AN ECONOMIC ANALYSIS OF THE USE OF SUGARCANE FEED FOR MILK PRODUCTION ON SMALL-SCALE FARMS IN TRINIDAD

by

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ABSTRACT

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AN ECONOMIC ANALYSIS OF THE USE OF SUGARCANE FEED FOR MILK PRODUCTION ON SMALL-SCALE FARMS IN TRINIDAD

Two tropical grasses - Pangola (Digitaria decumbens) and Napier (Pennesitum purpureum) were compared to whole sugarcane plant (Saccharum officinarum) as dairy cattle feeds in a dynamic linear programming model.

Numerous uncertainties due to a lack of data in the literature were evaluated by a sensitivity analysis using the multi-period, FIXED-COST model. Estimates of Net Return (NR) to Labor and Management were undertaken to evaluate potential economic performance.

In the formulation of least-cost rations the following factors were found to be of importance: the fixed-costs of sugarcane feeding, the severity of the dry season and its effect on the yield of pasture, the cost of production of forages, and the nutritional coefficients of all feedstuffs.

The inclusion of sugarcane in the least-cost rations increased NR per farm by up to 76%; however, NR per cow was only slightly improved. The former effect was due to a greatly increased stocking rate.

ABREGE

Une analyse economique, sur des fermes Trinidadiens de faible envergure, de l'utilisation de la canne a sucre dans les rations de la vache laitiere

Nous avons compare a la canne a sucre (*Saccharum officinarum*), en tant qu'alimentation pour vaches laitieres dans un modele de programmation lineaire dynamique, deux herbes tropicaux: soit le Pangola (*Digitaria decumbens*) et le Napier (*Pennesitum purpureum*).

Nous avons evalue au moyen d'une analyse de la sensitivite, employant un modele a periodes multiples et a cout fixe, de nombreuses incertitudes provenant d'une manque de donnees publiees dans la litterature sur le sujet. Les estimes de la benefice nette (BN) au main d'oeuvre et au patronat ont ete entrepris afin d'evaluer la performance economique potentielle.

Notre analyse a revele que les facteurs suivants sont d'une plus grande importance dans la formulation des rations a cout minimale: les couts fixes, la severite de la saison des secheresses et son effet sur le rendement des paturages, le cout de production des fourrages et les coefficients nutritionnels de tous les composants alimentaires du regime.

L'incorporation dans les rations a cout minimum de la canne a sucre augmenta la BN par ferme de jusqu'a 76%,

cependant que la benefice nette par tete de troupeau n'etait amelioree que tres peu. Le premier effet serait attribuable surtout a un nombre plus eleve de cheptel par ferme.

DEDICATION

The author wishes to dedicate this work to his wife, Koomok, who silently endured the difficulties incurred in conducting this research and provided the inspiration required for its completion.

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CHAPTER I

INTRODUCTION AND OBJECTIVES

1. An Overview of the Economy of Trinidad and Tobago

The most outstanding economic feature of Trinidad and Tobago (TT) is the duality of its economy. The export and re-export of crude and refined petroleum from domestic and foreign sources respectively constitute by far the major economic activities. The oil industry is a proportionately small employer of people, but the most prolific earner of foreign revenues; the second major industry - sugar - is distinctly the opposite. Since 1973 a dramatic change has occurred in the economy. Prior to 1973 (the year oil prices were increased three-fold) TT was in a position of chronic trade deficits; since then, there have been annual positive trade balances that are likely to continue (3,4).

Although the percentage of total domestic exports from petroleum and its products has only increased from 81 per cent in 1970 to 89 per cent in 1975, the absolute value of this trade has increased from 765 million dollars TT* in

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*One dollar TT is approximately equivalent to $0.40 Canadian.

1970 to 3,409 million in 1975; the most significant change occurring between 1973 and 1974. Over the same period, sugar varied little from its 1975 level of 4.3 per cent of exports, although in terms of value it increased from 42 to 116 million dollars TT (3,5).

Furthermore, domestic oil production increased from 47 million barrels in 1971 to 78 million in 1975, whereas sugar production declined. The sugar sector shows a trend of declining sugar production and exports, and particularly large increases in gross revenues for 1974, 1975 and 1976. However, there is a growing uncertainty for the future of the sugar industry and consideration of the need for crop and/or product diversification. In contrast, oil trade is favourable and likely to continue to increase in volume and value.

Considering domestic livestock production enterprises, only broilers and mutton increased over the 1970-1975 period, specifically, broiler production increased from 2,246,000 birds to 4,350,000 in 1975 (5). This level approximately meets domestic demand, however, most of the poultry feed used is imported. Mutton increased moderately from 81,000 pounds to 117,000 in 1975. The production of eggs, beef, veal and pork actually declined. Increasingly, large quantities of milk, mutton, beef and veal are being imported into

TT to meet demand as can be seen in Appendix I Table 1, while at the same time two important locally produced materials which could be used as feedstuffs for ruminants, urea and molasses, are exported on a large scale.

In order to place this trend of declining overall food production in context, it must be noted that population increased by about 122,000 over the 1970-1975 period according to the estimate of Shillingford (6). Furthermore, it has been estimated that the per cent annual increase in demand for beef, mutton, fresh milk, cheese and butter/margarine over the period 1971-1980 will be respectively 5.9, 4.3, 4.9, 4.8 and 6.5.

If this food deficit could be produced locally, the multiplying effects of this level of production on the farm input supply, farming and agri-business sub-sectors would be expected to provide a large number of employment opportunities - an important consideration in a nation with unemployment estimated to be 15%. The actual earning of foreign exchange through import substitution may be of less importance to TT because of its surplus of "petro-dollars."

Statistics for 1976 (5,3) show that imported dairy products (milk and cream, fresh and otherwise, butter, cheese and curd) were valued at 35 million dollars (TT) or an average of about 30 dollars per capita. Similarly, beef, goat and lamb products valued at 14,500,000 dollars were imported in 1975. These figures are consistent with the trend over the last five years of steadily increasing food imports. Using Shillingford's estimated demand coefficients, it can be estimated that in 1980 the combined beef-and-dairy import bill is likely to be approximately 67,250,000 dollars or about 53 dollars per person at 1975 prices.

This seems to be an insignificant import burden, when considered within the context of the foreign assets held by Trinidad and Tobago. Since 1973, total external assets (the bulk of which are balances with foreign banks in hard international currency) have increased from 120 million dollars (TT) to $1,768 million in 1975 (4). In 1975, Trinidad and Tobago had a net trade deficit in consumer goods of 335,949,600 dollars (non-durable, semi-durable and durable goods) a deficit of 425,922,200 dollars in capital goods, and a surplus of 1,374,547,300 in raw materials (and intermediate goods). The pattern of net trade for 1974 is similar to 1975; however, both these years show net trade surpluses compared to the 1970-1973 period pattern of consistent deficits for total trade. This upturn in the economy is undoubtedly due to the favourable export prices of oil, and secondarily, sugar from time to time.

2. The Problem

In 1976, 51 per cent of total domestic milk was produced by the farms established through the Crown Lands Development Programme (CLDP) now known as the State Lands Development Programme (SLDP). The balance was produced by three government farms, about ten large commercial farms and numerous non-descript small farms, which have one or more cows. However, in the previous years (1975, 1974, 1973, 1972, 1971) output from the SLDP constituted 54 per cent, 67 per cent, 66 per cent, 69 per cent and 73 per cent respectively of total fresh milk production (5). Thus, milk production from the SLDP has declined from more than 2/3's to about 50 per cent of total production. This trend is clearly seen in Appendix I Figure 1 - "Domestic Milk Production by Source."

The problem is that whereas up to 2/3 of domestic milk has been supplied from the SLDP in the recent past, and whereas the number of milking cows and their productivity show a pattern of decline, an investigation of this decline is warranted because of the heavy investment of both the government and farmers. Furthermore, and in direct association with the above, dairy production in the tropics requires analysis and the formulation of alternative systems or subsystems that will assist in the production of dairy products that are increasingly in demand.

3. The SLDP Dairy Farm

In the late 1960's, the government of Trinidad and Tobago secured an international loan of 5 million dollars US to assist in the undertaking of a land settlement scheme encompassing up to 12,000 acres of state land. The scheme would establish family specialist farms producing pork, milk, cocoa-citrus-coffee, tobacco and vegetables (1).

The overall objectives of the programme were to establish viable farms that would provide satisfactory incomes to presently unemployed or underemployed persons, and ease the burden of food importation, which was a serious concern at that time.

In regard to dairy production, 260 farms were to be developed on lots of 15 to 20 acres that were served by an adequate and progressive infra-structure, including an artificial insemination (AI) service. The production system utilized pangola grass (Digitaria decumbens) on a rotational pasture basis with Napier (Elephant) Grass (Pennesitum purpureum) as a forage supplement in the dry season. Protein and energy supplementation was envisaged at milk yields above 1½ gallons (7 kg) per day (1).

The milk would be processed by a large central commercial dairy, privately owned, for domestic consumption using the process of sterilized packaging. Little attention was to be paid to the production of other dairy products.

Farm size was initially fixed at 15 acres (6 ha) but this was subsequently raised to 20 acres (8 ha) on the assumption that this farm size would provide sufficient net income to attract and maintain an average Trinidadian family. It is now an often heard complaint that these farms may not be viable because of insufficient acreage given the extremely poor soil fertility and the deleterious effect of a four-month dry season. This suggests that farm expansion or farm intensification be considered as possible measures to improve the viability of these 260 family dairy farms.

Most farms were fully developed before being handed over to the tenant farmer, who can never acquire ownership of the land, but can eventually through a 15-year mortgage pay-off the house, pens, fences/pastures and stock, which constituted the fully developed farm unit. Other farms were less fully developed on hand-over but the same repayment-ownership principle was adhered to. A system of 25-year land leases has been established at 12 dollars per acre per year to complement the mortgage and enable the farmer to look upon the venture as a long-term investment in dairy farming.

Many casual observers indicate that taxi-drivers, dock-workers, construction workers, the unemployed and others were allocated farms with little or no regard to their farm background, or more importantly, their farm orientation. Informal training programmes were arranged for those requiring tuition in dairy farming. Indeed, it may be that the lack of farm background and orientation is an important reason for the apparent failure of the SLDP dairy farms in general.

In addition, to fixed farm size and the inexperience of the operators, another critical and limiting aspect is the soils on which the farms were sited. Four areas were selected for dairy farms with the largest being Wallerfield (with which this project is mainly concerned). About half of the 260 farms were established at Wallerfield, where the soils are generally recognized to be amongst the poorest soils in terms of fertility and moisture characteristics (2).

4. The Climate of Trinidad and Tobago

Trinidad is a small island of less than 5,000 square kilometers lying about ten miles off the north-east coast of South America. Because it is about $10\frac{1}{2}^{o}$ North of the equator it experiences a hot, humid tropical climate with marked seasonal changes in rainfall, as seen in Appendix I Figure 2. In addition to markedly less total rainfall in the dry season (DS) - January, February, March and April - the number of rainy days is significantly less during this period. The small amount of moisture that does fall during the DS is likely to evaporate rapidly because the mean open-pan evaporation index is 4.8 inches per month. Relative humidity is consistently high throughout the year, but does show some variation with season, as do soil and air temperatures (see Appendix I Table 2). These latter seasonal variations also influence the fluctuating quantity of forage produced on pasture lands, which is a serious limitation in farm planning and management.

5. The Soils of Wallerfield

In describing the soils of Wallerfield, Hardy (2) describes the fine sands of the Aripo Savanna, Piarco, Phoenix, Valencia and Long stretch series as containing scarcely measurable amounts of the essential plant nutrients as revealed by chemical analysis; consequently mobilizable nutrients are almost entirely absent.

In regard to the application of chemical fertilizers, he writes further

> During the dry season in Trinidad, nitrate accumulates in the profile as the soil slowly dries out. Later, when the wet season rains raise the soils content of water to field capacity, the nitrate dissolves and becomes rapidly available to a grass cover, which benefits greatly from the increased nutrient

> supply. As the wet season advances, surplus rain water leaches out any nitrate that is left.

Furthermore, these soils are characterized by a marked restricted internal drainage, a pH of 4.5 or lower, and the facility to dry out in the dry season and to become waterlogged in the wet season. That the SLDP farms have been sited on unsuitable soils is supported by Hardy's soil classification, which indicates that at least 60 per cent (and possibly more) of the land of the 125 dairy farms of Wallerfield is only suitable for "poor pasture and forest." However, Hardy does state that Piarco and Valencia sands can be suitable soils for deep-rooting sugarcane when treated with special management practices. This is supported by information from the Orange Grove Sugar Estate which cultivates sugarcane on Piarco Fine Sands in the general area of the subject dairy farms.

6. Hypotheses

Experiments in Florida, Barbados, Mexico and the Dominican Republic, discussed in Chapter II, have indicated that whole, mature sugarcane plants can be chopped or derinded and fed to ruminants with good to excellent results. Although these works have prompted many specific questions that relate to both the physiology and economics of sugarcane feeding, it is undoubtedly accepted that although sugarcane can supply adequate amounts of both energy and fibre for moderate dairy and beef production, the plant is particularly deficient in protein and other nutrients.

It is hypothesized that a zero-grazing dairy cattle feeding system utilizing sugarcane and protein supplements including urea will result in more consistent performance than a pangola grass pasture system.

It is also hypothesized that local plant by-products can be compounded to provide the additional protein required for moderate milk production from a sugarcane based ration at a lower overall total cost than the existing pangola system and therefore at a greater income[1].

7. Project Objectives

Preliminary observations indicate that the provision of adequate farm-grown feed for even the maintenance of dairy cows at a low level of milk yield is a goal that is not being met by many farmers of the SLDP. Because the majority, if not all, of the stock of the SLDP is purebred or grade Holstein, it seems reasonable to expect yields of at least 600 gallons (2,820 kg or 6,400 lb) per cow milked. In fact,

[1]Zero grazing: the process of man harvesting and transporting forage to cattle.

yields in this range were obtained on the SLDP farms at its earliest stages. However, in order to realize this, supplementary feeding of both protein and energy sources are required. The data therefore suggest that an analysis be undertaken to determine the least-cost complete dairy cattle ration using locally available feedstuffs for moderate levels of production.

As a direct outcome of the least-cost analysis, alternative production systems will be modelled and subsequently analyzed to determine the (optimum) one that is most likely to be successfully implemented by the current SLDP constituents. The final measure of optimality will be the maximization of Net Income (NI) of the systems that fall within the limits of resources.

In summary then, the following are the objectives of the project:

1. to determine the least-cost complete dairy rations for the SLDP under various conditions;
2. to model the various production systems suggested by the least-cost rations;
3. to determine optimality by means of the criteria of maximization of Net Income for each feasible system.

8. Organization of the Work

The major thrust of this project is the formulation of a multi-period least-cost linear programming model to determine the optimal complete feeding programme for small-scale (8 hectares) dairy farms. The model includes a fixed cost feature that allows for the consideration of those production activities that have both variable and fixed costs. This model is described in Chapter III. The determination of costs and technical coefficients is considered and presented in the format of the model in Chapter II. Chapter III describes the methods used. Chapter IV presents the results of the least-cost computer experiments outlining the least-cost feeding systems, their land requirements, and describes what they might actually look like in reality.

The ultimate 'acid-test' of a production system must undoubtedly be the net income it generates for the operator. Chapter IV will present Net Farm Incomes for all feasible systems considered. The availability of land and labour in conjunction with Net Income will indicate optimality; they will be discussed.

Conclusions and recommendations will be drafted on the basis of the foregoing analyses, and presented in Chapter V.

CHAPTER II

TECHNICAL COEFFICIENTS OF PANGOLA AND NAPIER GRASSES, SUGARCANE AND SUPPLEMENTS

1. Sugarcane as Cattle Feed

a. Early Sugarcane Trials

Mead and Noonan (32) have referred to conventional *high-sucrose varieties of sugarcane* as the 'poor man's silo', and recommended it when supplemented with protein for areas of drought, winter pasture shortage, or flood-stricken areas under Australian conditions, presumably because it maintains its high energy value when standing in the field at maturity. Bregger and Kidder (11) indicate that sugarcane was commonly used as a forage in Florida up to the mid-1950's when it was displaced by mechanized grass silage. They also indicated that it was unequalled as a forage in the production of TDN per acre. Prominent amongst this early Florida work are two reports (28,29) which indicate that sugarcane in lieu of improved pastures can be the basis of good cattle performance.

b. Derinded Sugarcane Trials

From 1970-1974 a series of trials was conducted in Barbados as reported by Donefer (17) using derinded/whole sugarcane. A relatively simple, but costly, derinding machine peeled off the outer rind of the sugarcane stalk while leaving the inner sugary pith (Comfith or sugar-fith) suitable for cattle feeding. After preliminary trials it was determined that cane tops, separately chopped, increased voluntary intake when included in the ration at a ratio of 30:70 with derinded stalks.

Over a cattle weight range of 200-1,000 lb, derinded sugarcane with canetops produced superior gains to those on cut pangola grass both fed free choice and supplemented with a protein-mineral-vitamin mixture. Gains of two pounds per day or more were regularly obtained with Holstein bulls which were by-products of the local dairy industry. Further supplementation with corn or molasses resulted in greater gains. Similarly, in various sheep trials, derinded whole sugarcane was superior to pangola grass in terms of weight gains achieved.

Post-slaughter carcass examination and most importantly palatability tests by Barbados hotels indicated that the product was of exceptional quality compared to local beef. There were no extraordinary reports of mortality, illness or management problems associated with these sugarcane diets.

Donefer (17), comparing the performance of dairy cows fed derinded sugarcane plus canetops with protein supplementation to cows fed a standard ration of hay, brewer's grains, with night-grazing, found no differences in milk yield between the experimental and the standard ration in terms of milk yield and quality over 21 weeks. However, intake of sugarcane during this period which corresponded with the wet season was 1.4% of body weight. Another trial (19) lasting 16 weeks and extending over both the dry and wet seasons, showed an average intake of sugarcane of 2.0% with little difference in performance between the sugarcane and standard rations.

In another trial with sheep over 12 consecutive months (18), marked variations in dry matter (DM) content of cane and Relative Intake (RI) were observed, which were closely associated with monthly rainfall. The correlation between DM content and RI was 0.69 indicating an important relationship exists between intake and dry matter and consequently to rainfall. It was noted that total sugars content did not fluctuate very much throughout the year and that periods of reduced intake correspond with the rainy season.

Preston *et al.* (40) compared the performance of 400 Zebu bulls over several months fed whole derinded sugarcane, or whole sugarcane chopped in a simple forage chopper resulting in a particle size of 3-5 mm. Both sugarcane rations were made isonitrogenous by supplementing with rice polishings and a solution of urea in final molasses spread on top of the processed sugarcane. Results indicated that there were no major differences between the two types of processed cane. Because of its lower cost and apparent simplicity the chopped sugarcane was more attractive economically. It is important to note that both feed conversion efficiency and daily gain increased for both types of cane with increasing levels of the rice polishings supplement when fed up to about 1,000 g per head per day.

c. Chopped Sugarcane Trials

Undoubtedly, the bulk of the recent work concerning whole chopped sugarcane has been done by T.R. Preston and his co-workers at Santo Domingo, Dominican Republic and Chetumal, Mexico. This has involved beef, dairy and dual purpose animals up to moderate levels of production. Out of these and the preceding Barbados trials, three key variables have been identified which must be considered in any sugarcane-based feeding system. These are:

- the index of voluntary consumption of dry matter - whole sugarcane (intake as a per cent of animal liveweight)
- the quantity and type of true protein supplement fed
- the level of non-protein nitrogen, usually urea, fed with sugarcane, either as a mixture or separately.

i. Voluntary Consumption of Sugarcane

Prominent publications in the chopped sugarcane feed literature (derived primarily from Preston and his co-workers) which pinpoint the problem of determining the probable voluntary intake of whole mature sugarcane under a variety of conditions are the following:

- Silvestre et al. (45), using two-year old Zebu steers, fed sugarcane ad libitum with a urea-molasses mixture separately found that as the concentration of urea in the molasses increased, the intake of sugarcane increased, DM conversion efficiently improved, and average daily gain (ADG) tended to increase also. A level of 125 g urea/kg molasses produced the highest ADG (0.531 kg), the highest efficiency (9.19 kg DM/kg gain) and an intake of sugarcane DM of 1.9 per cent of body weight. All diets were supplemented with 600 g of cottonseed cake.
- Lopez et al.(31) using Zebu bulls in the rainy season found that at various levels of supplementation with rice polishings and with urea-molasses available separately that sugarcane intake ranged from 1.5 to 1.7 per cent of animal liveweight.
- Silvestre et al. (44) using Zebu steers found sugarcane intake to be 1.7 per cent consistently at various levels of protein supplementation. As expected, ADG's and efficiency increased as protein intake increased.

