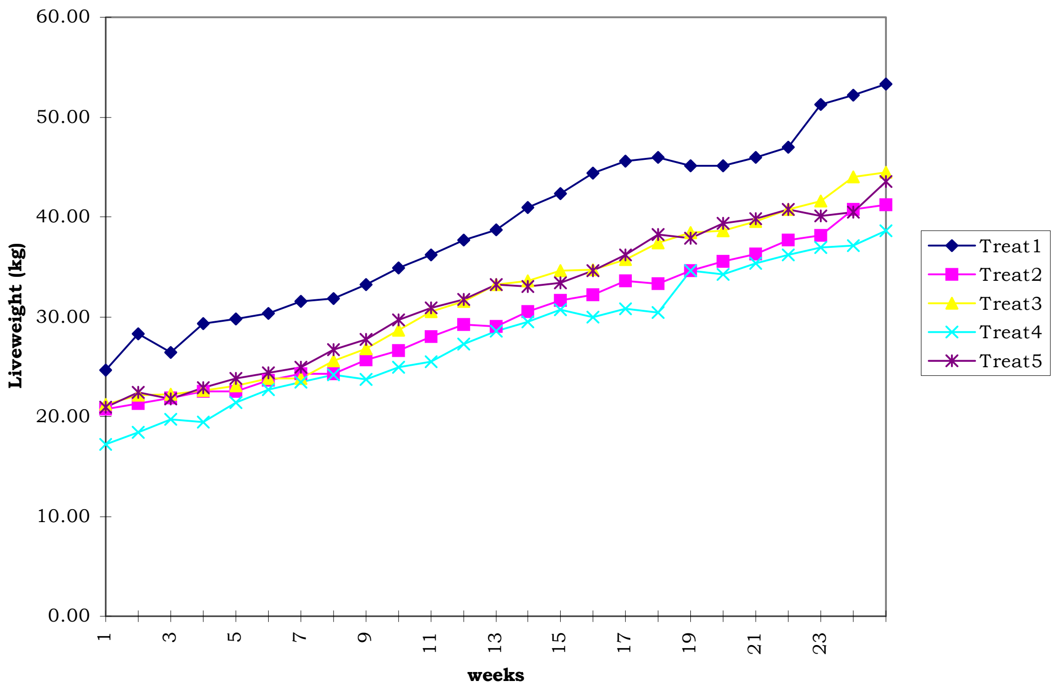


Figure 14: *Record of mean calf body weights of animals on the five experimental treatments.*



Bodyweight and Condition Score

Animals on all treatments lost condition just after calving but started to recover it around the time of the *spike* feeding period (Figure 12). These changes were reflected in reduced rates of bodyweight loss during period 2 and regaining weight during period 3 although there are some inconsistencies between the bodyweight and condition score data collected to date (Figure 13).

Milk Production

Data describing milk yields for the first 22 animals are also inconsistent. Weaning of calves increased milk yields, an effect that was particularly pronounced in animals on the control treatment with no *spike* feeding. In other treatments the effects of *spike* feeding and calf weaning appeared to have a limited impact on milk yields.

Calf Performance

Table 10: *Effects of treatment on birth weights and calf growth rates*.

Treatment	Birth weight (kg)	Growth rate (g/day)	
		Before weaning	After weaning
1	24.7	170	170
2	20.7	100	150
3	21.2	140	130
4	17.2	140	120
5	21.0	150	120

Calves under treatment one had the highest ($p<0.05$) birth weight compared to other treatments (Table 10). This appeared to be was associated with better body condition scores of the dams at calving. Calves on treatment 2 had the slowest growth rates before weaning of all treatments (Figure 14). This may be a result of the relatively low concentrate allocation to the dams over this period.

Conclusions to Date

The results available to date allow few conclusions to be drawn. It would appear that the use of a spike feeding period may have had beneficial effects on body condition score during it. However, by the end of the experimental period, animals on the unspiked treatments had recovered to the same degree. The implications of an earlier recovery of body condition due to spiking for more rapid returns to oestrus are not clear from the data currently available.