- Ferreiro <u>et</u> <u>al</u>. (22) found that at levels of urea in molasses of four, six, eight and ten per cent available separately, the voluntary consumption of sugarcane DM increased from 1.1 per cent to 1.4, 1.6 and 1.9 per cent, respectively. All treatments received one kg of rice polishings per head per day. ADG and conversion efficiently both showed a consistent pattern of improvement as sugarcane intake increased.
- Alvarez and Preston (3) in another experiment designed mainly to compare the performance of mature and immature sugarcane found the intake of mature cane (14 months old) to be 1.6 per cent.
- In an experiment in East Africa, Creek <u>et</u> <u>al</u>. (14) reported a voluntary intake of whole chopped sugarcane of 1.4 per cent of body weight. They did not, however, indicate the maturity of the sugarcane, or the season in which it was fed.

In summary then, the sparse literature suggests that the voluntary intake of chopped whole sugarcane (kg sugarcane dry matter/100 kg liveweight) may vary from a high 1.9 per cent in the dry season to a low 1.4 per cent in the wet season.

ii. True Protein Supplementation

Many reports indicate that the crude protein (N x 6.25) content of mature sugarcane is three per cent or lower, thus creating a critical need for the provision of additional protein in the ration. Urea has been used for this purpose, but the intake limitations associated with it necessitate the supply of additional true protein. The following studies indicate that a moderate amount of non-protein nitrogen in the form of urea, in association with a source of true protein, can be effectively used in association with a sugarcane ration.

- Silvestre et al. (43) compared fish meal, meat meal and cottonseed meal at levels of 0, 75, 150 and 225 g/head per day utilizing a basal-ration of chopped sugarcane with urea and ammonium sulphate. In all cases, ADG and conversion efficiency improved as protein supplementation increased. However, at each level, cottonseed was superior to fish meal and fish meal to meat meal.
- Alvarez et al. (5), using sugarcane supplemented with ammonia in molasses found that ADG improved from 36 to 381 g and conversion efficiency from 14.5 to 12.5 when the basal diet was supplemented with 500 g/head/day of rice polishings (as source of protein and energy).
- Preston et al. (40) found that increasing the level of rice polishings fed per head per day to 1,200 g resulted in improved ADG and conversion efficiency. The basal

ration of sugarcane was made iso-nitrogenous by varying the level of urea/molasses mixture added to the sugarcane. The response curve to rice polishings was curvilinear with only small increments in performance beyond 800 g of rice polishings.

- Lopez et al. (31) reported that conversion efficiency improved from 55.9 to 14.8, ADG from 0.09 to 0.585 kg as rice polishings increased from 400 to 1,000 g/head/day. Intake of fresh sugarcane also increased but as a percentage of body weight remained the same at 1.4 per cent.
- Silvestre et al. (45) found that as the level of a 30 per cent true protein supplement increased from 0 to 900 g/head/day in 300 g increments using a basal sugarcane/urea ration, ADG improved from 0.142 to 0.567 kg and conversion from 17.0 to 7.3. Consumption of total dry matter tended to increase also.

Thus, the addition of true protein as a supplement to a sugarcane-based ration is essential if even moderate performances are to be achieved.

iii. Non-Protein Nitrogen (Urea) as a Protein Supplement

Urea, a readily fermentable source of nitrogen, has been used for many years as a less expensive substitute for true protein in ruminant diets (13). The use of urea in sugarcane-based rations, which contain very soluble and readily fermentable disaccharides seems logical and opportune; however, there are certain limitations which must be borne in mind in regard to the effect of urea on voluntary intake, toxicity and its own utilization efficiency.

- Silvestre *et al*. (45) reported that as the concentration of urea(mixed with molasses)as a supplement to sugarcane increased up to 125 g/kg molasses, ADG and conversion efficiency increased. Similarly intake of the urea/molasses mixture decreased and intake of sugarcane increased.
- Montpellier and Preston (33) used urea mixed with final molasses (283 g urea/litre of mixture) at the rate 50 ml of mixture per kg of fresh sugarcane in a digestibility experiment with crossbred steers. This resulted in 14.15 g of urea per kg of fresh sugarcane or a 1.4 per cent level of urea in fresh cane.
- Alvarez *et al*. (4) tested three methods of incorporating urea in a sugarcane ration. The first method utilized an aqueous urea solution that was applied to fresh cane at the level of 1.25 per cent of urea, the second was a 10 per cent urea, water and molasses mixture available separately, the third used a urea/water/molasses mixture (35 kg urea, 30 litres water, 115 kg molasses) added to

cane at 50 ml/kg/ The results showed that adding urea directly to fresh cane at 1.25 per cent produced the lowest cost/kg gain and the best efficiency of conversion.

- Alvarez and Preston (4) used Zebu and Brown Swiss/Zebu steers to test five concentrations of urea in sugarcane from 0 to 15 g/kg cane (1.5%). In addition, 1 kg of rice polishings was fed per day per head. The highest gain and the best efficiency was obtained at the level of 15 g urea/kg cane (fresh). Intake of sugarcane increased as the urea percentage increased accounting for the increased ADG.
- Ferreiro and Preston (22) found that as the level of urea in molasses increased from 4 to 10 per cent, ADG and feed efficiency improved. Similarly, the intake of sugarcane increased.
- Perez-Infante and Garcia-Vila (38,39) have recommended the use of urea at a level of 10 g/kg fresh sugarcane for dairy animals at moderate production levels.

d. The Energy Value of Whole Sugarcane

In the determination of the energy available to the ruminant for maintenance and production, reference is made to those trials only for which apparently adequate protein supplementation has been made.

i. Sugarcane Maturity

The following studies suggest that mature sugarcane results in superior performance compared to immature sugarcane:

- Mature cane produced an ADG of 0.5 kg and a conversion efficiency of 9.48 compared to 0.27 and 19.4 respectively for immature sugarcane in one experiment reported by Alvarez and Preston (3).
- Ferreiro et al. (23) have reported that 'Brix in juice' (a measure common in the sugar industry used to indicate total soluble solids in the cane juice) of mature (19 nodes) sugarcane stalks and tops was 15.23 and 7.22 respectively, whereas for immature (7 nodes) stalk and tops the respective values were 9.63 and 5.61. This may be interpreted to mean that mature cane (approximately 12 months old, but dependent upon variety and local conditions) contains more total soluble sugars and consequently more readily available energy and, therefore, is likely to be more energy concentrated than immature sugarcane. Also as cane matures (reaches its maximum height and number of nodes) its DM content increases and its crude protein content declines.
- Banda and Valdez (10) testing 8 and 16-month old cane

have shown that digestibility, Brix and nitrogen-free extract (soluble carbohydrates) increase with age.

ii. Seasonal Effect on Sugarcane

In the dry season, mature sugarcane is generally accepted to be at its best for cattle feeding because of its higher content of dry matter and its higher content of soluble sugars (mainly sucrose and reducing sugars).

It has been suggested by Alexander (2) that as sugarcane goes into a period of stress such as the dry season it reduces its growth rate, thereby reducing the utilization of sugars for the formation of new tissue and stores more energy as soluble sugars, mainly sucrose. Immature cane in the wet season will grow rapidly by utilizing newly photosynthesized carbohydrate for structural tissues rather than sugar storage. At maturity, and independent of season, it is implied that soluble sugars are approximately constant. Furthermore a trial conducted at the University of the West Indies during the <u>wet season</u> of late 1976 produced ADG's of 0.7 kg in a heterogeneous herd of Holstein bulls. Brix in juice measured about 18 with some small variation throughout the trial. The sugarcane was mature (1 year plus) and on the basis of feed intake the ME value of sugarcane was estimated to be 2.28 Mcals/kg DM (47).

- Ferreiro et al. (23) tested the Brix in juice of sugarcane at Chetumal (Mexico) over a full year and found variations of more than 50 per cent. Brix rose to 19-21 from March until September when it rapidly fell to 11 in October and 9.5 in November thereafter rising to peak values in March. A formula was calculated which relates total sugars in dry matter to Brix in juice; however, the r^2 value is only 54 per cent. This indicates that Brix is not a wholly reliable index of total sugars in sugarcane.
- Alvarez _et al._ (4) state "during the last 28 days of trial the rainy season began and this resulted in a fall in Brix to 10.9." "The sugarcane was therefore supplemented at this time with a mixture of molasses-urea (10%) given free choice in a separate feeder." No data are presented indicating a change in voluntary intake or energy value of the dry matter.
- Lopez _et al._ (31) using two-year old Zebu bulls found marked differences in animal performance between the dry and wet season of the same experiment. Linear regressions relating digestible dry matter intake to ADG for the dry and wet seasons were $Y = 2271 + 0.60x$ ($r^2 = .97$) and $Y = 1153 + 0.31x$ ($r^2 = .99$) respectively. This seems to indicate a significant change in slope,

and may be interpreted as a reduction in ration nutritional value from dry season to wet season. Using these equations it can be estimated that at 0.6 kg ADG about 22 per cent more digestible dry matter is required in the wet season compared to the dry season. It is not clear if this intake is likely to be achieved given the higher moisture content of sugarcane in the wet season which may constitute a bulk restraint to increasing intake. Further work is obviously required in this area but it seems that reduced performance may be experienced in the wet season. The authors state: "the cane quality used in the present experiment did fall quite considerably during the course of the trial since this fall in Brix (soluble solids) was accompanied by a reduction in animal performance." Unfortunately, intake data and energy values for the cane were not presented. It may be that total energy was approximately constant in the sugarcane but that a dilution of solids caused voluntary intake of sugarcane to decline.

e. Technical Coefficients of Sugarcane

i. Sugarcane at Wallerfield (Trinidad)

The Orange Grove National Sugar Estate which harvests sugarcane stalks from Piarco Fine Sand soils near Wallerfield, has indicated that yields of 28, 26, 23 and 15 long tons per acre can be expected for plant cane (year 1) and three subsequent annual ratoon crops for an average of 23 tons/acre over four years. After the third ratoon yield drops off very quickly and it is recommended that cane be replanted. The Seemungal Report (42) indicates that a survey of small cane farmers (10-25 acres) in 1971 reported 30.2, 32.8, 29.4 and 26.3 tons/acre over four years for an average of 29.7 tons/acre/year, this is about 30 per cent higher than the yields expected on the poor soils at Wallerfield. Furthermore, in the same report, a submission by the Trinidad Island-wide Cane Farmer's Association in 1970 estimated national yields as 28.3, 34.5, 30.4 and 25.9 for an average of 29.8 tons/acre over four years.

Green leaves and tops constitute approximately 30 per cent on average of the aerial part of cane, therefore a yield of whole cane (stalk plus tops) of about 32.9 long tons/acre can be expected with a four-year cycle under good management at Wallerfield. This represents an average annual yield of 82.6 metric tonnes(82,600 kg) per hectare of fresh whole sugarcane.

ii. Metabolizable Energy (ME)

In Cuba Perez-Infante and Garcia Vila (39) report cross-bred cows supplemented with urea and 1.84 kg of concentrate (16% CP) produced 9.14 kg milk/cow/day from ground sugarcane in the dry season. They estimate that the energy value of cane "could only be compared to maize forage at silking." In an unpublished paper they have estimated its ME value at 2.6 Mcals/kg DM in the dry season. The Latin American tables of Feed Composition (30) present a range of values of ME with a mean value of 2.3 for fresh whole cane fed to cattle. Creek et al. (4), based on East African work, report an ME value of 2.5 for whole sugarcane. Pate (34) has estimated the ME of sugarcane to be up to 70% TDN or 2.5 Mcals of ME/kg.

Thus, on the basis of these recent reports of work with sugarcane, it seems reasonable to assume an ME value of 2.5 Mcals/kg DM for whole mature sugarcane harvested in the dry season. The ME value of cane in the wet season is as yet ill defined; therefore, it will be tested in the model at a value 20 per cent less than 2.5 as part of a sensitivity analysis.

iii. Digestible Protein

Crude protein in sugarcane is known to be very low (30,35). Thus, a CP value of 2.5 per cent is assumed on a dry matter basis with 50 per cent of this being digestible.

iv. Dry Matter

At approximately 30 per cent dry matter, 82.6 tonnes

(82.600 kg) of whole fresh sugarcane yields 24.8 m tonnes (24,800 kg) of dry matter. Assuming that 20 per cent may be lost in the feeding and processing operations, i.e., 80 per cent utilization, it can be expected that 19.8 m tonnes (19,800 kg) is actually available for consumption by cattle on a per hectare basis. If cane is cut in the wet season rather than the dry season, it seems reasonable to expect the same yield of dry matter per acre, but the actual dry matter content of the whole cane will be less - a water dilution effect simply.

v. Voluntary Intake

The voluntary intake of whole chopped mature sugarcane may vary quite significantly from season to season based upon the few reports available. Therefore, it is assumed to be 1.9% in the dry season and 1.4% in the wet season.

vi. Summary

The following table presents a summary of the assumed coefficients of sugarcane on a per hectare and dry matter basis.

Table II-1
Sugarcane Coefficients

	Season	
	Dry	Wet
Dry Matter Yield - kg/ha	19,600	19,600
ME - Mcals/kg	49,000*	49,000*
		39,200**
DP - kg/ha	245	245
Voluntary Intake (% of body wt)	1.9	1.4

*An ME value of 2.5 Mcals/kg of sugarcane dry matter.
**An ME value of 2.0 Mcals/kg of sugarcane dry matter.

2. Pangola Grass Pasture

a. Influence of Moisture

In many areas of the tropics there is a pronounced seasonal pattern of rainfall, which results usually in a 'dry season' during which there is little or no precipitation. At this time, it is also likely that soil moisture evaporation will be high. These two factors in conjunction often lead to the rapid dehydration of the soil and resultant plant moisture stress. This is the situation found in most of the Caribbean Islands; however, there is some variation in the length and severity of the dry season from island to island (12,38,41,48,49,50).

Stobbs (46) has outlined the general effects of seasonal dryness on animal performance as being comprised of two distinct phases. The first is one of gain in liveweight (in the case of beef cattle) during the wet season, when soil moisture is abundant and grass and/or legume growth prolific. The second is one of animal liveweight loss, most likely due to the fact that moisture is a major limiting nutrient for plant growth, and in these dry periods, forage growth is greatly reduced, thereby, making less nutrients available per unit of land per day. At any given stocking rate, this situation results in either a forage surplus in the wet season or a deficit in the dry season. This fluctuation greatly complicates livestock production because it is impossible for a cattleman to increase or decrease herd size rapidly.

To overcome the weight loss characteristic of the dry season, supplementary feeding with concentrates and/or forage such as Elephant (Napier) grass is common. The preservation of surplus forage as hay or silage has not found wide acceptance in the tropics and Trinidad in particular for a variety of reasons: high capital cost, large percentage loss of nutrient value, difficulty in processing and high risk.

In regard to beef cattle, the phenomenon of 'compensatory growth' can often be observed after the onset of the rainy season when grass is abundant and highly nutritious (46). However, for dairy cattle it is essential that the plane of nutrition be consistently high from several weeks before calving to near the end of the lactation period. Any break in this feeding regime is likely to result in a marked decline in milk yields from which the cow is not likely to recover if nutrition improves. Thus, 'compensatory milk yield' is not found in lactating cattle as a response to markedly improving nutrition after a period of inadequate nutrition. It is this fact which makes it absolutely essential that the dairyman make adequate provision for an unbroken plane of feeding at a high level for the 10-month period that approximates an average lactation.

b. Influence of Nitrogen

In addition to moisture, nitrogen, which can be readily broadcast as chemical fertilizer, is a major factor influencing forage yield. Vincente-Chandler in Puerto Rico (49), and others in Trinidad (9,25) have observed marked increases in both total dry matter yield per hectare and total protein with increasing applications of nitrogen fertilizer to improved tropical pastures, such as Pangola and Napier grasses. Rates of up to 800 pounds of nitrogen per acre per year in several applications have been used, although the optimum level will depend upon the cost of nitrogen and its application and the value of added output. In Trinidad, it is a standard practice to apply 1,200 lb per acre per year in three equal applications of a 15-10-5 fertilizer. This represents about 200 lb of N/acre/year.

However, there is an interaction between moisture and nitrogen in regard to forage yield, with a higher yield response to nitrogen being obtained in the wet season of generally fast growth (49).

c. Pasture Management Practices in Trinidad

Vincente-Chandler et al. (49) have described other factors such as fertilization with phosphorus, potassium, magnesium and other minerals, the effects of species differences, method of harvest, frequency of harvest which affect forage quality and yield. However, it is apparent that the combination of moisture and nitrogen is the major factor that must be considered in the management of pastures.

In reference to Trinidad, management practices for Pangola are designed to ensure optimum forage yield from Pangola pastures. These are summarized below.

Table II-2

Schedule for Trinidad Pastures
N-P-K Fertilizer (15-10-5)

Source					
Daily Bulletin(16)		Crop Bulletin(15)		Harland Society(21)	
Time	Application lb/acre	Time	Application lb/acre	Time	Application lb/acre
July-Aug.	336	Aug.-Sept.	400	Aug.-Sept.	336
Sept.-Nov.	448	Nov.-Dec.	400	Nov.-Dec.	336
Dec.-Feb.	500	May-June	400	May-June	448
Graze each paddock for 2-3 days every 3-4 weeks		Graze each paddock 2-3 days, then rest for 4-5 weeks		Graze each paddock 4-6 days, then rest for 4-6 weeks	

In all cases, the grazing intensity recommendation is dependent upon season and condition of pasture. The recommendations for Napier grass are essentially the same as for Pangola except for cutting instead of grazing management. Most operators use Napier grass as a dry season forage supplement to Pangola pasture.

d. Yield of Wallerfield Pastures

Experiments in Cuba (50), Puerto Rico (49) and Guadeloupe (41) indicate that the yield of dry matter (DM) per hectare per day (growth rate) shows a marked decline during the dry season, which each island experiences annually. Data presented earlier have led to the conclusion which has been confirmed by observation during the author's residence in Trinidad during the Sept.'76 - August '77 period, that Trinidad experiences an annual dry season (the four-month period of January - April inclusive, on average) that has serious effects on forage yield. The extent of this negative effect is now the object of the following discussion.

Fletcher (25) in comparing the yields of Pangola grass on Piarco Fine Sands at Wallerfield reported increases in dry matter/ha with increasing levels of N. Furthermore, yield sharply declined on the second harvest after the application of fertilizer compared to the first post-application harvest. Using the results of Fletcher the following table can be derived representing growth rates for the wet and dry season of the experiment.

Table II-3
Pangola Yield (Fletcher)
At N Level of 224 kg/N/ha/year*
(equivalent to 200 lb/acre/year)

	Season			
	Wet		Dry	
Harvest Number	4	5	6	7
Date	10 Oct.,1969	21 Nov.,1969	13 Feb.,1970	16 April,1970
Days of Growth	31	42	84	63
Yield of Pangola DM/ha/day	50.3	22.1	37.3	16.9
Mean	36.2		27.1	

*Nitrogen applied on 13 Sept. and 12 January.

The decline in growth rate from the wet season to the dry season was 25 per cent. However, during the test period, the dry season was unusually mild as indicated by rainfall records from the Central Experimental Station (Centeno) only six miles from the trial site. Dry season rainfall was: January - 4.82 inches, February - 2.43 inches, March - 1.09 inches, April - 2.71 inches. Thus, it may be reasonably concluded that the growth rate of Pangola at Wallerfield declines by at least 25 per cent in a mild dry season and a rate of growth of 36 kg DM per hectare per day may be expected during the wet season when fertilizer is applied in accordance with recommended practices.

Using Pangola grass at Wallerfield, Byam (12) applied irrigation and nitrogen treatments to determine grass yield; however, nitrogen was applied after each harvest of six weeks growth - a procedure which deviates from that recommended for Wallerfield dairy farmers. During the mild dry season of 1972, a growth rate of 47.6 kg DM/ha/day was recorded. However, during the dry season of 1973, which was very severe, a rate of 20.9 was obtained. These plots received N at the recommended application level and no irrigation. Rainfall values for the four-month January-April dry season of 1972 and 1973 were 7.29, 2.88, 6.05, 2.73 and 1.22, 1.79, 0.43 and 1.91, respectively. The use of irrigation water during the mild dry season of 1972 did not improve yields; however, in 1973, irrigation restored growth to the rate of 44.8 kg/ha/day. The higher yields of Byam (compared to Fletcher) can be explained, at least in part, as being due to the application of nitrogen after each harvest.

In summary then, it may be said that the effect of the dry season on grass growth is variable, depending in large part on the severity of the dry season. In a severe dry season, grass growth rate can be at least 58 per cent less than that in the wet season. However, it seems likely that if recommended fertilization practices are observed, the reduction in growth will be even greater.

In a second study using irrigation on Pangola grass at Wallerfield, Dookeran (20) used 1,200 lb of a 15-10-5 (NPK) fertilizer per acre per year with equal applications <u>after each harvest</u> of eight weeks regrowth. He found a growth rate of 54.4 kg DM/ha/day for the dry season compared to 78.7 for the wet season. The application of just four inches of irrigation water in the dry season raised growth rate to 70.0 kg/ha/day, furthermore, six inches of water increased output to 110.8 kg/ha/day. The increased growth rates in this trial compared to both Byam and Fletcher may be due to the combined effects of increased harvest interval and the application of NPK fertilizer after each eight-week harvest.

Further documented support for the notion of inhibited grass growth in Trinidad in the dry season is provided by Patterson (36,37) who indicated that the seasonal variation in yield and composition of all these fodder crops (Guatamala grass, Para grass, Elephant grass, Guinea grass) is very marked. In general, in the dry season the grass yield of herbage will be greatly reduced, the actual percentage varying with the variety.

Unsworth, Campbell and Butterworth (48) in a report on the problem of fluctuating fodder supply in Trinidad state that "during the dry season, an acre of Pangola grass supported two cows, in June and July, it supported four cows, and later in the year an estimate somewhere in between the two" at the government experimental station at Centeno. However, they do not indicate the level of milk production obtained or the management and fertilization practices applied.

Two separate trials conducted at Wallerfield designed to determine the yield of Pangola grass in the dry season (7) report yields of up to 4,000 lb DM/acre during the dry season at 450 lb N/acre applied in December and 3,000 lb DM/acre at 300 lb N/acre applied in December. These yields transform to daily growth rates of 36.8 kg DM/ha/day and 27.6 kg/ha/day respectively assuming the dry season to be four months (122 days). Three cuts were made during the dry season of both trials. It is to be noted that both fertilizer levels exceed those recommended (1,200 lb/acre/year of 15-10-5).

It is apparent then that the determination of the expected yield of Pangola dry matter per hectare per day will depend upon the degree of moisture stress, the level and frequency of fertilizer application and the length of the harvest interval. In regard to Wallerfield the following table summarizes the available data.

Table II-4

Pangola DM/kg/ha/day

Reference		Season Dry	Wet	Harvest Interval	Fertilizer level and frequency (N/ha/year)
Fletcher(25)		27.1	36.2	10 wks in DS 5 wks in WS	224 kg in 3 applications
Byam(12)					
	a)	47.6	49.2	6 wks	225 kg after each harvest
	b)	20.9	-		
Dookeran(20)					
	a)	54.4	78.7	8 wks	202 kg after each harvest
	b)	70.0*	-	8 wks	
(7)	a)	36.8	-	approx.6 wks	450 lb N/acre once in December
	b)	27.6	-	approx.6 wks	300 lb N/acre once in December

*With the application of four inches of irrigation water per month.

The table clearly indicates that yield is variable, however only the data of Fletcher and (7) correspond to the recommended fertilizing practice. The data of Byam and Dookeran may be expected to produce yields greater than might be expected under normal practices since nitrogen can be as important a stimulant for grass growth as moisture under some conditions. Excluding the value of 70.0 (irrigated in dry season) a mean growth rate of about 35 kg DM/ha/day may be expected. Since this includes the inflated values of 47.6

and 54.4, it seems reasonable to consider the maximum growth rate of Pangola on average in the dry season to be about 35 kg DM/ha/day. This is reinforced by realizing that the values of 36.8 and 27.6 (reference 8) both received N applications considerably in excess of the recommended practice.

Personal communications with Dr. K.A.E. Archibald of UWI, Dr. P. Osuji of CARDI and Dr. F. Gumbs, also of UWI, and consideration of the literature led to the conclusion that an average dry season will depress Pangola growth rate by 50 per cent or more under normal management practices. The mean value obtained from the sparse literature for wet season growth is 55 kg/ha/day. This should also be considered a maximum because of the application of fertilizer after each harvest in some experiments. In conclusion, it may be reasonable to consider a range of values for growth rate of Pangola until definitive experiments are conducted under management conditions at Wallerfield that correspond closely with the recommended practices.

Table II-5
Range of Growth Rates of Pangola Pasture by Season

	Season: Dry (kg DM/ha/day)	Season: Wet (kg DM/ha/day)
Minimum Rate	20	36
Maximum Rate	35	55

The upper limit growth rate for Pangola in the dry season is supported by data presented by Vincente-Chandler et al. (49) of Puerto Rico. They report a rate of 44.9 kg/ha/day for Pangola intensively managed (4000 lbs of 15-10-5/acre/year) on deep soils in the dry season. However, the data are from the humid region where the dry season is particularly mild compared to Trinidad. Furthermore, this rate is reduced to 35.3 kg/ha/day when corrected for the high level of fertilizer applied. Using additional data supplied by these authors, the mean of three growth rates for the wet season is 55, a value which must also be considered as an upper limit because of the application of fertilizer after each cutting.

The yields reported above are for mechanically cut grass to a uniform height of about 5 cm. Under grazing conditions such as those at Wallerfield, it is reasonable to expect a 60 per cent utilization of total available grass by grazing (1). This is consistent with the Puerto Rican data of Vincente-Chandler (49). At a higher utilization rate overgrazing may result with consequent negative effects on pasture vitality.

Archibald and Osuji (8,9) found crude protein values of 10.9 per cent of dry matter and 6.2 per cent for 12 tropical grasses cut at four and eight weeks of regrowth. On the basis of this report and those of Vincente-Chandler (49) it is assumed that under Wallerfield conditions a CP per cent of eight per cent can be achieved throughout the year on average. Furthermore, the Latin American tables of Feed Composition (30) report a mean value for Metabolizable Energy of 1.98 Mcals/kg of dry matter. Archibald and Osuji (8) have estimated the ME value of Pangola to be 2.25 and 1.64 at four and eight weeks of growth respectively. On this basis, it is assumed at the ME value of grazed Pangola can average 1.9 under Wallerfield conditions.

e. Technical Coefficients of Pangola Pasture

The following table summarizes the hypothesized output of one hectare of grazed Pangola grass under varying Wallerfield conditions and the noted assumptions.

3. Napier Grass

a. Yield at Wallerfield

Napier grass also commonly known as Elephant grass (Pennesitum purpureum) is a grass of importance at Wallerfield because it is utilized as a forage supplement to Pangola pasture during the dry season. It is only minimally utilized during the wet season.

Fletcher (25) conducted trials at Wallerfield with

Table II-6
Coefficients of Pangola Grass

Factor	Season: Dry — Value/ha	Dry — Assumptions	Wet — Value/ha	Wet — Assumptions
A. Dry Matter	35 kg/day x 122 days=4270 kg x 0.6=2562 kg	growth rate=35 kg/ha/day 60% utilization	55 kg/day x 122 days=6710 kg x 0.6=4026 kg	growth rate=55 kg/ha/day 60% utilization
Metabolizable Energy	2562 kg x 1.9 Mcals/kg= 4868 Mcals	ME=1.9 Mcals/kg DM	4026 kg x 1.9 Mcals/kg= 7649 Mcals	ME=1.90 Mcals/kg
Digestible Protein	2562 kg x 0.08 =205 kg 205 kg x 0.60 =123 kg	8% CP 60% Digestibility	4026 kg x 0.08 =322 kg x 0.6 =193 kg	8% CP 60% Digestibility
B. Dry Matter	20 kg/day x 122 days=2440 kg x 0.6=1464 kg	growth rate=20 kg/ha/day 60% utilization		
Metabolizable Energy	1464 kg x 1.9 Mcals/kg= 2782 Mcals	ME=1.9 Mcals/kg		
Digestible Protein	1464 x 0.08= 195 kg x 0.60 = 70 kg	8% CP 60% Digestibility		

Elephant grass, but did not observe any decline in yield (growth rate) during the dry season. However, Patterson (36) states that although it is more resistant to drought than other conventional grasses, it does produce less during the dry season (DS). Fletcher's work indicates a growth rate of 35 kg DM/ha/day in the DS which is about 30 per cent greater than Fletcher's derived rate for Pangola. Patterson (37) harvested Elephant grass on better quality soil - River Estate Loam - from January-December 1932 and found a growth rate of 43.3 kg DM/ha/day over this period which included the dry and wet seasons when cut at eight-week intervals. Crude protein averaged 7.4 per cent of dry matter. Furthermore, in an experiment in the dry season of 1966 at Wallerfield, Elephant grass was fertilized with NPK at the rate of 150 lb N applied in January with two harvests at eight-week intervals. The average growth rate was 42 kg/ha/day (7).

Using the above as a guide, and assuming the growth rate of Napier to be about 30 per cent greater than Pangola in the dry season, a rate of 46 kg DM/ha/day (35 x 130%) can be expected from one hectare of Napier grass on average in the dry season by cutting management.

b. Technical Coefficients of Napier Grass

Because Napier grass is generally cut at about eight weeks regrowth and carried to the cattle (zero-grazed), its utilization is assumed to be 80 per cent of total yield - the 20 per cent loss being due to the cutting and carrying operations mainly. It is assumed that at eight weeks Napier grass contains 1.8 Mcals/kg DM of ME, furthermore, a CP percentage of eight is assumed of which 60 per cent is digestible. The following table summarizes the Coefficients of Napier grass on a per hectare basis in the dry season at Wallerfield.

Table II-7
Coefficients of Napier Grass

Factor	Value	Assumption
Dry Matter	122 days x 46 kg/day=5615 kg 5612 x 0.80 = 4490 kg	Growth rate of 46 kg DM/ha/day and 80% utilization
ME	4490 kg x 1.9 Mcals/kg=8531 Mcals	1.9 Mcals of ME/kg dry matter
DP	4490 kg x 8% x 60% = 216 kg	8% crude protein (DM) with 60% digestibility

4. Protein Supplements

a. Technical Coefficients and Costs

The coefficients of the <u>available</u> concentrate materials are derived from three prominent publications in the area

(26,27,30); where serious discrepancies exist between observations in regard to a particular parameter, an average value is used. However, it is fully recognized that complete analyses of indigenous materials would present a more accurate profile of coefficients for the local Trinidad situation. Moreover, it is unlikely that major distortions in the formulation of the least-cost ration will result because of the procedure used.

Table II-8

Coefficients of Supplements and Costs on a per kg of dry matter basis (DNB)

	Urea	Coconut Meal	Citrus Meal	Wheat Middl -ings	Commer -cial Dairy Ration	Spent Brewer's Grains	Molasses
ME (Mcals)	0.0	2.88	2.17	2.74	2.80	2.68	3.40
DP (kg)	2.88	0.22	0.05	0.125	0.140	0.160	0.026
Cost (DMB)	0.66	0.25	0.20	0.15	0.47	0.24	0.17

CHAPTER III

METHODOLOGY AND COSTS

1. Sources of Information

This chapter's objective is to develop and describe the methods used in the overall analysis, which include budgetting, linear programming, calculation of net returns and sensitivity analysis. Wherever possible the most up-to-date costs were used; sources included commercial suppliers and the Manager of the UWI Field Station. However, the costs used were those in effect in the second quarter of 1977. Mr. A. Fortuna of the Orange Grove Sugar Factory provided information on the production of sugarcane on Piarco Fine Sand soils. Other data were developed from the literature, experience and observation and exchanges with colleagues of the various departments of the UWI.

2. Nutrient Requirements

a. The Milk Cow Unit (MCU)

To determine the theoretical total feed requirements of a dairy enterprise, an aggregate called the Milk Cow Unit (MCU) is defined, which represents one milk cow and her followers, which are raised as herd replacements. The following assumptions on which the MCU is based are designed to reflect the situation at Wallerfield under average management conditions: (a) bull calves are sold as soon as possible after birth, (b) the calf crop is 60%, and (c) culling is at the rate of 20%.

The Milk Cow Unit is assumed to be comprised of the following:

- the mature milk cow averaging 450 kg liveweight
- 0.3 weaned heifer calves, averaging 100 kg liveweight, less than one year old
- 0.3 heifer yearlings, averaging 200 kg, less than two years old
- 0.2 replacement heifers, averaging 300 kg, over two years old.

It may be easier to envisage the MCU on the basis of a properly managed herd of 10 milk cows. On average in such a herd, there would be three heifer calves, three heifer yearlings and two replacement heifers. This would provide for the replacement of two culled cows per year. Three bull calves would be sold. Mortality accounts for the loss of one heifer at some point during the three-year period required to raise a replacement heifer. The total feed required per MCU is the sum of the individual requirements for each category of follower plus that for the milk cow at a given level of milk production and average daily gain in weight (ADG).

b. Ration Nutrient Criteria

On the basis of the nutrient requirements published by Church (8), the following criteria have been selected for inclusion in the least-cost complete ration formulation linear programme:

- a minimum quantity of Metabolizable Energy (ME) as measured in MegaCalories (MCals)
- a minimum quantity of Digestible Crude Protein (DP) as measured in Kilograms (kg)
- a maximum restriction on the quantity of urea
- a maximum restriction on the amount of dry matter than can be readily consumed per MCU per day (DMI)
- a minimum restriction on the amount of dry matter of the complete ration that must come from forage material, i.e. sugarcane, and/or Napier grass and/or Pangola grass.

c. The Milk Cow

On the basis of observation and the literature (see Chapter I) 600 gallons of whole milk per cow per year is considered to be a good yield for dairy cows under Wallerfield conditions. The relative lack of forage in the dry season and the high moisture content of forages in the wet season (which may limit dry matter intake) and other factors preclude the animal performances commonly attained in temperate environments. Nevertheless, this yield represents the yield found at Wallerfield and/or thought to be obtainable given the appropriate feed and managerial inputs. On the assumption that the year is partitioned into three equal periods (1, 2, 3) of 122 days each, 600 gallons of milk represents, over a 300-day lactation, an average daily yield of 9.4 kg of milk.

The nutrient requirements per cow are outlined in Appendix I Table 3A, which exceeds by 10% the NRC requirements.

d. The Followers

The nutrient requirements of the three categories of followers of the MCU are calculated on the assumption that the average gain is 0.25 kg liveweight per day and these are outlined in Appendix I Table 3B.

e. Feed Requirements Per MCU

The sum of the individual requirements for one milk cow and the heifers is the total feed required per day for 1

MCU. The following table indicates the needs of one MCU per 122-day period based upon the requirements of the followers and the cow.

Table III-1

Total Nutrient Requirements for One (1) MCU at 9.4 kg milk/day for any 122 Day Period

Nutrient	Milking Cow	Heifers	Total per Day	Days of Period	Total per Period
ME	24.5	8.1	32.6	122	3977
DP	0.799	0.237	1.04	122	126.9
DM1	13.5	3.5	17.0	122	2074.0

3. The Costs of Farm-Grown Feeds

a. General Outline of Cost Schemes

In order to ensure that equivalent cost comparisons are made between sugarcane, Napier Grass and Pangola as feeding alternatives charges for labour and capital (variable and fixed) and interest are made in the budgets for each forage. The cost scheme encompasses establishment costs, annual operating costs (both of which are variable costs) and fixed costs in the case of sugarcane, which is chopped on the farm for immediate feeding to cattle. Establishment costs are those incurred in the initial cultivation of the stand and are depreciated over four years in the case of sugarcane and five years for Napier and Pangola grasses. The annual operating costs are those that are incurred in production, they are not depreciated and are approximately evenly distributed throughout the year. The fixed cost required for any level of on-farm chopping of sugarcane is the sum of annual depreciated costs of a chopping machine and motor, and a wagon and bullock used to transport cut sugarcane from the field to the zero-grazing shed. The cost of capital invested in fixed-cost items is estimated by charging interest at seven per cent per annum on one-half the total value of the depreciated items in accordance with the guidelines of Edwards _et al._ (10) and Barnard and Nix (6) and Osburn _et al._ (14). Furthermore, it is assumed that operating expenses are approximately evenly distributed throughout the year, thus interest at seven per cent per annum is charged on one-half the total value of these annual operating expenses. Seven per cent is currently the lowest rate at which farmers can borrow money in Trinidad for agricultural purposes.

b. Sugarcane Chopped On-Farm

In assessing the use of whole sugarcane as a major feedstuff for dairy cattle, four optional systems could be considered: (1) on-farm processing of the sugarcane as opposed to (2) centralized processing with subsequent delivery to the farm of feedable material, and (3) the chopping of the leaves and stalk of whole sugarcane as opposed to the derinding of the stalk and subsequent feeding of the sugary pith and leaves.

Because studies conducted to date (15,18) comparing chopped and derinded sugarcane indicate that derinding offers no apparently significant advantage, yet it does cost considerably more to purchase machinery ($37,000 Can vs $1,000 Can) derinding is not included in these analyses. Secondly, centralized chopping and delivery to the farm is discounted in the present analysis as being too complex an undertaking at this time from a commercial viewpoint.

The following are the assumptions on which the on-farm chopping system is based:

1. Over a four-year period on Wallerfield Piarco Fine Sands (PFS) an average yield of cane stalk of 23 tons per acre can be expected. Assuming that cane tops comprise about 30 per cent of whole cane (stalk and tops), 32.9 tons of whole cane will be reaped on average per year per acre at Wallerfield.

2. Cane planting material is not costed on the assumption that if sugarcane became recognized as a viable livestock feed, the Ministry of Agriculture would make it

available to bona fide farmers at no cost as it currently does with other grass materials. Furthermore, a substantial acreage of mature ripened sugarcane is not harvested by the sugar industry each year for a variety of reasons. It is hypothesized that this sugarcane could be made available to farmers as planting stock.

3. Cane for livestock feeding is reaped at approximately 12 months of age, ie, mature.

4. All labour is costed at $19.00 per eight-hour working day (one man-day).

5. Cane stalks can be cut at 4.4 tons per man-day; similarly whole cane (stalk and tops) can be cut and piled at 6.3 tons/day (4.4 ÷ 0.7).

6. Whole cane can be hauled from the field by wagon and bullock to the chopper at a rate of 1.2 tons per hour, or more.

7. Cane can be chopped, and mixed with urea, at one ton/hour.

8. The year is divided into dry and wet seasons comprising four and eight months respectively. For convenience only, the latter period is sub-divided into two equal periods of four months each.

Arising out of No. 3 above, it must be noted that cane cut in any one period is allowed to grow untouched except for normal weeding, fertilizing and pest control for 12 months, when it is again cut and fed.

The sum of the establishment and fixed costs as developed in the Appendix I Tables 4A and 4B equal the total variable costs per acre by period of harvesting. Operating costs are developed in Appendix I Table 5.

The variable and fixed costs of feeding chopped sugarcane are summarized below.

Table III-2
Sugarcane Costs

	Season		
	Dry	Wet	
	P_1	P_2	P_3
Establishment Costs per acre	$ 97.59	$ 97.59	$97.59
Operating Costs per acre	756.70	798.97	798.97
Total Variable Costs	854.29	896.56	896.56
Fixed Costs		$ 415.83	

c. Pangola Pasture

It is recommended practice in Trinidad to rotationally graze Pangola grass at four to six weeks age of regrowth during the wet season (P_2 and P_3) and at a lower level of intensity in the dry season (P_1) when supplementation with cut Napier grass is recommended (1). This latter practice is undertaken only by the better producers.

The following are the assumptions on which the costs of pangola grazing are based:

1. Annual costs are partitioned into three equal four-month periods (P_1, P_2, P_3).

2. Pastures are divided into approximately one acre paddocks and enclosed with internal-grade fencing costing $269.00/acre. Perimeter fencing, which is considerably stronger, is about 25 per cent more costly.