Contribution of Outputs

It is anticipated that the project's outputs will contribute at the purpose level by:

1. Clarifying the extent to which individual farms vary in their needs and opportunities with respect to the management of dairy feeding;
2. Providing information on the responsiveness of the reproductive performance small-holder dairy cows to nutritional interventions that can be used in conjunction with 1, above to plan practical feeding strategies;
3. Developing a modelling approach to integrating nutritional and reproductive responses. This could be used in future to extend the utility of simple decision support tools such as DRASTIC, providing practical assistance in maintaining feeding strategies on the ground.

The location of the work in Tanga is likely to be beneficial as the on-going relationship with TDDP offers an effective channel for the transfer of these outputs to client farmers.

Dissemination Activities

Some of the findings of the longitudinal study were discussed during a local workshop held in Tanga during January of 1999. This included their implications for planning dairy feeding strategies. As results from the project's other activities become available, these will be fed into the activities of the Tanga Dairy Development Project through the continuing professional linkages with TLRC staff.

List of Dissemination Outputs

Msangi, B.S.J. Bryant, M.J., Dijkman, J.T. and Thorne, P.J. (1998) Characteristics of small scale dairying in urban, sub-urban and peri-urban areas of coastal Tanzania. In: *Food, Lands and Livelihoods: Setting Agendas for Animal Science*. International Conference held at the KARI Conference Centre, Nairobi, Kenya, 27 - 30 January, 1998. 9.

Further dissemination outputs are anticipated for 2000 including the Ph.D. thesis of the principal investigator in Tanzania and approximately three scientific publications based on the findings of the longitudinal study and the on-station experiment.

Requirements for Further Research and Dissemination

Research

Due to the delays in experienced in executing this project, not all data are available at the time of writing. In particular, progesterone analyses on the samples collected during the on-station experiment are incomplete due to delays in the collaborating institution. Further analysis of data from the longitudinal study and on-station study will be forthcoming by Mid-2000 and will be included and discussed in a Ph.D. thesis to be written by the principal investigator in TLRC.

This project revealed a number of difficulties in executing controlled studies on the scale adopted. The lessons learned are likely to be invaluable but it is suggested that future research should identify more practicable approaches to integrating on-farm and on-station experimentation where issues relating to reproductive performance, that of necessity, requires a long-term approach, need to be identified.

Dissemination

Recommendations on suitable approaches to the dissemination of the project's finding should await the production of the Ph.D. thesis of the Tanzanian principal investigator. It is suggested that there are two main channels for this.

- The existing link with TDDP. The project can feed information into the extension material that is produced routinely by TDDP.
- Project R7431 (Talking Pictures) is developing pictorial extension material for small-scale dairy producers. The project's findings could inform the development of the software required to do this.

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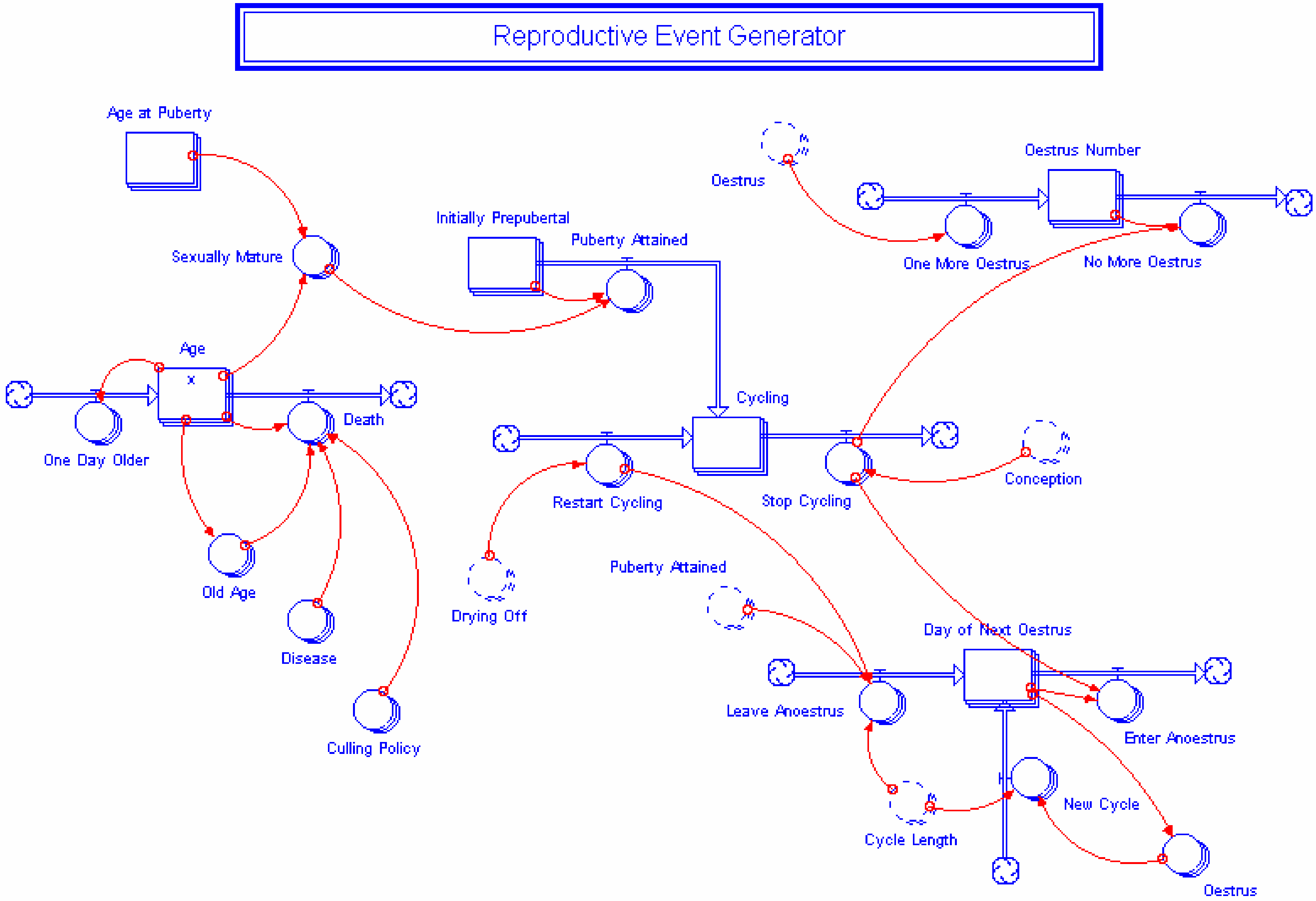
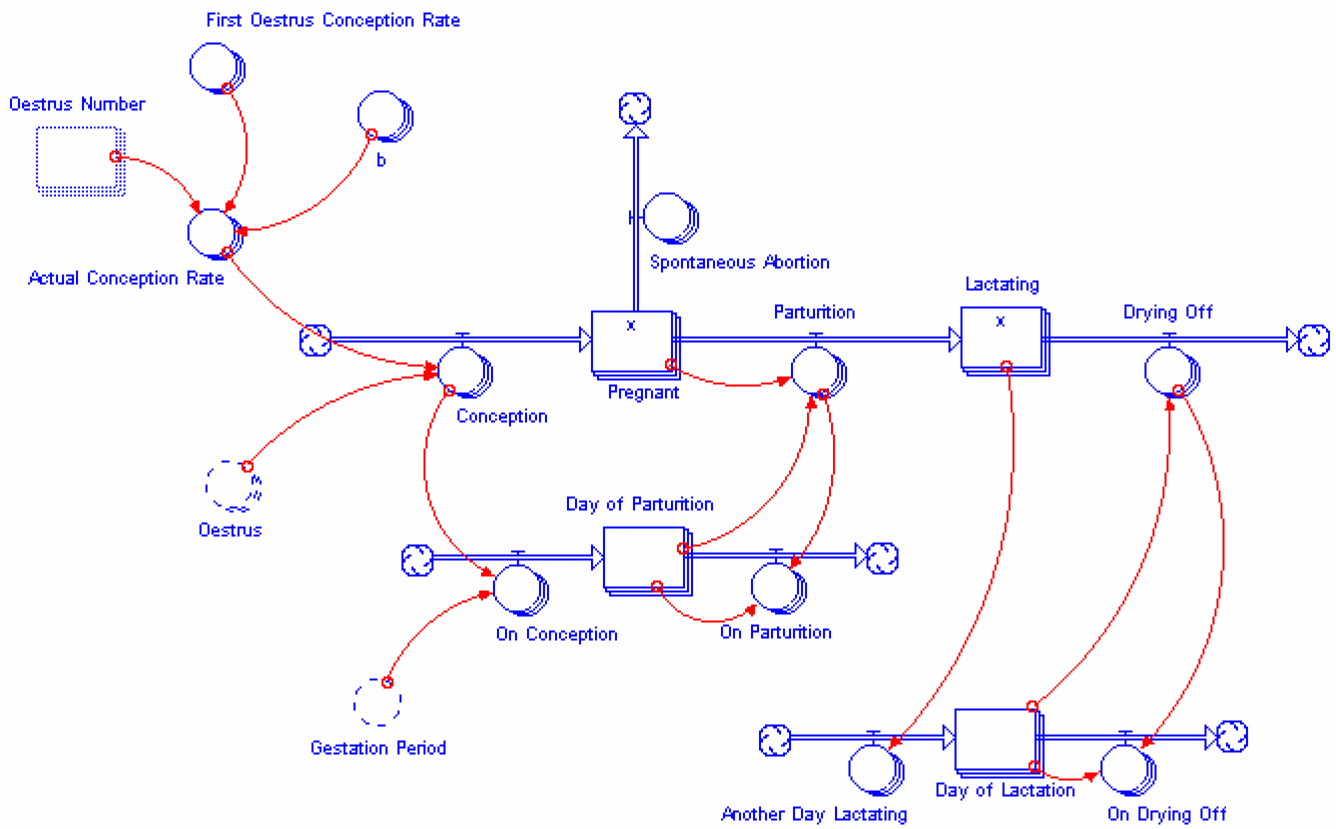