The costs for one acre of Pangola pasture suitable for rotational grazing throughout the three periods of the year as developed in Appendix I Table 6 are summarized below.

Table III-3
Pangola Costs

	Season		
	Dry	Wet	
	P_1	P_2	P_3
Establishment Costs per acre	$ 34.29	$ 34.29	$ 34.29
Operating Costs per acre	121.87	121.87	121.87
Total Costs/Period per acre	156.16	156.16	156.16
Total Cost/Year/Acre		468.48	

d. Napier Grass (Elephant Grass)

The following are the assumptions used in the determination of the costs of using Napier grass (<u>Pennisetum purpureum</u>) as a 'cut-and-cary' forage. Recommendations by the Ministry of Agriculture suggest that Napier Grass (NG) be used as a forage supplement to Pangola pasture in the dry season (P_1) as such, it is costed on a one-season (P_1) basis.

Assumptions:

- A man can cut Napier grass suitable for cattle feeding at a rate of 6.3 tons/day (the same as for whole sugarcane).

- One acre of Napier grass produces 3416 kg/acre of DM during P_1 when cut at seven to eight weeks of regrowth - equal to 2.7 man-days of labour.

- A man can carry (and chop into small pieces with a cutlass) one-half ton of fresh Napier grass to the place where cattle can feed on it in one hour. The total labour required for this task will be 4.2 man days/acre of Napier grass.

Annual costs for Napier grass are presented in Appendix I Table 7 and summarized below.

Establishment Costs per acre	$ 81.64
Operating Costs per acre	303.10
Total Costs per acre	384.74

4. The Least-Cost, Multiperiod, Complete Ration Formulation Model

a. General LP Model

Each linear programming problem is comprised of an objective function which is to be optimized - one or more restraints on the selection of activities for the optimal solution and the activities themselves. In this case the activities are the forage materials and concentrates, the restraints are the nutrient requirements of the cows and heifers and the objective is to compound the complete ration from the optional feedstuffs at the lowest possible cost (2,3,7,12,16,17).

The standard cost minimization linear program problem (Z) may be written in matrix form where: 'Z' is the objective, 'C' is a vector of costs, 'X' is a vector of feedstuffs, 'B' is a vector of constraints, and 'A' is a matrix of technical coefficients as: minimize $Z = CX$

subject to: $AX \gtreqless B$ and $X \geq 0$

Furthermore, for a problem with n feedstuffs (activities) and m restraints the following may be written as the general case:

$$\text{Minimize } Z = C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4 \cdots C_nX_n$$

subject to the following m restraints:

$$a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + a_{14}X_4 \cdots a_{1n}X_n \gtreqless b_1$$

$$a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + a_{24}X_4 \cdots a_{2n}X_n \gtreqless b_2$$

$$\begin{matrix} \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \end{matrix}$$

$$a_{m1}X_1 + a_{m2}X_2 + a_{m3}X_3 + a_{m4}X_4 \cdots a_{mn}X_n \gtreqless b_m$$

with $X_1 \geq 0$, $X_2 \geq 0$, $X_3 \geq 0$, $X_4 \geq 0 \cdots X_n \geq 0$

b. Key Features of the Model

i. Least-Cost Complete Feeds

The overall objective of the model is to determine the least-costly Completely balanced ration over the whole year for dairy cows (at up to moderate production) and their daughters using readily available feedstuffs. The cost effective ration will in most situations result in maximum net return; however, this hypothesis will be specifically tested as a critical portion of the overall analysis. Many reports have indicated that these computer formulated cost effective rations can be efficient in terms of animal performance as any other non-computerized ration (4,5,7,8,9,11,13,16).

ii. The Multiperiod Feature

Data presented earlier (Cahpter I) clearly established that Trinidad, like other islands in the Caribbean experiences an annual dry season during which monthly precipitation is normally less than soil moisture evaporation. Secondly, the critical importance of season on forage growth was established. This seasonal fluctuation in feed supply - specifically of forages - will be considered by the least-cost model by means of its multiperiod feature. The year will be divided into three four-month (122 day) periods with period 1 corresponding to the average four-month dry season of January, February, March and April inclusive. Periods 2 and 3 comprise generally the wet season with high monthly rainfall values. Each feedstuff - forage, sugarcane, or concentrate - available in a period will constitute an alternative for the compounding of the complete feed for that respective period.

iii. The Fixed-Cost Feature

One of the feeds to be considered is Whole Chopped Sugarcane (stalk and tops), which requires a certain minimum of equipment and machinery for on-farm processing of the cane for cattle feeding. This involves cutting the cane at ground level, transporting it to a chopper, which then chops the stalk and tops into particles approximately 5 mm in length. These capital cost items are more properly called 'fixed costs' because they are independent of the size of operation, and are usually depreciated over a period of years. Using Integer Programming Techniques (2,12) these fixed costs associated with sugarcane will be incorporated into the model so that the selection of feeds for the least-cost ration will be made after consideration by the model of those fixed costs, which will of necessity be incurred by even the smallest sugarcane feeding program.

iv. Complete Feeding Program

The model is designed to select both forages and concentrates to compound a complete feed (excluding water, vitamins, trace minerals, calcium and phosphorus). The optimum solution will be comprised of actual acreages of forages to be cultivated on-farm and the amounts of various concentrates to be procured off-farm for cattle maintenance and milk production for the entire year.

c. Elements of the Model

i. The Feedstuffs or Activities

Each feedstuff considered for inclusion in the model must be described in accordance with its availability in each of the three periods so that if a feedstuff is available in any period it will constitute a separate activity in the model. Furthermore, if the quality and/or availability of any feedstuff varies from season to season (period to period) this is reflected in the coefficients of the variables, which comprise the restraint equations or inequalities.

Since the primary goal of this analysis is to compare a sugarcane-based milk production system with the orthodox system (Pangola and Napier grasses and concentrates) the following list outlines the feedstuffs (forages and concentrates) to be considered by the model:

One hectare of whole Sugarcane to be chopped on the farm and fed in period 1.

One hectare of whole Sugarcane to be chopped on the farm and fed in period 2.

One hectare of whole Sugarcane to be chopped on the farm and fed in period 3.

One hectare of Napier grass forage fed in period 1.

One hectare of Pangola grass grazed in period 1.

One hectare of Pangola grass grazed in period 2.

One hectare of Pangola grass grazed in period 3.

Napier grass is currently used as a forage supplement to Pangola pasture in the dry season by most dairymen in Trinidad, therefore in order to simulate the existing production system, Napier grass is available in period 1 only.

One kilogram (kg) of fertilizer grade urea available in period 1.*

One kg urea available in period 2.

One kg urea available in period 3.

One kg of coconut meal available in period 1.

One kg of coconut meal available in period 2.

One kg of coconut meal available in period 3.

One kg of citrus meal available in period 1.

*All concentrates are expressed on a dry matter basis.

One kg of citrus meal available in period 2.

One kg of citrus meal available in period 3.

One kg of wheat middlings available in period 1.

One kg of wheat middlings available in period 2.

One kg of wheat middlings available in period 3.

One kg of a commercial dairy ration available in period 1.

One kg of a commercial dairy ration available in period 2.

One kg of a commercial dairy ration available in period 3.

One kg of dried Brewer's grains available in period 1.

One kg of dried Brewer's grains available in period 2.

One kg of dried Brewer's grains available in period 3.

One kg of final molasses available in period 1.

One kg of final molasses available in period 2.

One kg of final molasses available in period 3.

ii. The Restraints

In order to compound a complete ration suitable for dairy cows and their daughters, which are raised as herd replacements, the following ration criteria are incorporated into the model: A minimum restriction on the amount of Metabolizable Energy (ME) measured in MegaCalories (MCals) in total ration dry matter in each individual period — 1, 2 and 3; A minimum restriction on the amount of Digestible Protein (DP) measured in Kilograms in total ration dry matter in each individual period - 1, 2 and 3; A maximum restriction on the amount of total ration dry matter in kilograms in each individual period - 1, 2 and 3, and for roughage, and

a minimum restriction on ration dry matter that must be provided by forage ie. Sugarcane and/or Pangola and/or Napier grass, equal to 50% or more of the maximum amount of dry matter in the complete ration.

iii. Ration Requirements

The right-hand side values of the inequalities which form the restraints outlined above are the actual nutrient requirements for each of the three periods of the dairy cows and their daughters. These are derived from standard NRC nutrition tables and the literature, and were developed earlier in this chapter.

iv. The Objective Function

The objective row of the LP matrix contains the costs of the various feedstuffs that are available for ration formulation. However, consideration of price, nutritional characteristics and availability of each activity (feedstuff) will be undertaken by the LP model in formulating the ration in accordance with the restraints at the lowest possible cost - the least-cost.

v. The Consistency of Pangola Use

One aspect of the overall objective of this analysis.

is to organize the on-farm production of forage in such a way that the feed deficit of the dry season and/or the surplus of the wet season are avoided so that total annual feed cost is minimized. By means of transfer rows within the matrix (7), the acreage of Pangola grass is made equal in each of the three periods. This procedure is designed to simulate the orthodox system whereby any given acreage of Pangola is grazed in each period, but supplemented by Napier grass in period 1, the dry season.

vi. Voluntary Intake (VI) of Sugarcane

The IBM linear programming package*, MPSX, has provision for controlling the value of any activity by means of a bounds feature inherent in the program itself. This will be utilized to restrict the amount of sugarcane incorporated into the ration for each period to simulate the limitations on sugarcane voluntary intake as discussed in Chapter II.

It will be recalled that the milk cow unit (MCU) was defined as: one 450 kg cow, 0.2 three hundred kg heifers, 0.3 two hundred kg heifers and 0.3 one hundred kg heifers on average. Assuming the sugarcane V.I. does not vary with each type of animal of the MCU, the maximum intake of sugarcane dry matter can be readily calculated, then transformed into

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*This model is run on an IBM model 360 computer using IBM MPSX with the MIP option.

hectares of sugarcane, this latter figure representing the maximum VI of sugarcane for 1 MCU at a given level of voluntary intake.

For example, at a V.I. of 1.9%, the following calculation applies for 1 MCU for one day:

Body Wt.	x No.	x VI factor	= Max. Total sugarcane DM/MCU/day
450	x 1	x 0.019	= 8.55
300	x 0.2	x 0.019	= 1.14
200	x 0.3	x 0.019	= 1.14
100	x 0.3	x 0.019	= 0.57
		Total	11.4 kg

For each period of 122 days, this represents a maximum of 1391 kg of sugarcane dry matter, or 0.071 hectares (1391 ÷ 19600 kg/ha x 100). Thus, the maximum V.I. for 1 MCU at 1.9% VI is assumed to be 0.071 ha. Likewise, for 1.65% VI and 1.4% VI, the units are 0.062 and 0.052 hectares respectively. Of course, these limits increase linearly with increasing numbers of MCU.

vii. Maximum Urea in Ration

This restriction is implemented in the model by means of the upper bounds feature of the MPSX program. Urea is restricted to a value equal to, or less than, the equivalent of 30% of total crude protein. As indicated earlier one MCU requires at least 127 kg of DP/period. Assuming 50% digestibility this represents 254 kg of CP. At 30% NPN, this means that 76 kg of CP-equivalent can be from urea. At 281% crude equivalent, this results in an upper limit of 27 kg of urea per MCU per period.

viii. The Fixed Cost of Sugarcane Chopping

The use of a small chopping machine and a bullock and wagon are considered to be fixed costs for the on-farm preparation of Sugarcane. These fixed costs are evaluated by the model through the use of integer programming whereby the fixed cost activity is predetermined to take either the value of zero (0) or one (1). The Sugarcane activities themselves are linked to the fixed cost activity by the use of a transfer row. To do this, a <u>Fixed Cost activity</u> for on-farm chopping of Sugarcane that can take a value of 1 (when any quantity of sugarcane is chopped) or 0 (when sugarcane is not chopped), is created.

The value of this activity in the objective row is, of course, the cost of the equipment which constitutes the fixed costs. With the sole exception of this fixed cost activity, all others are continuous, ie. can take any value equal to, or greater than, zero.

On the basis of the determination of maximum V.I. during periods 1, 2 and 3 at 1.9, 1.4 and 1.4% VI respectively, one MCU cannot consume more than 0.071, 0.062 and 0.052 hectares of sugarcane (section vi. above). For 30 MCU, the maximum intake will be 2.13, 1.56 and 1.56 hectares respectively, or a total of 5.25 hectares/year.

Using this and the fact that the fixed cost activity must take the integral value of 1 exactly if sugarcane enters the optional solution at any level and 0 if it does not, a 'switch' is developed using MIP and a transfer row as shown below where X_1, X_2 and X_3 represent sugarcane activities in periods 1, 2 and 3 respectively and X_4 the integer fixed cost activity.

$$+1X_1 + 1X_2 + 1X_3 - 6X_4 \leq 0 \quad \text{(subject to } X_4 = 1 \text{ or } 0\text{)}$$

Assuming that the fixed cost activity can only take a value of 0 or 1 because the mixed integer programming option is used, if any sugarcane activity takes a value greater than zero, then X_4 will logically be 1. Similarly, if no sugarcane enters the optimal solution, X_4 must be 0 in order for the inequality to be satisfied. The number 6 is chosen arbitrarily - in reality any number larger than 5.25 would be satisfactory for a problem up to 30 MCU's. Activities X_5 to X_n inclusive would each have a technical coefficient of zero in this row.

ix. Land Restraint

The last restraint in the problem matrix is a control on land use. The SLDP farms are 20 acres on average, with 1 acre occupied by buildings, the homestead and the family garden. This leaves about 19 acres, or 7.7 hectares, for crop production - sugarcane and/or Pangola and/or Napier grass. Thus, the total crop program cannot exceed 7.7 hectares. Also, this row will conveniently indicate total land utilized in the optimal program and the surplus, if any, that is not used for crops.

5. Sensitivity Analysis

It is apparent that in spite of the relatively large amount of experimental sugarcane work completed to date, there are several fundamental factors that are unclear and require further investigation. The following are the factors, which were varied in a sensitivity analysis to determine under what conditions sugarcane may play a role in milk production by 'small scale farmers':

i. The Voluntary Intake (VI) of whole, fresh, mature chopped sugarcane - kg of sugarcane dry matter/100 kg liveweight.

ii. The Metabolizable Energy (ME) value of sugarcane - Megacalories/kg dry matter.

iii. The cost of production of sugarcane feed.

iv. Furthermore, although it is widely recognized that the dry season has a serious negative effect on forage yield, it is unclear under Wallerfield conditions by how much the dry season yield of Pangola pasture will be reduced. Thus, this factor - yield of Pangola in the dry season, P_1 - will be varied also.

v. Lastly, a shadow price will be developed for land at Wallerfield that more realistically represents its economic value. Presently, farmers under the SLDP pay a nominal rent (to government) of $12.00 per acre per year. It is hypothesized that this low rental cost might encourage the use of more pasture for milk production than is warranted. This will be tested by the analysis by varying the rental cost of land.

a. Metabolizable Energy

On the basis of the literature it seems likely that the ME value of whole mature sugarcane will either remain relatively constant on a dry matter basis throughout the year, or decline in the wet season. To accomodate these two alternatives in the model, two schemes for ME are considered for the yearly production cycle of periods 1, 2 and 3:

a) ME values of 2.5, 2.5 and 2.5 for periods 1, 2 and 3, respectively, designated as '<u>HIGH</u>'.

b) A 'LOW' ME cycle of 2.5, 2.0 and 2.0 for periods 1, 2 and 3, respectively, representing a 20% decline in ME in the wet season (P_1 and P_2).

b. Voluntary Intake

Similarly, two schemes were considered to reflect the doubt that exists surrounding the Voluntary intake of sugarcane, especially in conjunction with a grazing program.

a) 'HIGH' - voluntary intake values of 1.9%, 1.4% and 1.4% for periods ~~1, 2 and~~ 3, respectively.

b) 'LOW' - VI's of 1.65%, 1.40% and 1.4% for periods

1, 2 and 3, respectively.

c. Sugarcane Costs

Two cost schemes are used for sugarcane:

a) 'LOW' - costs of $2110, $2215 and $2215 per hectare for periods 1, 2 and 3, respectively, the costs determined earlier in this chapter.

b) 'HIGH' - cost inflations of 20% over the 'LOW' costs - $2532, $2658 and $2658 per hectare for periods 1, 2 and 3, respectively.

d. Yield of Pangola

Because the determination of the precise yield of Pangola pasture is confounded by many factors, one of the most important being the lack of reliable, agronomic data, a range of values based upon the literature has been developed to test for variation in this factor:

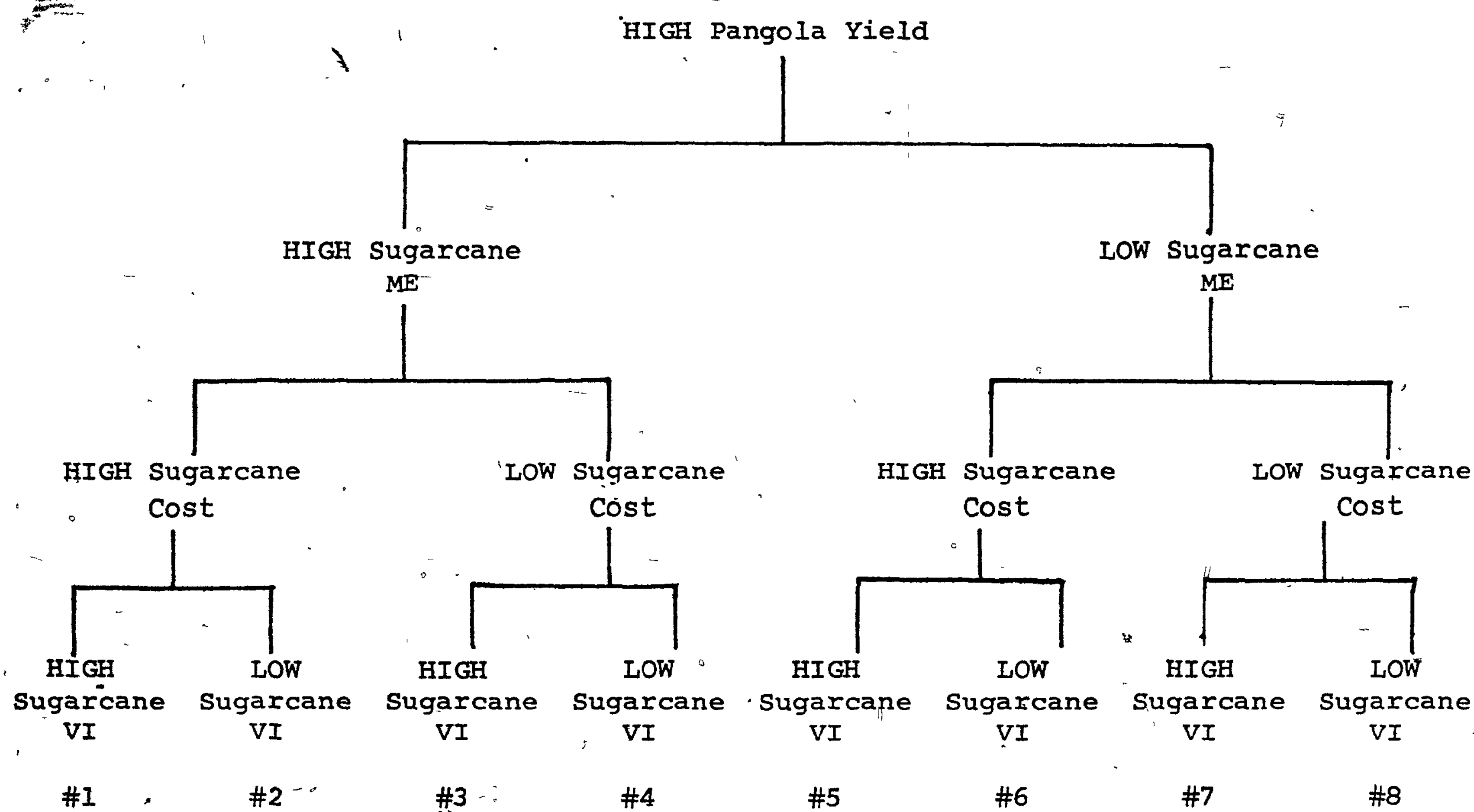
a) 'HIGH' - yields of 35, 55 and 55 kg per hectare per day of Pangola dry matter in periods 1, 2 and 3, respectively.

b) 'LOW' - yields of 20, 55 and 55 kg/ha/day for periods 1, 2 and 3, respectively.

e. Shadow Price of Land

It is hypothesized that the land rental cost of $12.00/ acre/year seriously underestimates the cost of agricultural

Figure III-1



Problem 6, for example, may be considered a severe test for sugarcane - the original hypothesis - because the VI and ME of sugarcane are LOW, its cost is HIGH and it is in competition with HIGH yielding Pangola pasture.