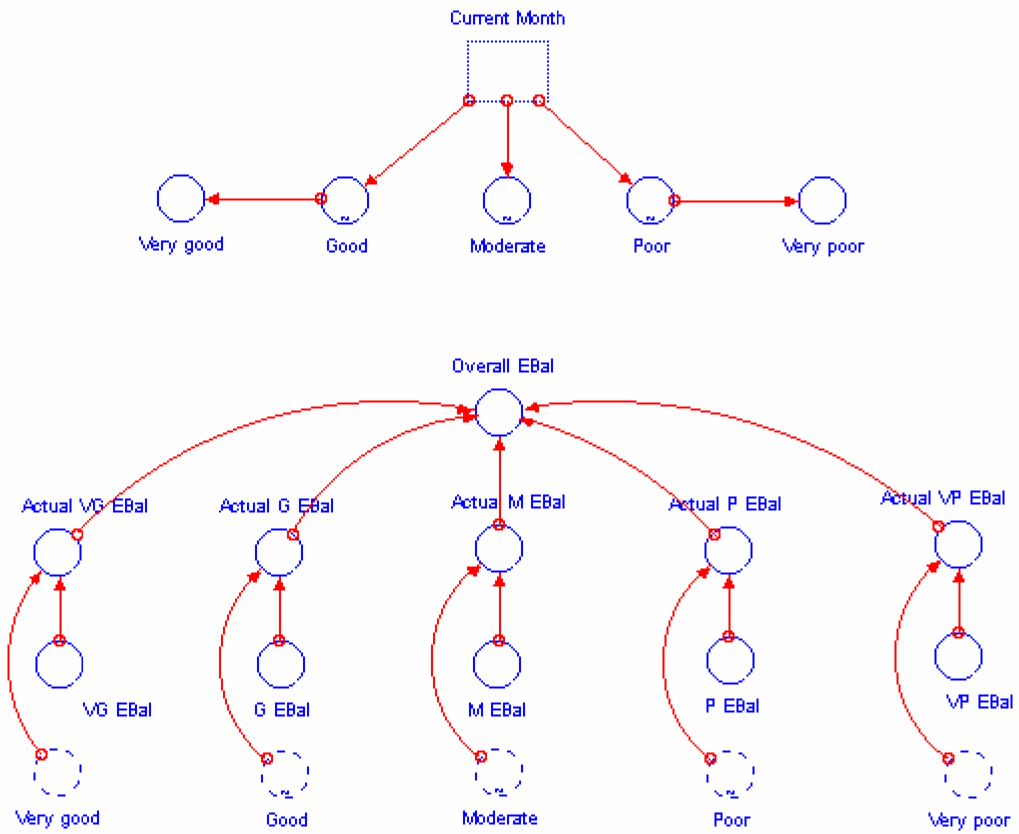
Appendix 1: Summary of the Structure of the Model Simulating the Impacts of Nutrition on Reproductive Performance and Herd Dynamics



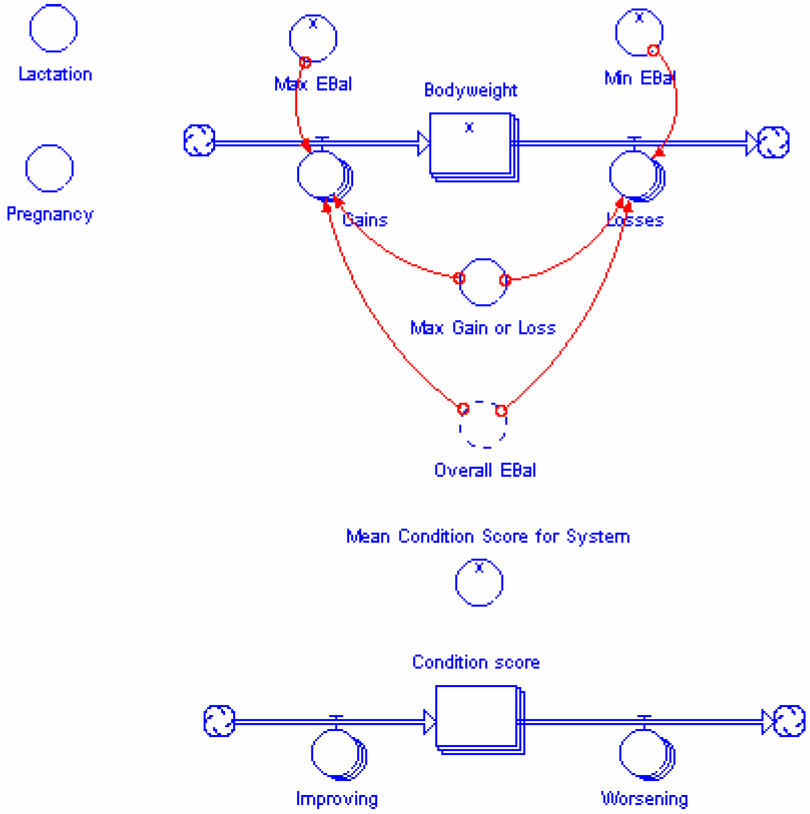
Stages of the Reproductive Cycle

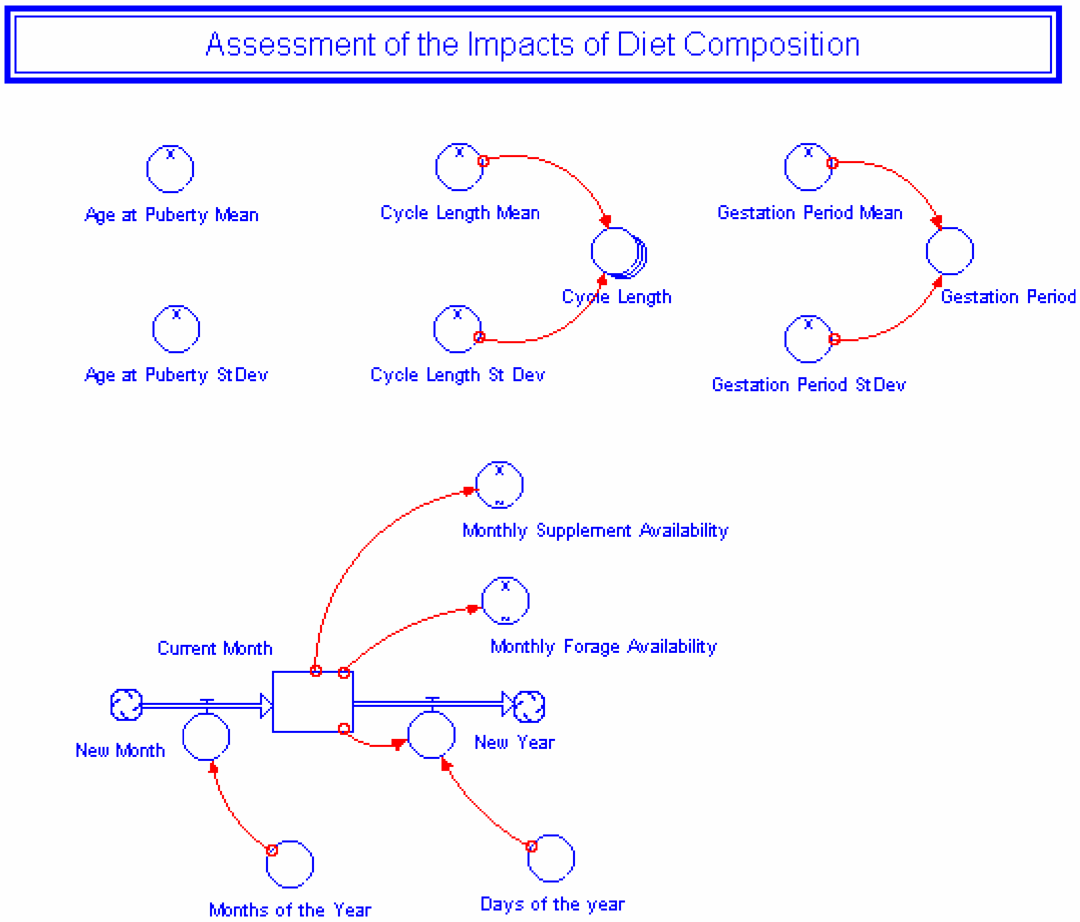


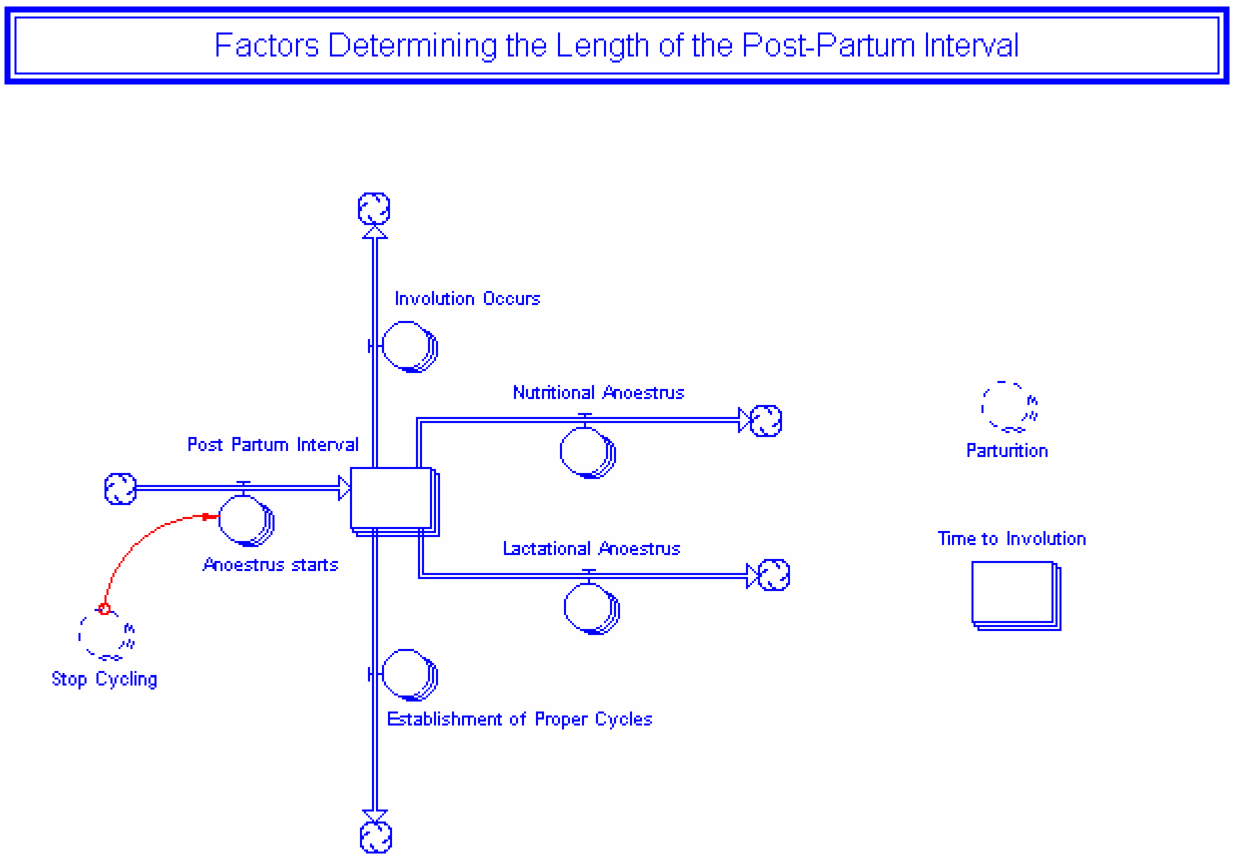
Assessment of Nutritional Status



Energy Balance Calculations




Assessment of the Impacts of Diet Composition
Age at Puberty Mean
Cycle Length Mean
Gestation Period Mean
Cycle Length
Gestation Period
Age at Puberty StDev
Cycle Length St Dev
Gestation Period StDev
Monthly Supplement Availability
Monthly Forage Availability
Current Month
New Month
New Year
Months of the Year
Days of the year



Factors Determining the Length of the Post-Partum Interval
Involution Occurs
Nutritional Anoestrus
Post Partum Interval
Parturition
Anoestrus starts
Lactational Anoestrus
Time to Involution
Stop Cycling
Establishment of Proper Cycles

Annexe 1: Checklist for Enumerators Conducting the Initial Characterisation Study of Farms Participating in the Project's Monitoring Activities.

Code farmer, name, zone (from SDEP database, ensure you have a print-out of the famers' SDEP data when visiting farms!).

Introduction: Explain the purpose of the visit, why you are asking the questions and how the research might be beneficial to the farmer. Also ensure you introduce the fact that you'll be visiting the farmer monthly for monitoring visits.