Figure III-2

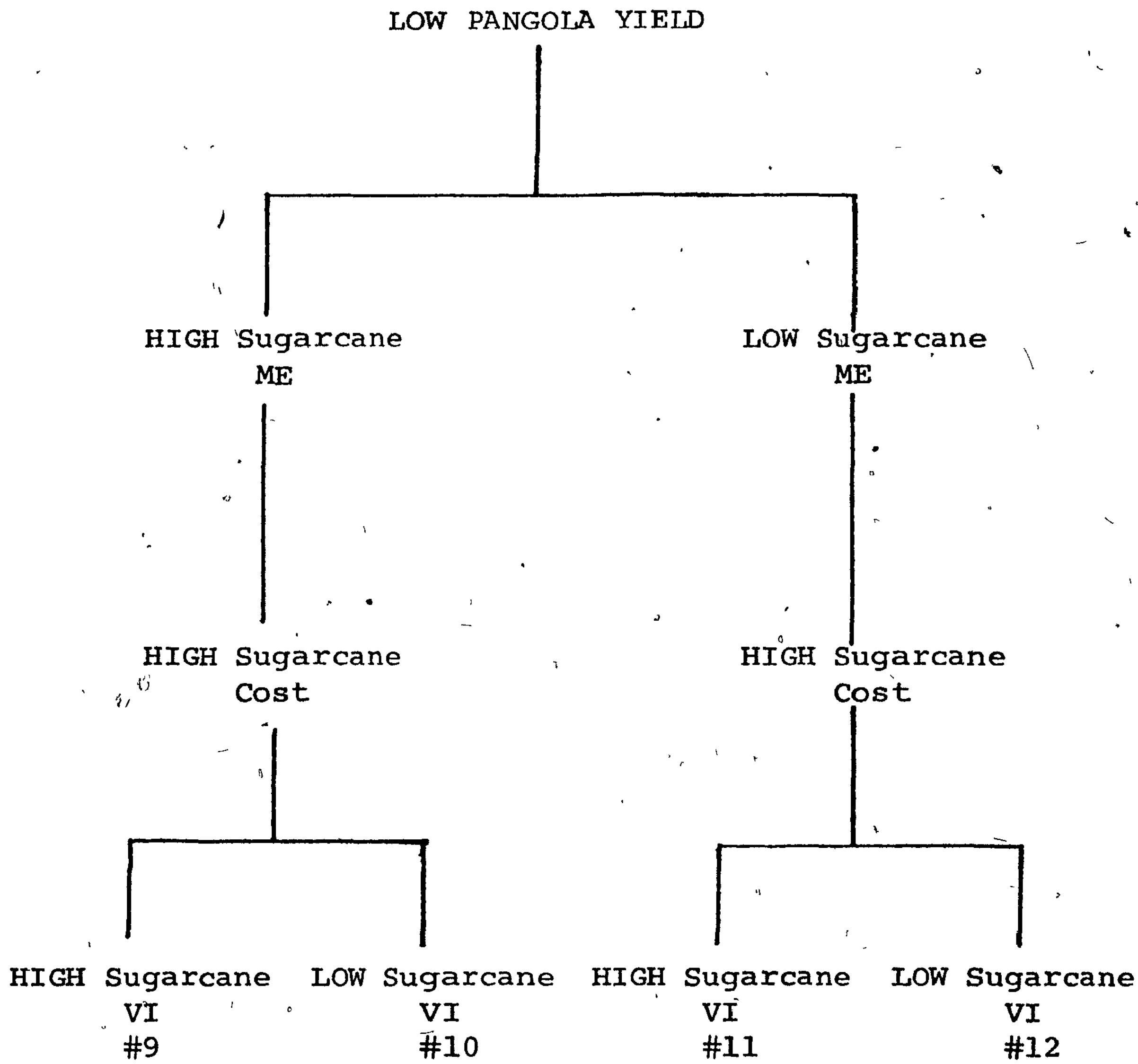

LOW PANGOLA YIELD
HIGH Sugarcane ME
LOW Sugarcane ME
HIGH Sugarcane Cost
HIGH Sugarcane Cost
HIGH Sugarcane VI #9
LOW Sugarcane VI #10
HIGH Sugarcane VI #11
LOW Sugarcane VI #12

Figure III-3
Shadow Price of Land

HIGH Pangola Yield
|
LOW Sugarcane ME
|
HIGH Sugarcane Cost
|
LOW Sugarcane VI
|
Shadow Price-Land Rental

#13

LOW Pangola Yield
|
LOW Sugarcane ME
|
HIGH Sugarcane Cost
|
LOW Sugarcane VI
|
Shadow Price-Land Rental

#14

Figure III-4
Controls

LOW Pangola Yield

#15

Without Sugarcane

HIGH Pangola Yield

#16

Without Sugarcane

land, albeit poor as it is, in the Wallerfield area. To estimate a more realistic cost, it is assumed that the present market selling cost is $2000/acre (or 4940/ha), and that the opportunity cost of long term low risk capital is 4%. This would result in a rental cost of $198/ha (2000 x 0.04 x 2.47). Thus, two schemes are used to value land:

a) 'HIGH' - land costed in the budgets at $198/ha or $80/acre - the Shadow Price.

b) 'LOW' - a cost of $30/ha or $12/acre - the present SLDP rental cost.

f. Strategy

The sensitivity analysis undertaken using the least-cost model will test for the effect(s) of variation, in the ME, VI, the cost of sugarcane and the yield of Pangola pasture by season and the cost of land. This is comprised of a series of problems numbered 1 to 16 as outlined (Figure III-1 to 4).

6. Net Income Analysis

a. Calculation of Revenues and Costs

This outline considers only three sources of revenues from the model farms, since it is assumed that all heifer calves are reared as replacements. Interest on operating costs, which are assumed to be evenly distributed throughout the year is also computed. Charges for depreciation, maintenance and repair (M/R) are calculated for each capital asset. Interest is charged on half the original value of the asset at the rate of 7% per annum. Labour has not been costed because these represent family farms where labour is relatively abundant and in many cases not utilized, or underutilized (18).

b. Revenues

The total revenue generated by the farm is dependent upon the number of cow units (MCU) since this factor determines the following:

- Milk Sales
  No. of MCU x 600 gallons/cow/year x $3.00/gallon

- Bull Calf Sales
  No. of MCU x .03 bull calves/cow/year x $100

- Culled Cow Sales
  No. of MCU x 0.2 x 450 kg x $2.20/kg

c. Variable Costs

- NPK Fertilizer
  1) Pangola Pasture - (10 cwt x $23.30/acre/year x 2.47 acres/hectare)
     No. of ha of Pangola x $576

  2) Napier Grass - (3½ cwt x 23.30/acre/year x 2.47)
     No. of ha of Napier x $201

  3) Sugarcane - (5 cwt x 23.30/acre/year x 2.47)
     No. of ha of sugarcane x $288

- Lime
  1) Pangola
     No. of ha x $12/ha

  2) Napier
     No. of ha x $12/ha

  3) Sugarcane
     No. of ha x $12/ha

- Crop Chemicals
  a) Pangola 0
  b) Napier 0
  c) Sugarcane
     No. of ha x $158

- Cattle Chemicals
  No. of MCU x $20

- Drugs & Vet Services
  No. of MCU x $30

- Supplements
  Urea (U)
  $(\text{kg } U_{P_1} + \text{kg } U_{P_2} + \text{kg } U_{P_3}) \times \$0.66$
  Wheat Middlings (WM)
  $(\text{kg } WM_{P_1} + \text{kg } WM_{P_2} + \text{kg } WM_{P_3}) \times 0.15$
  Molasses (M)
  $(\text{kg } M_{P_1} + \text{kg } M_{P_2} + \text{kg } M_{P_3}) \times \$0.17$

- Milk Replacer & Calf Starter
  No. of MCU x 0.3 x $62.00

- Breeding Costs
  No. of MCU x $4.00

- Milk Collection
  20/month x 12 = $240/year

- Utilities
  Water
  No. of MCU x $10
  Electricity
  No. of MCU x $20

- Chopper Fuel/Oil*
  No. of ha of sugarcane x $20/ha

- Interest
  7% (0.07) on half the sum of the operating expenses (a to k above)

d. Fixed Costs

- Land
  1) Rental a) 8.1 ha x $30/ha = $243/year
  b) 8.1 ha x $80/ha = $648/year
  2) Interest - Rental x ½ x 0.07[1] = 8.51

- Fences
  Perimeter (for 8.1 ha form)
  Depreciation, $5000 original value x 0.07 = 350
  M/R, $5000 original value x 0.05 = 250
  Interest, $5000 original value x ½ x 0.07 = 175

  Internal
  $664 x no. of ha of Pangola = original value
  Depreciation, original value x 0.07
  M/R, original value x 0.05
  Interest, original value x ½ x 0.07

- Chopper* - original value, $2400
  Depreciation, 2400 x0.10 = 240
  M/R, 2400 x0.05 = 120
  Interest, 2400 x ½ x 0.07 = 84

- Calf Pens - original value, $2450
  Depreciation, 2450 x 0.10 = 245
  M/R, 2450 x 0.01 = 25
  Interest, 2450 x ½ x 0.07 = 86

- Milk Barn - original value, $5150
  Depreciation, 5150 x 0.05 = 258
  M/R, 5150 x 0.01 = 52
  Interest, 5150 x ½ x 0.07 = 180

---

*If sugarcane feed is used.

[1]0.07 factor for 7% interest per annum.

- Zero-grazing shed* - original value, $5000
  - Depreciation, 5000 x 0.05 = 250
  - M/R, 5000 x 0.01 = 50
  - Interest, 5000 x ½ x 0.07 = 175

- Milking Machine - original value, $3500
  - Depreciation, 3500 x 0.10 = 350
  - M/R, 3500 x 0.01 = 35
  - Interest, 3500 x ½ x 0.07 = 123

- Bullock and Wagon* - original value, $1100
  - Depreciation, 1100 x 0.10 = 110
  - M/R, 1100 x 0.03 = 33
  - Interest 1100 x ½ x 0.07 = 39

- Tools and Sundries ($200)
  - Depreciation 200 x 0.10 = 20
  - M/R, 200 x 0.01 = 2
  - Interest, 200 x ½ x 0.07 = 7

- Perennial Crops
  1) Pangola Pasture - Establishment cost$858/ha (excluding fencing)

     Original Value = No. of ha x 858

     Depreciation, original value x 0.20
     M/R, -
     Interest, original value x ½ x 0.07

  2) Napier Grass - Establishment cost $858/ha

     Original Value = No. of ha x 858

     Depreciation, original value x 0.20
     M/R, -
     Interest, original value x ½ x 0.07

  3) Sugarcane - Establishment cost $846/ha

     Original Value = No. of ha x 846

     Depreciation, original value x 0.25
     M/R,
     Interest, original value x ½ x 0.07

---

*If sugarcane feed used.

- Cattle

Interest at 7% on investment in cattle

No. of MCU x value/MCU* x 0.07

e. Return to Labor and Management

Revenues less Variable costs less Fixed costs equals the estimated Net Return to family and operator labour and management.

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*1 MCU equals 1 cow at $2000, 0.2 heifers at $1380, 0.3 heifers at $760, and 0.3 heifers at $150. Total value is $2550.

CHAPTER IV

RESULTS AND DISCUSSION

1. General

The solutions to the series of 16 problems which constitute the sensitivity analysis are presented in Appendix II and are labelled as Tables 1 to 16 inclusive. Each problem as such is further divided into a set of 7 sub-problems representing increasing numbers of cows (MCU's) in increments of 5. Furthermore, at the outset, it is important to note that these results represent hypothetical farms and as such the comparison of the absolute value of Net Return is not very appropriate. The most useful comparisons will involve the determination of the magnitude of change from one situation to another, this is usually expressed on a percentage basis.

2. The Controls

Tables 15 and 16 of Appendix II present the optimal solutions for the Controls, that is problems in which sugar-cane was not included as an activity in the problem. The results are linear up to the limit of about 19 MCU for the 7.7 hectares (20 acres/farm - 1 acre for homestead/buildings ÷ 2.47 acres/ha) available on the SLDP farms for cropping.

The differences between these solutions are due to the difference in yield of Pangola grass by season - 'HIGH' being 35 kg/ha/day and 'LOW' being 20 kg/ha/day. These are illustrated by the optimal solution at 15 MCU.

	'LOW' Pangola Yield 20,55,55 kg/ha/day for P_1, P_2 & P_3	'HIGH' Pangola Yield 35,55,55 kg/ha/day for P_1, P_2 & P_3
Period 1		
Napier Grass, ha	2.20	0.0
Pangola Grass, ha	3.86	6.07
Wheat Middlings, kg	8436	8435
Molasses, kg	2054	2055
Period 2		
Pangola Grass, ha	3.86	6.07
Wheat Middlings, kg	8445	4823
Urea, kg	0	37
Molasses, kg	2048	0
Period 3		
Pangola Grass, ha	3.86	6.07
Wheat Middlings, kg	8445	4823
Urea, kg	0	37
Molasses, kg	2048	0
Cost/MCU	761	676
Land/MCU	0.40	0.40

The land requirement of 0.4 ha (1.0 acre) per MCU is consistent with the expectation of good pasture and general management combined with ration supplementation. The use of

Napier grass is advantageous under the LOW Pangola yield condition. Of the two problems, the one representing a Pangola yield of 20 kg/ha/day in the dry season probably more accurately reflects the present conditions at Wallerfield. The author's observations there revealed that the better farmers are moving toward more Napier grass in the dry season, confirming the ability of the model to reflect the actual farming reality at Wallerfield.

3. The Effect of Variation in Sugarcane ME by Season

The comparisons that should be made to assess the importance of variation in the ME of sugarcane between the dry and wet seasons are: 1 and 5, 2 and 6, 3 and 7, and 4 and 8.

a. Comparison 1 and 5 (Tables 1, 5)

These problems in which only ME varies (HIGH sugarcane cost and VI, and HIGH Pangola yield) show that sugarcane enters the optimal solution at the same scale at the same level - 0.38 ha at 20 MCU. This is likely a response to the land limitation of 7.7 ha, since without the inclusion of sugarcane the maximum number of MCU possible on 7.7 ha would be 19. The decrease in ME in P_2 and P_3 appears not to be of great importance since the differences between the two are minimal. The deficit in energy is overcome by increasing the level of molasses. These differences are illustrated below at 30 MCU.

	#1	#5
	'HIGH' Sugarcane ME 2.5,2.5,2.5 Mcals/kg in P_1, P_2, P_3	'LOW' Sugarcane ME 2.5,2.0,2.0 Mcals/kg in P_1, P_2, P_3
Period 1		
Sugarcane	0.75	0.75
Pangola Grass	6.41	6.41
Urea	139	139
Wheat Middlings	18754	18754
Molasses	0	0
Period 2		
Sugarcane	0.27	0.27
Pangola Grass	6.41	6.41
Urea	0	0
Wheat Middlings	18934	18712
Molasses	1512	2471
Period 3		
Sugarcane	0.27	0.27
Pangola Grass	6.41	6.41
Urea	0	0
Wheat Middlings	18934	18712
Molasses	1512	2471
Cost/MCU	676	684
Land/MCU	0.26	0.27

The effect of size of operation on the utilization of sugarcane is worth noting at this point; this will be elaborated upon later.

b. Comparison 2 and 6 (Tables 2, 6)

Problems 2 and 6 in which only ME is varied (HIGH sugarcane cost, LOW VI, HIGH Pangola yield) are similar to problems 1 and 5 discussed above. These results indicate that seasonal variation in sugarcane ME is not a critical factor in the determination of the least-cost ration.

It is worthwhile noting that problem 6 (Table 6) represents sugarcane 'at its worst' since its cost is HIGH, its VI and ME LOW, and it is in competition with HIGH yielding Pangola. In spite of this, sugarcane is part of the optimal ration, but only at or above 20 MCU - an important effect of scale of operation.

c. Comparison 3 and 7 (Tables 3, 7)

In these problems sugarcane cost is LOW, VI is HIGH, Pangola yield is HIGH and ME is variable. Sugarcane is included in the complete ration in each period after a certain critical scale of operation (no. of MCU) is reached. At HIGH ME, sugarcane enters the solution at 5-10 MCU, whereas it enters at 10-15 MCU at LOW ME. It is also important to note that problem 3 is an optimistic representation of sugarcane in competition with HIGH yielding Pangola pasture. This results in almost the complete exclusion of Pangola above 10 MCU.

The following table compares the two problems at 10 MCU.

	#3 'HIGH' ME	#7 'LOW' ME
Period 1		
Sugarcane	0.67	0.0
Napier Grass	0	0
Pangola	0.04	4.05
Urea	270	0
Wheat Middlings	2487	5623
Molasses	0	1370
Period 2		
Sugarcane	0.52	0
Pangola	0.04	4.05
Urea	164	25
Wheat Middlings	5092	3215
Molasses	0	0
Period 3		
Sugarcane	0.52	0
Pangola	0.04	4.05
Urea	164	25
Wheat Middlings	5092	3215
Molasses	0	0
Cost/MCU	648	676
Land/MCU	0.18	0.41

These differences are maintained at higher MCU indicating that ME under some conditions can be a very important variable influencing the formulation of the ration and thereby the cost and land use pattern per MCU.

d. Comparison 4 and 8 (Tables 4, 8)

Problems 4 and 8 yield results very similar to 3 and 7 above - intensive utilization of sugarcane above 10 MCU, its use in all 3 periods, more intensive overall land use and lower costs/MCU with increasing numbers of MCU.

e. Summary

It is apparent that variation in the ME of sugarcane by season is an important factor in the compounding of a least-cost complete ration. Under some conditions, LOW ME sugarcane is utilized but not as intensively as when ME is HIGH in all seasons. HIGH ME sugarcane results in lower costs/MCU and more MCU/hectare. The results indicate that the definitive determination of the energy value of whole, mature sugarcane throughout the whole year is a worthwhile research goal.

4. Effect of Variation in Voluntary Intake of Sugarcane

The appropriate comparisons for the determination of the effect of variation in VI are: 1 and 2, 3 and 4, 5 and 6, and 7 and 8.

a. Comparison 1 and 2 (Tables 1, 2)

Comparison of problems 1 and 2 reveals that variation in VI has no effect on the optimal solutions to these problems in which sugarcane cost is HIGH, ME is HIGH and Pangola yield is HIGH.

Sugarcane forms a part of the ration in the dry season only at 15-20 MCU. It is utilized in all three periods at 30 MCU but at low levels in P_2 and P_3. This reinforces the notions of economy of scale for sugarcane forage and sensitivity to seasonal variation, which are discussed in more detail later.

b. Comparison 3 and 4 (Tables 3, 4)

Sugarcane becomes the predominant part of the ration at 5-10 MCU and is utilized in all three periods in both problems. There are only minor differences between 3 and 4. However, the level of sugarcane in the LOW VI problem at all MCU levels is less than that in the HIGH VI problem, suggesting that the LOW VI restriction reduces the amount of sugarcane selected. This supports an objective of the model which was to simulate the VI actually determined from biological data. The use of the upper bound procedure is effective for this purpose. It is important to note that Pangola grass is of little importance above 5-10 MCU. The following table illustrates these points at 30 MCU for HIGH and LOW VI when sugarcane costs and ME are HIGH and Pangola yield is HIGH.

	#3	#4
	HIGH VI	LOW VI
Period 1		
Sugarcane	2.01	1.86
Napier Grass	0	0
Pangola	0.13	0.13
Urea	810	706
Wheat Middlings	7460	10045
Molasses	0	0
Period 2		
Sugarcane	1.56	1.56
Pangola	0.13	0.13
Urea	492	492
Wheat Middlings	15276	15276
Molasses	0	0
Period 3		
Sugarcane	1.56	1.56
Pangola	0.13	0.13
Urea	492	492
Wheat Middlings	15276	15276
Molasses	0	0
Cost/MCU	620	620
Land/MCU	0.18	0.17

c. Comparison 5 and 6 (Tables 5, 6)

The results of problems 5 and 6 are identical, indicating that variation in VI is not a major constraint to sugarcane feeding when combined with high yielding Pangola pastures. At higher scales of operation sugarcane becomes increasingly important in the dry season.

d. Comparison 7 and 8 (Tables 7, 8)

There are no differences between the results of problem 7 and 8 due to the seasonal variation in sugarcane voluntary intake.

e. Summary

Variation in the Voluntary Intake alone of whole mature chopped sugarcane from 1.9% to 1.65% in the dry season (P_1) (combined with VI's of 1.4% in P_2 and P_3) appears not to be a major limiting factor in the selection of sugarcane as an ingredient in a least-cost complete dairy feed.

5. Effect of Variation in the Production Cost of Sugarcane

The appropriate comparisons for the determination of the effects of increasing the cost of sugarcane by 20% are: 1 and 3, 2 and 4, 5 and 6, 6 and 7.

a. Comparison 1 and 3 (Tables 1, 3)

Problems 1 and 3 compare the effects of HIGH and LOW sugarcane costs with the following factors held constant: HIGH sugarcane VI and ME, and HIGH Pangola yield. The following table for 30 MCU illustrates the major effects of inflating the cost of sugarcane, confirming that the use of sugarcane feed is very sensitive to its cost of production, or the opportunity cost, whichever may be the case.

	#1	#3
	'HIGH' Sugarcane Cost	'LOW' Sugarcane Cost
Period 1		
Sugarcane	0.75	2.01
Napier Grass	0	0
Pangola	6.41	0.13
Urea	139	810
Wheat Middlings	18754	7460
Molasses	0	0
Period 2		
Sugarcane	0.27	1.56
Pangola	6.41	0.13
Urea	0	492
Wheat Middlings	18934	15276
Molasses	1512	0
Period 3		
Sugarcane	0.27	1.56
Pangola	6.41	0.13
Urea	0	492
Wheat Middlings	18934	15276
Molasses	1512	0
Cost/MCU	676	620
Land/MCU	0.26	0.18

Inflating the cost of sugarcane while holding the cost of all other feedstuffs constant has the following effects: it increases the COST/MCU, and reduces the intensity of land use by increasing the use of pasture and reducing the amount of sugarcane used. Furthermore, the HIGH(er) cost of sugarcane prevents its use for even dry season feeding until the 15-20 MCU scale of operation is reached, at which point it is a supplement to Pangola.

b. Comparison 2 and 4 (Tables 2, 4)

The results of this comparison are similar to those of 1 and 3 above.

c. Comparison 5 and 7 (Tables 4, 7)

Again, the effects of HIGH cost of sugarcane are marked, and indicate that the least-cost program is sensitive to the cost of production of sugarcane.

d. Comparison 6 and 8 (Tables 6, 8)

Increasing the cost of sugarcane has an effect similar to that reported in the above three comparisons.

e. Summary

The cost of production of sugarcane, independent of its nutritional characteristics, is one of the most important factors influencing its use in least-cost rations.

6. Effect of Variation in Yield of Pangola Pasture

The appropriate comparisons for the determination of the effects of variation in the yield of Pangola are: 1 and 9, 2 and 10, 5 and 11, and 6 and 12.

a. Comparison 1 and 9 (Tables 1, 9)

Problems 1 and 9 compare the effect of HIGH and LOW Pangola yield on the optimal ration while the following are held constant: HIGH sugarcane cost, VI and ME. The marked difference between these two problems is illustrated in the table below for 30 MCU.

	#1	#9
	'HIGH' Pangola Yield in Dry Season	'LOW Pangola Yield in Dry Season
Period 1		
Sugarcane	0.75	1.58
Napier Grass	0	0
Pangola	6.41	0.13
Urea	139	499
Wheat Middlings	18754	15201
Molasses	0	0
Period 2		
Sugarcane	0.27	1.56
Pangola	6.41	0.13
Urea	0	492
Wheat Middlings	18934	15276
Molasses	1512	0
Period 3		
Sugarcane	0.27	1.56
Pangola	6.41	0.13
Urea	0	492
Wheat Middlings	18934	15276
Molasses	1512	0
Cost/MCU	676	690
Land/MCU	0.26	0.16

LOW yielding Pangola pasture is conducive to the inclusion of a large amount of sugarcane in the ration even at the inflated cost of sugarcane. At 1-5 MCU, sugarcane enters the ration and in all three periods to almost the complete exclusion of Pangola.

b. Comparison 2 and 10 (Tables 2, 10)

The major differences between problems 2 and 10 are due to variation in Pangola yield in the dry season (P_1) only. Moreover, they are identical to those found above confirming the importance of Pangola yield and the dry season as correlated factors that have a great influence on ration formulation and land use.

c. Comparison 5 and 11 (Tables 5, 11)

The differences between 5 and 11 are similar to those reported above for 1 and 9, and 2 and 10 and confirm the importance of determining expected Pangola yield in the dry season in formulating feeding systems.

d. Comparison 6 and 12 (Tables 6, 12)

The differences between 6 and 12 are similar to those reported above and again confirm the effect of the dry season on Pangola yield and their subsequent effect on ration formulation.

e. Summary

The analyses of this section strongly suggest that the yield of Pangola grass is a very critical factor in the formulation of optimal complete rations. If the yield of Pangola pasture is consistently HIGH, sugarcane feeding may be advantageous but only with large numbers of cows. On the other hand, if the probability of a LOW Pangola yield is high, it is advantageous to utilize sugarcane intensively.

7. The Effect of a Shadow Price for Land

The appropriate comparisons to determine the effect of increasing the cost of land to a level which better represents its economic value are: 6 and 13, and 12 and 14.

a. Comparison 6 and 13 (Tables 6, 13)

The major difference between these problems is total cost, this is not unexpected because of the increased cost of land ($12/acre compared to $80/acre). However, at the higher land cost, sugarcane becomes a part of the feed plan at 10-15 MCU, whereas at the normal land cost it enters at 15-20 MCU. These are seen in the table below at the 15 MCU level.

At 20, 25 and 30 MCU the two rations are identical indicating that the effect of the Shadow Price on the solutions is minor, representing only a lowering of the threshold at which the inherent advantages of sugarcane outweigh its disadvantages.

	#13 HIGH Land Cost (Shadow Price)	#6 LOW Land Cost
Period 1		
Sugarcane	0.29	0
Napier Grass	0	0
Pangola	3.86	6.07
Urea	32	0
Wheat Middlings	9745	8435
Molasses	0	2055
Period 2		
Sugarcane	0	0
Pangola	3.86	6.07
Urea	0	37
Wheat Middlings	8445	4823
Molasses	2048	0
Period 3		
Sugarcane	0	0
Pangola	3.86	6.07
Urea	0	37
Wheat Middlings	8445	4823
Molasses	2048	0
Cost/MCU	735	676
Land/MCU	0.28	0.41

b. Comparison 12 and 14 (Tables 12, 14)

These problems result in solutions different in detail from problems 6 and 12 above. However, the pattern of sugarcane being a part of the ration at a low number of cows is present. The 'LOW' yield of Pangola, which was identified earlier as a critical factor in the ration formulation process, again demonstrates that unless pasture yield in the dry season is substantial, sugarcane feeding is preferable <u>at that time</u>. The differences at 5 MCU are illustrated in the table below.

	#14 HIGH Land Cost	#12 LOW Land Cost
<u>Period 1</u>		
Sugarcane	0.17	0
Napier Grass	0	0.73
Pangola	1.29	1.29
Urea	42	0
Wheat Middlings	2939	2812
Molasses	0	685
<u>Period 2</u>		
Sugarcane	0	0
Pangola	1.29	1.29
Urea	0	0
Wheat Middlings	2815	2815
Molasses	683	683
<u>Period 3</u>		
Sugarcane	0	0
Pangola	1.29	1.29
Urea	0	0
Wheat Middlings	2815	2815
Molasses	683	683
Cost/MCU	825	761
Land/MCU	0.29	0.40

c. Summary

The use of a shadow price for land in Trinidad to better estimate the economic value of land has the effect of increasing the utilization of sugarcane feed at the lower end of the farm-size scale. As the cost of land increases for whatever reason, the attractiveness of sugarcane feed increases. This is not unexpected because of the high carrying capacity of an acre of sugarcane forage.

8. The Effect of Scale

Perusal of the 16 problems that constitute the sensitivity analysis indicates that the size of operation (number of cows and heifers) has an important effect on the feed plan. The following is just one example of many that could be made from the results of this economy of scale effect.

a. Comparison 13 and 14 (Tables 13, 14)

Under conditions of HIGH Pangola pasture yield in the dry season, sugarcane is not utilized in the formulation of the optimal ration <u>until</u> the number of cows reaches 10-15, whereas, if Pangola yield is LOW in the dry season, sugarcane is used at 1-5 cows.

At 30 MCU, 1.16 and 0.75 hectares of sugarcane are utilized in the dry season for the HIGH and LOW yielding

Pangola pastures, respectively. These represent about 6.2 kg and 4.0 kg of sugarcane dry matter per MCU per day of the dry season, which are substantial portions of the total dry matter consumed per MCU per day.

The following table illustrates the interaction of season and scale when sugarcane cost is HIGH, its ME and VI LOW, and using the shadow price for land.

	#13	#14
No. of MCU	HIGH Pangola Yield	LOW Pangola Yield
	Hectares of Sugarcane in P_1	
1	0	0
5	0	0.17
10	0	0.34
15	0.29	0.51
20	0.38	0.67
25	0.48	0.84
30	0.75	1.16

b. Summary

The feeding of sugarcane under a variety of conditions is not advantageous at all farm sizes. A specific minimum number of cows is required to offset the fixed costs of cutting, transporting and chopping sugarcane. It is apparent that the scale of operation is an important factor in the formulation of optimal rations using sugarcane.

9. The Effect of Season

The variation in yield of Pangola by season, primarily due to moisture stress, is of great significance in the formulation of optimal rations. Depending upon the degree of decline in yield from the wet season, either concentrates and Napier grass, or concentrates and sugarcane, are utilized to supplement Pangola pasture. This is confirmed by the many problems presented in the Appendix Tables 1 to 16 inclusive.

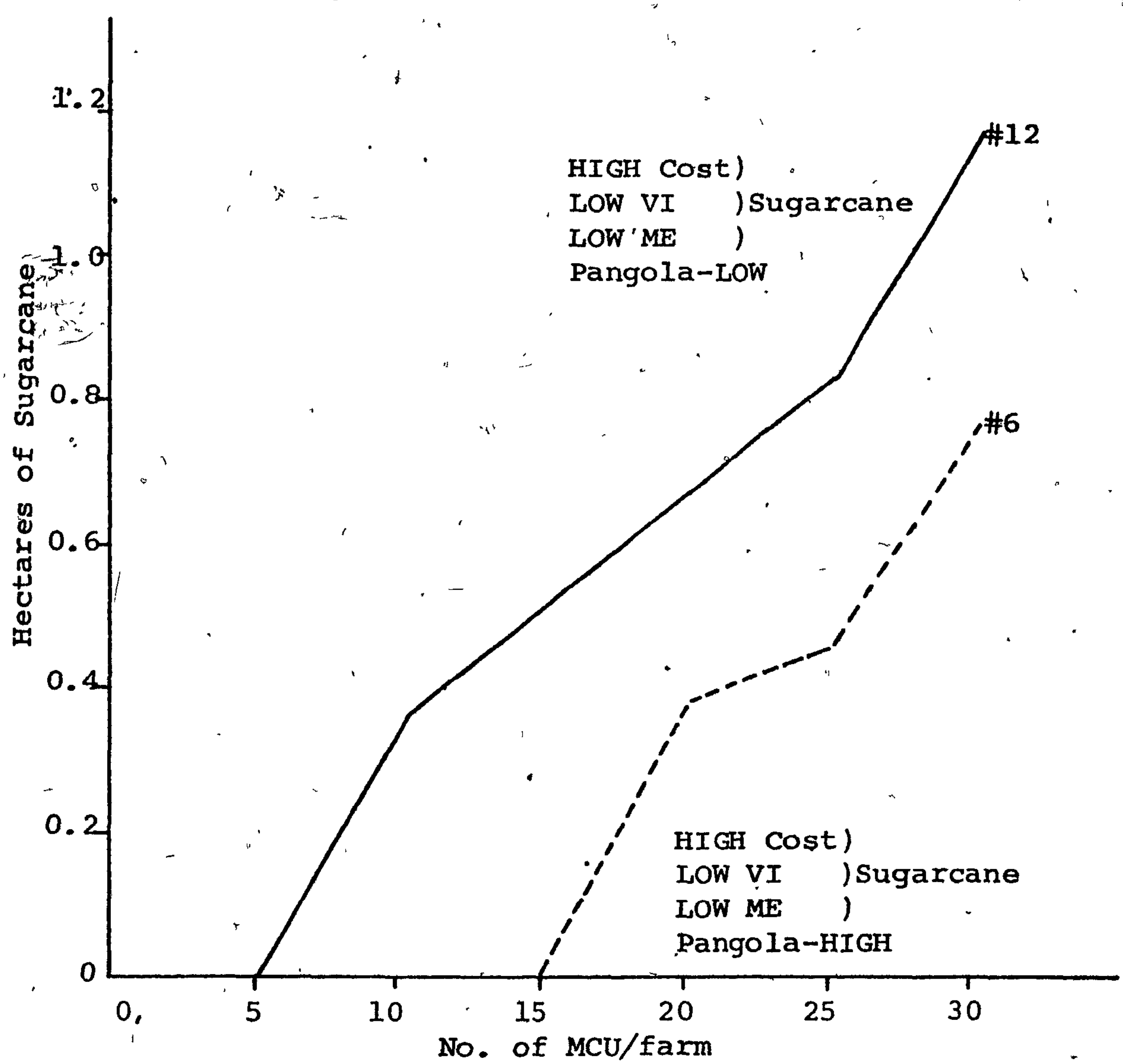
The Figure below illustrates the effect of scale of operation and severity of season (fluctuating Pangola yield) on sugarcane and land use for conditions which conservatively represent sugarcane, i.e., HIGH Cost, LOW ME and VI (Fig. IV-1).

10. Comparison of Net Income

Firstly, estimated Net Incomes were calculated for problems #16, #15, #12, #8 and #6, at the scale of operation corresponding to the land limitation. It is assumed that sufficient family labor is available for these hypothesized farms to be satisfactorily implemented. These selected comparisons are summarized in the following table. It is

Figure IV-1

Effect of scale and season on sugarcane use



apparent that sugarcane, when incorporated into the least-cost complete ration, allows for a much higher stocking rate and an even greater Net Income per farm. The margin per cow is only slightly more favorable. Problems 14, 13, 11, 10, 9, 7, 5, 4, 3, 2 and 1 are also tabulated in Table 2 . However, they represent sugarcane in most cases more favorably than #12, #8 and #6, and are therefore likely to result in an even larger positive margin than 12, 8 and 6.

Two of the most important of many comparisons that can be made to determine the effect of sugarcane on dairy production are: 15-12 and 16-6. Both 15 and 16 represent 'control' situations wherein sugarcane was excluded from consideration, as such they represent the existing production system with the uncertainty of Pangola yield in the dry season. Both 12 and 6 charterize sugarcane conservatively. The following table outlines the percentage changes of these comparisons.

	12 compared to 15	6 compared to 16
Net Return/MCU	11% increase	4% increase
Net Return/Farm	76% increase	65% increase
Net Return/ha	76% increase	65% increase
No.of MCU/Farm	58% increase	58% increase

Table IV-1

Net Income (Return) to Labor and Management

	Problem 15	16	6	8	12
A. Characteristics					
1) Sugarcane					
1) ME	NA	NA	Low	Low	Low
2) VI	NA	NA	Low	Low	Low
3) Cost	NA	NA	High	Low	High
2) Pangola Yield	Low	High	High	High	Low
3) No.of MCU at land limit	19	19	30	30	30
4) Land Rental Cost	Low	Low	Low	Low	Low
B. Revenues					
Milk	34200	34200	54000	54000	54000
Bull Calves	570	570	900	900	900
Cull Cows	3762	3762	5940	5940	5940
Sub-Total $	38532	38532	60840	60840	60840
C. Variable Costs					
Fertilizer	3405	4493	4064	3438	3859
Lime	94	94	93	91	93
Crop Chemicals	0	0	204	496	313
Cattle Chemicals	380	380	600	600	600
Drug & Vet Services	570	570	900	900	900
Supplements	6140	3942	9359	7656	9210
Milk Replacer & Calf Starter	353	353	558	558	558
Breeding	76	76	120	120	120
Milk Collection	240	240	240	240	240
Utilities	570	570	900	900	900
Chopper V.C.	0	0	26	63	39
Interest	414	368	597	524	589
Sub-Total $	12242	10896	17661	15486	17421
D. Fixed Costs					
Land	251	251	251	251	251
Fences	1280	1577	1435	1288	1363
Chopper	0	0	444	444	444
Calf Pens	356	356	356	356	356
Milk Barn	490	490	490	490	490
Zero Shed	0	0	475	475	475
Milk Machine	508	508	508	508	508
Bullock & Wagon	0	0	182	182	182
Tools & Sundries	29	29	29	29	29

(cont'd)

Table IV-1 (continued)

	Problem 15	16	6	8	12
Perennial Crops	1572	1572	1604	1644	1630
Cattle	3392	3392	5355	5355	5355
Sub-Total $	7879	8176	11130	10963	11083
E. Net Return/MCU	969	1025	1068	1146	1078
Net Return/Farm	18411	19460	32049	34391	32336
Net Return/ha	2273	2403	3957	4246	3992

Sugarcane utilization will increase Net Return in all these parameters but most significantly on a per farm basis. The positive effect on income in the situation of a severe dry season (LOW Pangola yield) is slightly greater than when the dry season is milder. This is mainly due to the increased carrying capacity of the farms. These results are not unexpected, and if the biological performance coefficients used in even the conservative situations are proven to be correct, there seems little doubt about the usefulness of sugarcane feed at Wallerfield and under similar conditions elsewhere.

11. Forage and Ration Dry Matter

Lastly, and as a test of the ability of the model to formulate rations that are likely to be consumed by cattle, the following tables 3 and 4 describe two important parameters of the formulated rations, and indicate that they are within acceptable limits.

Table IV-2

Net Income (Return)

	Problem 14	13	11	10	9	7	5	4	3	2	1
A. Characteristics											
1) Sugarcane											
1) ME	LOW	LOW	LOW	HIGH	HIGH	HIGH	LOW	HIGH	HIGH	HIGH	HIGH
2) VI	LOW	LOW	HIGH	LOW	HIGH	HIGH	HIGH	LOW	HIGH	LOW	HIGH
3) Cost	HIGH	HIGH	HIGH	HIGH	HIGH	LOW	HIGH	LOW	LOW	HIGH	HIGH
2) Pangola Yield	LOW	HIGH	LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
3) No.of MCU at Land Limit	30	30	30	30+	30+	30+	30	30+	30+	30	30
4) Land Rental Cost	Shadow Price	Shadow Price	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
B. Net Return/MCU	1064	1144	1064	1233	1147	1147	1064	1269	1224	1077	1077
Net Return/Farm	31919	34329	31919	36982	36982	34418	31919	38028	36733	32321	32321
Net Return/ha	3941	4238	3941	4566	4565	4249	3941	4701	4535	3990	3990

Table IV-3

Forage as a Per Cent of Total Ration Dry Matter[1]

	P_1	P_2	P_3
Problem #6			
1 MCU	60%	83%	83%
5 MCU	60	83	83
10 MCU	60	83	83
15 MCU	60	83	83
20 MCU	60	60	60
25 MCU	61	61	61
30 MCU	62	59	59
Mean	60.4	73.1	73.1
Problem #12			
1 MCU	60	60	60
5 MCU	60	60	60
10 MCU	63	60	60
15 MCU	63	60	60
20 MCU	63	60	60
25 MCU	63	60	60
30 MCU	64	59	59
Mean	62.3	59.9	60.0

1 $\frac{\text{Forage DM}}{\text{Total (Ration) DM}} \times 100$

Table IV-4

Ration Dry Matter as a Per Cent of Maximum Dry Matter Intake[2]

Problem #6			
1 MCU	84%	94%	94%
5 MCU	84	94	94
10 MCU	84	94	94
15 MCU	84	94	94
20 MCU	81	84	84
25 MCU	82	82	82
30 MCU	80	80	80
Mean	82.7	88.9	88.9
Problem #12			
1 MCU	84	84	84
5 MCU	84	84	84
10 MCU	79	84	84
15 MCU	79	84	84
20 MCU	79	84	84
25 MCU	79	84	84
30 MCU	78	84	84
Mean	80.3	84.0	84.0

2 $\frac{\text{Ration DM}}{\text{Maximum DM Limit}} \times 100$

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1. Summary

a. Procedure

The technical coefficients and costs of two conventional tropical grasses (Pangola and Napier) have been compared to those for mature, whole plant, chopped sugarcane as cattlefeed. A multi-period, least-cost linear programming model was developed and used to formulate complete rations for dairy cows and replacement heifers at fixed levels of animal performance. This model calculated the optimal combination of forages and concentrates for farms under eight hectares, based upon their variable and fixed costs, increasing sizes of the herd and at NRC nutrient requirements.