Demographic information:

- Name, age, gender, marital status, village etc. (Most of these data can be obtained from the SDEP database).

Land resource assessment:

- Availability and use of land (owner or tenant)
- total land available
- access to communal land (used for what, when and why).

Activities:

- cultivation, livestock, other occupations.
- rank activities according to the percentage income of total and importance.

Labour:

- distribution and availability for the various activities
- daily available labour (how many people work on the farm)
- hired (what are the costs) or family labour
- seasonal variations in labour costs, requirements and availability, means of transport.

Livestock enterprise:

- types of animals owned (specify species, classes and numbers)
- purpose of keeping animals (for each species)

- Cattle-feeding regimes (grazing or cut-and -carry, roughage and supplements) - what, how, why and how much are animals fed, are animals fed differentially (especially in relation to different physiological states of cattle)
- seasonal variation in feeds and feeding regime (ask farmer to rank), if possible try to quantify the weight of the measures farmer will give you (a bucket, a bundle etc.)
- sources of feed (bought or cultivated), where, what, why and how do they buy, how are bought feeds transported, seasonal availability of bought feedstuffs
- use of manure and refusals from the cow shed
- problems related to the livestock enterprise (rank in terms of seriousness), seasonal changes in the problems, why does the farmer have these problems and how does s/he solve them
- how does the farmer observe oestrus, what are the signs of oestrus (bull housed or grazed with cows), what course of action is taken if animal is in oestrus, how reliable and available are both Al and bulls, what does the farmer use when and why, costs of these services
- milk yield (SDEP data, ask to see the recording charts!), what proportion of the milk is consumed by the household, what proportion is sold, where and at what price, seasonal changes in price and market, seasonal changes in amounts consumed and sold, do they make any other products from the milk (What, why and when)
- calving interval (SDEP), system of feeding calves (suckling or bucket), changes in this system with time, how is the decision to wean calves made, what else do calves get fed, (why and when).

ALWAYS REMEMBER TO ASK YOURSELF: WHAT, HOW, WHY and WHEN!

Annexe 2: Checklist for Enumerators Conducting the Longitudinal Study of Farms Participating in the Project's Monitoring Activities.

Feeds / feeding Regime

- seasonal variation in feeds and feeding regime (ask farmer to rank), if possible try and quantify the weight of the measures farmer will give you (a bucket, a bundle etc.)
- -sources of feed (bought or cultivated), where, what, why and how do they buy, how are bought feeds transported, seasonal availability of bought feedstuffs

Routine measurement of the following parameters:

- heart girth, withers to tail bone for cows and young stock
- body condition scoring
- milk yield (ask to see SDEP recording chart!)
- number of days to first oestrus (after parturition) (what action was taken if empty animals have been in oestrus)

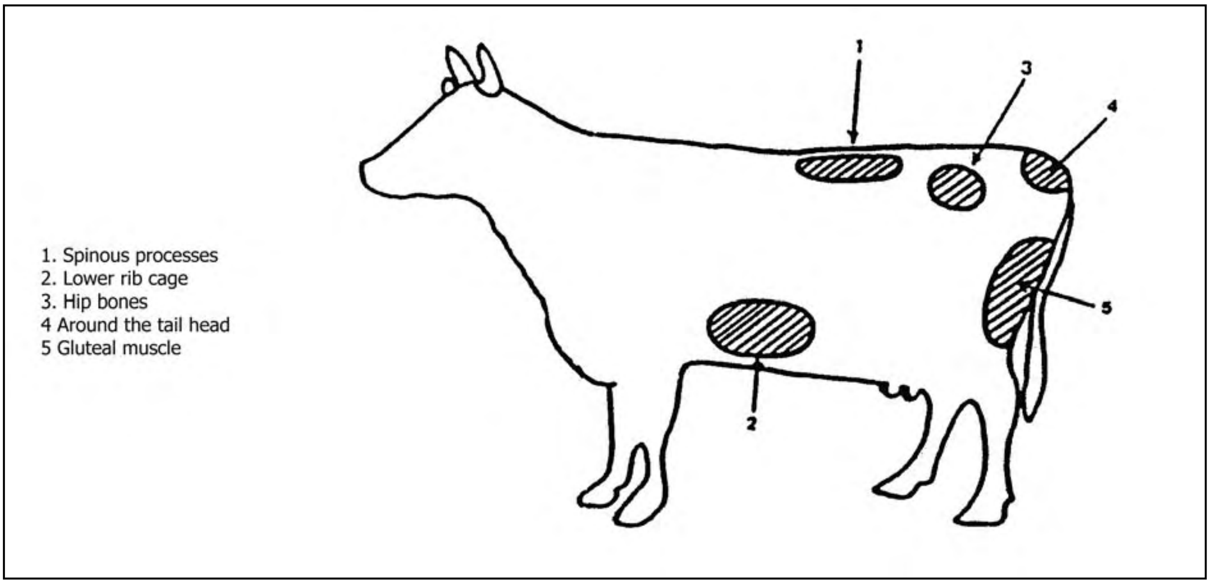
Constraints

- -observation of disease incidence, special attention to ECF, tryps, anaplasmosis, mixed infections etc. If any, what action was taken.
- any other problems (probe!) such as availability of bulls and Al, housing/hygiene (observe), availability of feeds, labour, anything else the farmer wants to talk to you about ....

REMEMBER !!!

- always ask to see SDEP records
- when asking, probe but don't suggest the answers
- Take your time, don't just take your measurements and push-off - Be observant of changes and things going on

Annexe 3: Condition Scoring System used in the longitudinal and On-station Studies



Score 0

Gluteal muscle wasted and has concave appearance. The animal is emaciated and hipbones, tail head, ribs and spinous processes projecting prominently.

Score I

Gluteal muscle wasted and has concave appearance, The hip bones, tail head, ribs and spinous processes less obvious but still feel sharp when touched. No fat around the tail head.

Score 2

Gluteal muscle has a straight appearance. Individual ribs can still be felt with slight hand pressure. There is tissue cover around the tail head and over the hip bones. The spinous processes can be identified individually when touched.

Score 3

Gluteal muscle has a straight appearance. The ribs can not be easily felt. The hip bones are less prominent and feel rounded. The spinous processes cannot be felt even with pressure. The areas on either side of the tail head have a degree of fat cover which can be easily felt.

Score 4

The gluteal muscle bulges and looks convex. The hip bones are covered with tissue and no longer feel hard. The spinous processes cannot be felt even with firm pressure. Folds of fat are beginning to develop over the ribs and thighs of the animal.

Score 5

The gluteal muscle bulges and looks convex. Animal has a blocky appearance. The spinous processes are completely covered by fat and the animals mobility is impaired by the large amount of fat carried.