The changing availability (and quality) of feedstuffs by season was a major feature of the model. A sensitivity analysis was conducted to determine the effect of variation in the costs and coefficients due to the existing uncertainty of certain parameters. The ration formulations were used as the basis to calculate Net Returns for many feeding programs in an effort to determine the plan(s) which maximized income.

b. Results

From the ration formulation and net income analyses, the following results were obtained:

- Under conditions where the effect of the dry season was large (low yield of pasture), Napier grass was used as a substitute for pasture. It was determined that 30% of the total acreage of cropped land was used for Napier grass with the balance as Pangola pasture (in the dry season only). This least cost ration formulation will support one milk cow unit per acre with protein supplementation as required by NRC standards (problem 15).
- Because of fixed costs associated with any sugarcane feeding system, a threshold level (number of cows) must be reached before sugarcane enters a cost effective ration. This threshold level varied from five to ten cows depending mainly upon the yield of Pangola pasture in the dry season.
- Under severe dry season conditions (problem 14), sugarcane readily substituted for Napier grass at the threshold level of five to ten cows. At a scale of operation below this threshold level, Napier grass substituted for sugarcane in least-cost rations (problem 12).
- The cost of production of sugarcane feed (or its opportunity cost where a sugar-production market exists)

determined the composition of least-cost rations independent of other factors

- Variation in the energy and intake characteristics of sugarcane feed under some least-cost ration conditions affected the composition of least-cost rations
- The use of sugarcane in least-cost rations greatly increased net income per farm and per hectare (by up to 76%) but only slightly increased net return per cow. The use of sugarcane greatly increased the carrying capacity of fixed-size farms.

2. Conclusions

a. Major Conclusions

On the basis of the analyses and noting the many assumptions and uncertainties indicated in the text, the following major conclusions can be drawn:

- The cost of production (or opportunity cost if appropriate) of sugarcane is critically important in the determination of how much, if any, sugarcane should be used as cattle feed in least-cost rations.
- The yield and particularly the fluctuation in pasture yield due to seasonal changes in rainfall, determine the usefulness of sugarcane in general and in least-cost rations, as the grazing of pasture grasses is a lower

cost means of feeding cattle compared to zero-grazing sugarcane.

- The scale of operation, ie number of cows and heifers, per farm unit must be determined before sugarcane should be utilized in least-cost rations because of the fixed costs associated with the feeding of even the smallest amount of sugarcane. Units with a small number of cattle may not warrant these fixed expenditures. This 'threshold' level varies markedly from situation to situation.
- The utilization of sugarcane as cattle feed, when properly supplemented, offers the opportunity to greatly increase the carrying capacity of a given unit of land. In situations where arable land is a limiting resource, sugarcane feed should be particularly considered.
- Under a wide range of conditions sugarcane feeding results in slightly increased net return per cow, and markedly increased net returns per farm and per hectare. The improvement in net return by the use of sugarcane compared to the existing system may be independent of the use of least-cost rations, ie using sugarcane feed in non-least-cost rations may also result in increased net return/farm, compared to the existing production system.

b. Minor Conclusions

In addition the following minor conclusions can be drawn:

- The uncertainty due to lack of information concerning the energy value and voluntary intake of sugarcane feed are important limiting factors to accurate economic analyses.
- The rental value or cost of owning land will influence the choice of a feeding system and should be considered in planning a dairy operation.

3. Recommendations

a. General

Most of the situations investigated in the analysis indicate that sugarcane feeding in the dry season is economically viable. However, there is considerable uncertainty surrounding several important factors that require further investigation:

- The technical coefficients used in the analyses must be confirmed and expanded (eg under a variety of conditions, as such biological research should be undertaken to definitively characterize all aspects of sugarcane feeding.
- Biological research should be undertaken wherever

sugarcane is a potential feed, to determine the quality and quantity of pasture grasses that would be available in both wet and dry seasons.

b. Wallerfield

In regard to Wallerfield milk producers specifically, the data suggest that sugarcane feed be used in the dry season at a scale of operation of 15-20 cows or more per eight-hectare unit on a least-cost ration basis.

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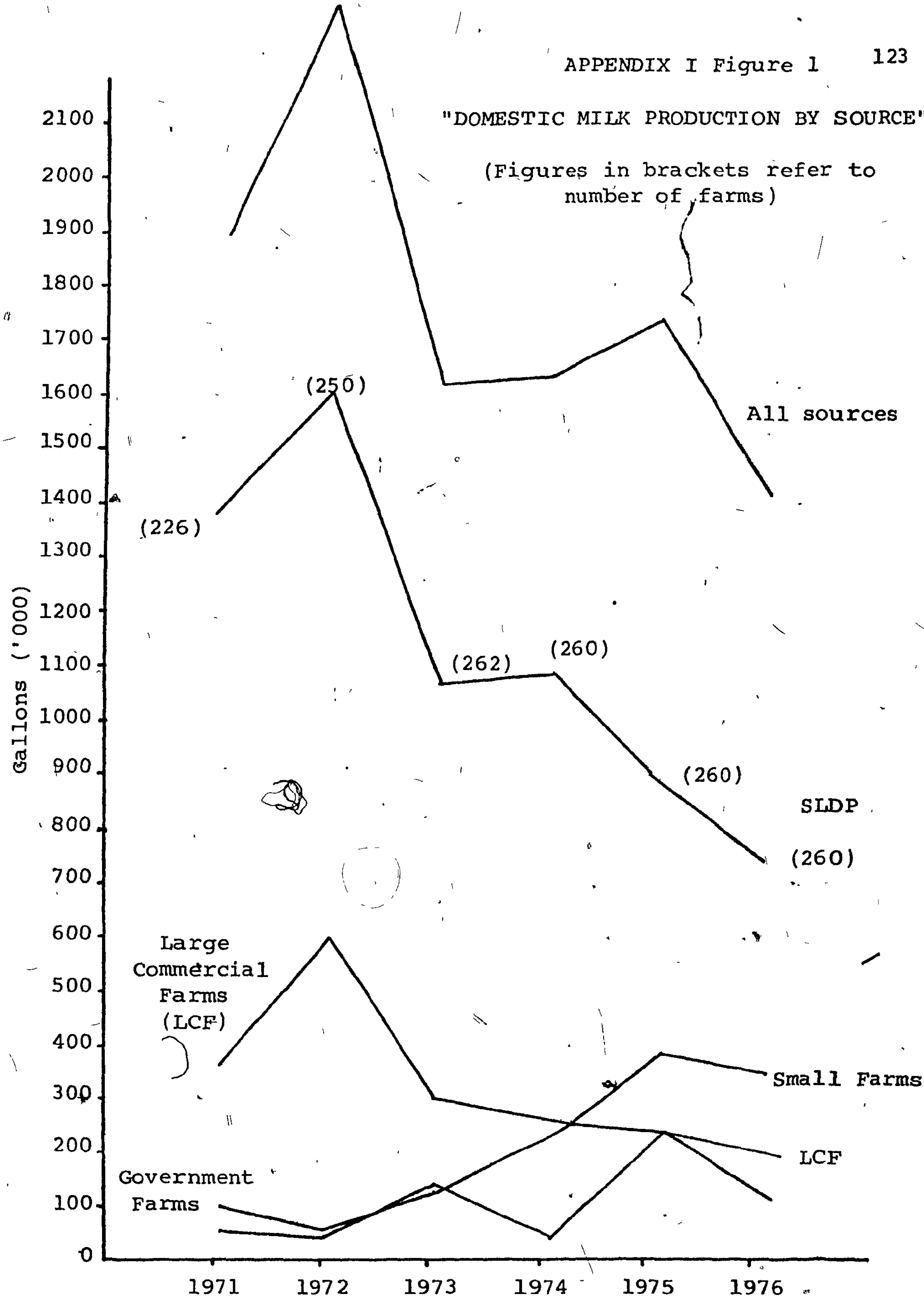
APPENDIX I Figure 1

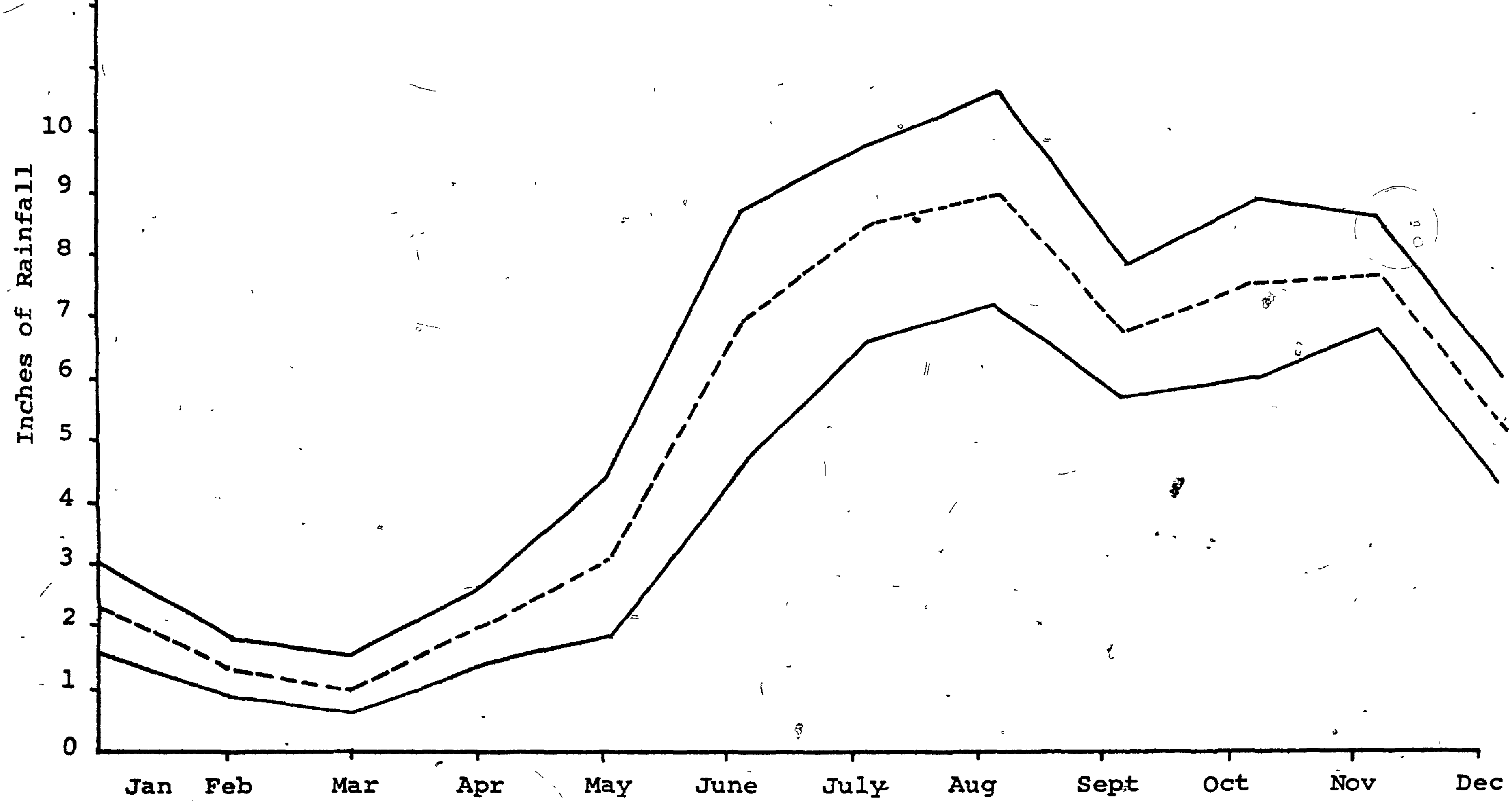
"DOMESTIC MILK PRODUCTION BY SOURCE"

(Figures in brackets refer to number of farms)



APPENDIX I Figure 2

Average Rainfall by Month for Years 1954-55
to 1975-76 inclusive at St. Augustine, Trinidad
(Mean and 95% Confidence Limits)



Source: Recorded at UWI Field Station, Trinidad.

APPENDIX I TABLE 1

PRODUCTION AND TRADE IN LIVESTOCK PRODUCTS AND UREA AND MOLASSES - TRINIDAD AND TOBAGO

YEAR	BEEF/VEAL		MUTTON		MILK/MILK PRODUCTS		UREA		MOLASSES	
	Production	Imports	Production	Imports	Production	Imports	Production	Exports	Production	Exports
	'000 lb	'000 lb	'000 lb	'000 lb	'000 gal	'000$TT	Stons	Stons	'000 lb	'000$TT
1971	3506	6,235	51	1,286	1838.8	19,894.9	62,169	61,726	159,686	2,878
1972	3244	7,450	106	1,537	2266.3	24,853.8	72,940	73,526	124,120	2,241
1973	3444	5,849	107	1,050	1591.6	25,999.1	82,702	78,373	120,830	5,871
1974	3236	4,949	118	1,466	1601.3	36,200.0	78,978	81,929	74,254	5,423
1975	2707	10,119	117	1,423	1702.9	40,118.9	71,100	68,172	56,043	2,288
1976	2858	13,569	172	1,844	1390.1	35,034.8	74,254	74,240	123,471	7,892

Source: QER, 1976, Tables 22 and 23.

QAR, 1976, Tables 26 and 52.

APPENDIX I TABLE 2

CLIMATE OF TRINIDAD AND TOBAGO

(5 Year Average)
1972 - 1976

Month	Air Temp °F Max	Air Temp °F Min	Soil Temp °F at 1 Foot	Rel.Humidity % 9:00 a.m.	Rel.Humidity % Min	Open Pan Evaporation in Inches
January	85	68	77.2	73	64	3.97
February	86	67	77.8	75	62	4.32
March	86	68	79.4	73	62	5.33
April	87	69	81.1	71	62	5.59
May	88	70	82.5	69	63	6.24
June	87	72	81.3	75	67	5.08
July	87	71	80.6	77	66	4.73
August	87	71	80.5	78	68	4.23
September	88	70	81.0	78	67	4.20
October	88	71	80.8	79	69	4.11
November	87	71	79.5	80	68	3.71
December	86	69	77.6	79	68	3.54

Source: Unpublished data of UWI, recorded at UWI Field Station, Trinidad.

APPENDIX I TABLE 3A

Daily Nutrient Requirements for a 450 kg Milking Cow Yielding 9.4 kg of Milk (3.5% Fat)

Nutrient Name	Nutrient Type of Requirement	For Maintenance	For Production	Total Sum	Total Plus 10%
ME	≥	12.3	10.0	22.3	24.5
DP	≥	0.275	0.451	0.726	0.799
DMI	≤	13.5	13.5	13.5	-

APPENDIX I TABLE 3B

Daily Nutrient Requirements of 3 Categories of Heifers of MCU at 0.25 ADG

Name	Nutrient Name	Nutrient Type of Requirement	Total Requirement	No. of Animals Units/MCU	Total Requirement per MCU	Total Plus 10%
Calf - 100 kg	ME	≥	6.3	0.3	1.9	2.09
	DP	≥	0.230		0.069	0.076
	DMI	≤	2.9		0.87	
Yearling - 200 kg	ME	≥	9.5	0.3	2.85	3.14
	DP	≥	0.276		0.083	0.091
	DMI	≤	4.6		1.38	
Replacement - 300 kg	ME	≥	12.8	0.2	2.56	2.82
	DP	≥	0.322		0.064	0.070
	DMI	≤	6.2		1.24	

APPENDIX I TABLE 4A

Establishment Costs of Sugarcane per Acre

	Unit/Cost ($)	Total Cost	Dep.[1]	Cost per Period
Fertilizer	5 cwt at 23.30	116.50	4 yrs	29.13
Lime	2 tons at 4.90	9.80	4 yrs	2.45
Brushcutting	25.00 per acre	25.00	4 yrs	6.25
Banking/ploughing	45.00 per acre	45.00	4 yrs	11.25
Rotovating	25.00 per acre	25.00	4 yrs	6.25
Transport	20.00 per load	20.00	4 yrs	5.00
Planting labour (hired)	84.00 per acre	84.00	4 yrs	21.00
Fertilizing labour (hired)	2 times at 3.80/acre	7.60	4 yrs	1.90
Liming[2] labour (hired)	Once at 9.50/acre	9.50	4 yrs	2.38
Sub-total		342.40		85.61
7 per cent interest on half of 342.40				11.98
Total Establishment Costs				97.59

[1]Depreciation - straight-line method used throughout these analyses.

[2]Liming - refers to the application of lime.

APPENDIX I TABLE 4B

Fixed Costs of Sugarcane*

	Total Cost	Dep. in Years	Annual Cost
Chopper	$ 1,500	10*	150.00
5 H.P. Gasoline Motor	900	15	60.00
Wagon	500	15	33.33
Bullock (Buffalo)	600	12	50.00
Sub-Total	3,500		293.33
Interest of half of 3,500 at 7 per cent			122.50
Total Fixed Cost			415.83

*Assumes daily use throughout the year, otherwise depreciation (Dep.) would be over a proportionally longer period e.g., if chopper is used only 4 months of the year it may be expected to be depreciated over a period considerably longer than 10 years.

APPENDIX I TABLE 5

Operating Costs of Sugarcane per acre

Item	Unit/Cost ($)	Season of Cutting and Feeding P_1-Dry	P_2-Wet	P_3-Wet
Fertilizer (15-10-5)	5 cwt/at 23.30	116.50	116.50	116.50
Lime	1 ton at 4.90	4.90	4.90	4.90
Land Rent	12.00 per acre/year	12.00	12.00	12.00
Fertilizing Labour	once at 3.80/acre	3.80	3.80	3.80
Liming Labour	Once at 9.50/acre	9.50	9.50	9.50
Chemicals	64.00/acre	64.00	64.00	64.00
Moulding & Manual Weed Control	8 man-days/19.00	152.00	152.00	152.00
Pest Control Labour	4 man-days/19.00	76.00	76.00	76.00
Weeding Labour (chemical)	2 man-days/19.00	38.00	38.00	38.00
Cane Cutting	5.2 man-days/19.00	98.80	123.50[2]	123.50[2]
Cane Hauling to Chopper	3.4 man-days/19.00	64.60	80.75[2]	80.75[2]
Chopping labour	4.1 man-days/19.00	77.90	77.90	77.90
Chopper M/R		5.00	5.00	5.00
Chopper Operating cost		8.10	8.10	8.10
	Sub-total	731.11	771.95	771.95
7 per cent interest on half of operating capital		25.59	27.02	27.02
Total operating costs per acre by season		756.70	798.97	798.97

[1]Refers to cultivation and processing of 1 acre of sugarcane for feeding in Period 1 (January-April inclusive).

[2]Assume 25 per cent increase in labour cost for P_2 and P_3 cutting/processing (P_2-May-August inclusive, P_3-September-December inclusive).

APPENDIX I TABLE 6

Establishment and Operating Costs of
Pangola Pasture Per Acre

	Unit/Cost $	Total	Dep. in Years	P_1	P_2	P_3
A. <u>Establishment Costs</u>						
Fertilizer	5 cwt at 23.30	116.50	5 yrs	7.77*	7.77	7.77
Lime	2 tons at 4.90	9.80	5 yrs	0.65	0.65	0.65
Fencing	269.00/acre	269.00	12 yrs	7.47	7.47	7.47
Brushcutting	25.00/acre	25.00	5 yrs	1.66	1.66	1.66
Rotovating	30.00/acre	30.00	5 yrs	2.00	2.00	2.00
Transport	1 load at 20.00	20.00	5 yrs	1.33	1.33	1.33
Planting labour	84.00/acre	84.00	5 yrs	5.60	5.60	5.60
Fertilizing labour	twice at 3.80/acre	7.60	5 yrs	0.51	0.51	0.51
Liming labour	once at 9.50/acre	9.50	5 yrs	0.63	0.63	0.63
Sub-total		571.40		27.62	27.62	27.62
7 per cent interest on half of 571.40		20.00		6.67	6.67	6.67
Total Establishment Costs/ acre (102.87/acre/year)				34.29	34.29	34.29
B. <u>Operating Costs</u> (Annual)						
Fertilizer (15-10-5)	10 cwt. at 23.30	233.00		77.67	77.67	77.67
Lime	1 ton at 4.90	4.90		1.63	1.63	1.63
Brushcutting	twice at 25.00/acre	50.00		16.67	16.67	16.67
Land Rent	12.00/acre	12.00		4.00	4.00	4.00
M.R Fences	5%/acre	13.45		4.48	4.48	4.48
Fertilizing labour	3 times at 3.80/acre	11.40		3.80	3.80	3.80
Liming labour	once at 9.50/acre	9.50		3.17	3.17	3.17
Pasture Management	1 man-day	19.00		6.33	6.33	6.33
Sub-total		353.25		117.75	117.75	117.75
7 per cent interest on half of 353.25		12.36		4.12	4.12	4.12
<u>Total Operating Cost/acre/year</u>				121.87	121.87	121.87

*$116.50 ÷ 5 years = 23.30 ÷ 3 periods = $7.77/period

APPENDIX I TABLE 7

Establishment and Operating Costs of Napier Grass

	Unit/Cost ($)	Total	Dep. in Years	Per Year[1]
A. Establishment Costs				
Fertilizer (15-10-5)	5 cwt at 23.30	116.50	5	23.30
Lime	2 tons at 4.90	9.80	5	1.96
Brushcutting	25.00/acre	25.00	5	5.00
Banking/ Ploughing	45.00/acre	45.00	5	9.00
Rotovating	30.00/acre	30.00	5	6.00
Transport	1 load at 20.00	20.00	5	4.00
Planting labour	84.00/acre	84.00	5	16.80
Fertilizing labour	twice at 3.80/acre	7.60	5	1.52
Liming labour	once at 9.50/acre	9.50	5	1.90
Sub-total		347.50		69.48
7 per cent interest on half of 347.50				12.16
Total Establishment Costs				81.64
B. Operating Costs				
Fertilizer (15-10-5)	3½ cwt. at 23.30			81.55
Lime	1 ton at 4.90			4.90
Brushcutting	twice at 25.00/acre			50.00
Land Rent	12.00/acre			12.00
Fertilizing labour	once at 3.80/acre			3.80
Liming labour	once at 9.50/acre			9.50
Cutting labour	2.7 man days at 19.00/man day			51.30
Hauling labour[2]	4.2 man days at 19.00/man day			79.80
Sub-total				292.85
7 per cent interest on half of 292.85				10.25
Total Operating Costs				303.10

[1]NG cost per year is actually the cost for period 1 - it is utilized in the dry season only.

[2]Includes cutting by cutlass into quite small pieces suitable for feeding to cattle.

APPENDIX II TABLE 1

Least-cost feeding program under following conditions:
HIGH sugarcane cost, HIGH sugarcane Voluntary Intake
HIGH sugarcane ME, HIGH Pangola yield.

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0	0.41	0	562	137	0	0.41	3	321	0	0	0.41	3	321	0	676	0.41
5	0	0	2.02	0	2812	685	0	2.02	12	1608	0	0	2.02	12	1608	0	676	0.40
10	0	0	4.05	0	5623	1370	0	4.05	25	3215	0	0	4.05	25	3215	0	676	0.41
15	0	0	6.07	0	8435	2055	0	6.07	37	4823	0	0	6.07	37	4823	0	676	0.41
20	0.38	0	5.15	42	12996	0	0	5.15	0	11260	2730	0	5.15	0	11260	2730	682	0.28
25	0.48	0	6.44	53	16244	0	0	6.44	0	14076	3413	0	6.44	0	14076	2604	678	0.28
30	0.75	0	6.41	139	18754	0	0.27	6.41	0	18934	1512	0.27	6.41	0	18934	1512	676	0.26

APPENDIX II, TABLE 2

Least-cost feeding program under following conditions:
HIGH sugarcane cost, LOW sugarcane Voluntary Intake,
HIGH sugarcane ME, HIGH Pangola yield.

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0	0.41	0	562	137	0	0.41	3	322	0	0	0.41	3	322	0	676	0.41
5	0	0	2.02	0	2812	685	0	2.02	12	1608	0	0	2.02	12	1608	0	676	0.40
10	0	0	4.05	0	5623	1370	0	4.05	25	3215	0	0	4.05	25	3215	0	676	0.41
15	0	0	6.07	0	8435	2055	0	6.07	37	4823	0	0	6.07	37	4823	0	676	0.41
20	0.38	0	5.15	43	12996	0	0	5.15	0	11260	2730	0	5.15	0	11260	2730	682	0.28
25	0.48	0	6.44	53	16245	0	0	6.44	0	14076	3413	0	6.44	0	14166	2604	678	0.28
30	0.75	0	6.41	139	18754	0	0.27	6.41	0	18933	1512	0.27	6.41	0	18933	1512	676	0.26

APPENDIX II, TABLE 3

Least-cost feeding program under following conditions:
LOW sugarcane cost, HIGH Voluntary Intake,
HIGH sugarcane ME, HIGH Pangola yield

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0	0.41	0	562	137	0	0.41	3	322	0	0	0.41	3	322	0	676	0.41
5	0	0	2.02	0	2812	685	0	2.02	12	1608	0	0	2.02	12	1608	0	676	0.40
10	0.67	0	0.04	270	2487	0	0.52	0.04	164	5092	0	0.52	0.04	164	5092	0	648	0.18
15	1.00	0	0.07	405	3730	0	0.78	0.07	246	7638	0	0.78	0.07	246	7638	0	634	0.18
20	1.33	0	0.09	540	4973	0	1.04	0.09	328	10184	0	1.04	0.09	328	10184	0	627	0.18
25	1.66	0	0.36	675	6006	0	1.25	0.36	388	12949	0	1.30	0.36	424	12036	0	624	0.18
30	2.01	0	0.13	810	7460	0	1.56	0.13	492	15276	0	1.56	0.13	492	15276	0	620	0.18

APPENDIX II, TABLE 4

Least-cost feeding program under following conditions:
LOW sugarcane cost, LOW sugarcane Voluntary Intake,
HIGH sugarcane ME, HIGH Pangola yield.

	SEASON																		
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0.0	0	0.41	0	562	137	0	0.41	3	322	0	0	0.41	3	322	0	676	0.41
5	0	0	2.02	0	2812	685	0	2.02	12	1608	0	0	2.02	12	1608	0	676	0.40
10	0.62	0	0.04	235	3349	0	0.52	0.04	164	5092	0	0.52	0.04	164	5092	0	648	0.17
15	0.93	0	0.07	353	5023	0	0.78	0.07	246	7638	0	0.78	0.07	246	7638	0	634	0.17
20	1.24	0	0.09	470	6697	0	1.04	0.09	328	10184	0	1.04	0.09	328	10184	0	627	0.17
25	1.55	0	0.36	597	7930	0	1.24	0.36	388	12949	0	1.30	0.36	388	12036	0	625	0.18
30	1.86	0	0.13	706	10045	0	1.56	0.13	492	15276	0	1.56	0.13	492	15276	0	620	0.17

APPENDIX II, TABLE 5

Least-cost feeding program under following conditions: HIGH sugarcane cost, HIGH sugarcane Voluntary Intake, LOW sugarcane ME, HIGH Pangola yield.

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0	0.41	0	562	137	0	0.41	3	322	0	0	0.41	3	322	0	676	0.41
5	0	0	2.02	0	2812	685	0	2.02	12	1608	0	0	2.02	12	1608	0	676	0.40
10	0	0	4.04	0	5623	1370	0	4.04	26	3215	0	0	4.04	26	3215	0	676	0.41
15	0	0	6.07	0	8435	2055	0	6.07	37	4823	0	0	6.07	37	4823	0	676	0.41
20	0.38	0	5.15	43	12996	0	0	5.15	0	11260	2730	0	5.15	0	11260	2730	682	0.28
25	0.45	0	6.69	39	16384	0	0	6.69	0	13781	3091	0	6.69	0	13781	3091	679	0.29
30	0.75	0	6.41	139	18754	0	0.27	6.41	0	18712	2471	0.27	6.41	0	18712	2471	684	0.27

APPENDIX II, TABLE 6

Least-cost feeding program under following conditions:
HIGH sugarcane cost, LOW sugarcane Voluntary Intake,
LOW sugarcane ME, HIGH Pangola yield.

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0	0.41	0	562	137	0	0.41	3	322	0	0	0.41	3	322	0	676	0.41
5	0	0	2.02	0	2818	685	0	2.02	12	1608	0	0	2.02	12	1608	0	676	0.40
10	0	0	4.05	0	5623	1370	0	4.05	25	3215	0	0	4.05	25	3215	0	676	0.41
15	0	0	6.07	0	8435	2055	0	6.07	37	4823	0	0	6.07	37	4823	0	676	0.41
20	0.38	0	5.15	43	12996	0	0	5.15	0	11260	2730	0	5.15	0	11260	2730	682	0.28
25	0.45	0	6.69	39	16384	0	0	6.69	0	13781	3091	0	6.69	0	13781	3091	679	0.29
30	0.75	0	6.41	139	18754	0	0.27	6.41	0	18712	2471	0.27	6.41	0	18712	2471	684	0.27

APPENDIX II, TABLE 7

Least-cost feeding program under following conditions: LOW sugarcane cost, HIGH sugarcane Voluntary Intake, LOW sugarcane ME, HIGH Pangola yield.

	SEASON																		
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0	0.41	0	562	137	0	0.41	0	322	3	0	0.41	3	322	0	676	0.41
5	0	0	2.02	0	2812	685	0	2.02	12	1608	0	0	2.02	12	1608	0	676	0.40
10	0	0	4.05	0	5623	1370	0	4.05	25	3215	0	0	4.05	25	3215	0	676	0.41
15	0.89	0	2.20	405	1918	0	0.34	2.20	0	10742	0	0.34	2.20	0	10742	0	676	0.25
20	1.19	0	2.94	540	2558	0	0.46	2.94	0	14322	0	0.46	2.94	0	14322	0	669	0.25
25	1.46	0	4.18	675	2765	0	0.46	4.18	0	17199	627	0.52	4.18	0	17248	0	666	0.25
30	1.78	0	4.40	810	3837	0	0.68	4.40	0	21483	0	0.68	4.40	0	21483	0	662	0.25

APPENDIX II, TABLE 8

Least-cost feeding program under following conditions:
LOW sugarcane cost, LOW sugarcane Voluntary Intake,
LOW sugarcane ME, HIGH Pangola yield.

	SEASON																		
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No.of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Co-st/MCU	Land per MCU
1	0	0	0.41	0	562	137	0	0.41	3	322	0	0	0.41	3	322	0	676	0.41
5	0	0	2.02	0	2812	685	0	2.02	12	1608	0	0	2.02	12	1608	0	676	0.40
10	0	0	4.05	0	2623	1370	0	4.05	25	3215	0	0	4.05	25	3215	0	676	0.41
15	0.89	0	2.20	405	1918	0	0.34	2.20	0	10742	0	0.34	2.20	0	10742	0	676	0.25
20	1.19	0	2.94	540	2558	0	0.46	2.94	0	14322	0	0.46	2.94	0	14322	0	669	0.25
25	1.46	0	4.18	675	2765	0	0.46	4.18	0	17199	627	0.52	4.18	0	17247	0	666	0.25
30	1.78	0	4.40	810	3837	0	0.68	4.40	0	21483	0	0.68	4.40	0	21483	0	662	0.25

APPENDIX II, TABLE 9

Least-cost feeding program under following conditions:
HIGH sugarcane cost, HIGH sugarcane Voluntary Intake,
HIGH sugarcane ME, LOW Pangola yield.

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0.15	0.26	0	562	137	0	0.26	0	563	137	0	0.26	0	563	137	761	0.41
5	0.26	0	0.02	83	2534	0	0.26	0.02	82	2546	0	0.26	0.02	82	2546	0	759	0.16
10	0.53	0	0.04	166	5067	0	0.52	0.04	164	5092	0	0.52	0.04	164	5092	0	718	0.16
15	0.79	0	0.07	250	7601	0	0.78	0.07	246	7638	0	0.78	0.07	246	7638	0	704	0.16
20	1.05	0	0.09	333	10134	0	1.04	0.09	328	10184	0	1.04	0.09	328	10184	0	697	0.16
25	1.30	0	0.36	408	12747	0	1.25	0.36	388	12948	0	1.30	0.36	425	12036	0	694	0.17
30	1.58	0	0.13	499	15201	0	1.56	0.13	492	15276	0	1.56	0.13	492	15276	0	690	0.16

APPENDIX II, TABLE 10

Least-cost feeding program under following conditions:
HIGH sugarcane cost, LOW sugarcane Voluntary Intake,
HIGH sugarcane ME, LOW Pangola yield.

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No.of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0.15	0.26	0	562	137	0	0.26	0	563	137	0	0.26	0	563	137	761	0.41
5	0.26	0	0.02	83	2534	0	0.26	0.02	82	2546	0	0.26	0.02	82	2546	0	760	0.16
10	0.53	0	0.04	166	5067	0	0.52	0.04	164	5092	0	0.52	0.04	164	5092	0	718	0.16
15	0.79	0	0.07	250	7601	0	0.78	0.07	246	7638	0	0.78	0.07	246	7638	0	704	0.16
20	1.05	0	0.09	333	10134	0	1.04	0.09	328	10184	0	1.04	0.09	328	10184	0	697	0.16
25	1.30	0	0.36	408	12747	0	1.25	0.36	388	12949	0	1.30	0.36	424	12036	0	694	0.17
30	1.58	0	0.13	499	15201	0	1.56	0.13	492	15276	0	1.56	0.13	492	15276	0	690	0.16

APPENDIX II, TABLE 11

Least-cost feeding program under following conditions:
HIGH sugarcane cost, HIGH sugarcane Voluntary Intake,
LOW sugarcane ME, LOW Pangola yield.

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0.15	0.26	0	562	137	0	0.26	0	563	137	0	0.26	0	563	137	761	0.41
5	0	0.73	1.29	0	2812	685	0	1.29	0	2815	683	0	1.29	0	2815	683	761	0.40
10	0.34		2.58	84	5878	0	0	2.58	0	5630	1365	0	2.58	0	5630	1365	734	0.29
15	0.51	0	3.86	127	8817	0	0	3.86	0	8445	2048	0	3.86	0	8445	2048	720	0.29
20	0.67	0	5.15	169	11757	0	0	5.15	0	11260	2730	0	5.15	0	11260	2730	713	0.29
25	0.84	0	6.44	211	14696	0	0	6.44	0	14076	5413	0.05	6.44	0	14124	2785	710	0.29
30	1.16	0	5.71	319	16989	0	0.41	5.71	0	19677	1611	0.41	5.71	0	19677	1611	713	0.26

APPENDIX II, TABLE 12

Least-cost feeding program under following conditions:
HIGH sugarcane cost, LOW sugarcane Voluntary Intake,
LOW sugarcane ME, LOW Pangola yield.

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0.15	0.26	0	562	137	0	0.26	0	563	137	0	0.26	0	563	137	761	0.41
5	0	0.73	1.29	0	2812	685	0	1.29	0	2815	683	0	1.29	0	2815	683	761	0.40
10	0.34	0	2.58	84	5878	0	0	2.58	0	5630	1365	0	2.58	0	5630	1365	734	0.29
15	0.51	0	3.86	127	8817	0	0	3.86	0	8445	2048	0	3.86	0	8445	2048	720	0.29
20	0.67	0	5.15	169	11757	0	0	5.15	0	11260	2730	0	5.15	0	11260	2730	713	0.29
25	0.84	0	6.44	211	14696	0	0	6.44	0	14076	3413	0.05	6.44	0	14124	2785	711	0.29
30	1.16	0	5.71	319	16989	0	0.41	5.71	0	19677	1611	0.41	5.71	0	19677	1611	713	0.26

APPENDIX II TABLE 13

Least-cost feeding program under following conditions: HIGH Sugarcane cost, Low sugarcane Voluntary Intake, LOW sugarcane ME, HIGH Pangola yield, and a Shadow Price for Land

	SEASON																AVERAGE	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)						
No. of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0	0.41	0	562	137	0	0.41	3	322	0	0	0.41	3	322	0	744	0.41
5	0	0	2.02	0	2812	685	0	2.02	12	1608	0	0	2.02	12	1608	0	744	0.40
10	0	0	4.05	0	5623	1370	0	4.05	25	3215	0	0	4.05	25	3215	0	744	0.40
15	0.29	0	3.86	32	9745	0	0	3.86	0	8445	2048	0	3.86	0	8445	2048	735	0.28
20	0.38	0	5.15	43	12996	0	0	5.15	0	11260	2730	0	5.15	0	11260	2730	729	0.28
25	0.48	0	6.44	53	16245	0	0	6.44	0	14076	3413	0.05	6.44	0	14124	2785	726	0.28
30	0.75	0	6.41	139	18754	0	0.27	6.41	0	18712	2471	0.27	6.41	0	18712	2471	728	0.26

APPENDIX II, TABLE 14

Least-cost feeding program under following conditions:
HIGH sugarcane cost, LOW sugarcane Voluntary Intake,
LOW sugarcane ME, LOW Pangola yield,
and a SHADOW PRICE for Land.

	SEASON																AVERAGE	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)						
No.of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1	0	0.15	0.26	0	562	137	0	0.26	0	563	137	0	0.26	0	563	137	829	0.41
5	0.17	0	1.29	42	2939	0	0	1.29	0	2815	683	0	1.29	0	2815	683	825	0.29
10	0.34	0	2.58	84	5878	0	0	2.58	0	5630	1365	0	2.58	0	5630	1365	783	0.29
15	0.51	0	3.86	127	8817	0	0	3.86	0	8445	2048	0	3.86	0	8445	2048	769	0.29
20	0.67	0	5.15	169	11757	0	0	5.15	0	11260	2730	0	5.15	0	11260	2730	762	0.29
25	0.84	0	6.44	211	14696	0	0	6.44	0	14076	3413	0.05	6.44	0	14124	2785	760	0.29
30	1.16	0	5.71	319	16989	0	0.41	5.71	0	19677	1611	0.41	5.71	0	19677	1611	756	0.26

APPENDIX II, TABLE 15

Least-cost feeding program under following conditions:
LOW Pangola yield and EXCLUDING sugarcane,
a 'CONTROL'

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No.of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1		0.15	0.26	0	562	137		0.26	0	563	137		0.26	0	563	137	761	0.41
5																		
10																		
15		2.20	3.86	0	8436	2054		3.86	0	8445	2048		3.86	0	8445	2048	761	0.40
20																		
25																		
30																		

APPENDIX II, TABLE 16

Least-cost feeding program under following conditions:
HIGH Pangola yield and EXCLUDING sugarcane,
a 'CONTROL'

	SEASON																	
	PERIOD 1 (DRY)						PERIOD 2 (WET)					PERIOD 3 (WET)					AVERAGE	
No.of MCU	Sugarcane ha	Napier Grass ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Sugarcane ha	Pangola Grass ha	Urea kg	Wheat Middlings kg	Molasses kg	Least Cost/MCU	Land per MCU
1		0	0.41	0	562	137		0.41	3	322	0		0.41	3	322	0	676	0.41
5																		
10																		
15		0	6.07	0	8435	2055		6.07	37	4823	0		6.07	37	4823	0	676	0.40
20																		
25																		
30																		