EFFECTS OF BURNING ON DIET QUALITY AND ASSOCIATED PRODUCTION SYSTEMS OF CATTLE AND GOATS IN *ACACIA* SAVANNAHS OF KENYA

A Thesis

by

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ABSTRACT

Effects of Burning on Diet Quality and Associated Production Systems of Cattle and Goats in *Acacia* Savannahs of Kenya. (December 1984)

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A one-year study on the seasonal effects of burning on the dietary nutrition of cattle and goats was conducted at Kiboko from March 1982 to March 1983. Four esophageally fistulated heifers and two goats were utilized to collect diet samples from two adjacent burned and unburned paddocks. Pre-burn and post-burn herbaceous plant species frequency and density were evaluated in both paddocks. Post-burn shrub/woody plant species were evaluated for density and canopy parameters. Diet samples were subjected to laboratory analysis for crude protein (CP) and organic matter digestibility (OMD). Digestible energy was calculated.

Burning did not significantly affect the frequency and density of most of the important forage species but enhanced species diversity and density of forbs and subshrubs at the expense of some desirable forage grasses. Burning enhanced the regeneration of some important browse species.

The highest diet quality values for cattle occurred during the wet seasons, while the dry seasons had the lowest values. Burning enhanced dietary CP content during the wet seasons and into the early part of the dry seasons. Also, burning had positive effects on dietary OMD during the wet seasons but for shorter durations.

The seasonal trend of dietary quality contents for goats was similar to that of cattle but the seasonal variations were not as dramatic as in cattle. Burning had detectable positive effects on dietary CP and OMD of goat diets during the wet season only.

A cattle nutritional profiles model for Sahiwal, Boran and small East African shorthorn zebu breeds with January, May and October mean calving dates was run to estimate daily CP and net energy (NE) balances at selected production levels and rainfall conditions. For above average rainfall conditions and unlimited forage availability, the heavier, higher milk-yield breeds benefited more than the lighter breeds, and the October mean calving date was more preferable. Under low rainfall conditions, there were many months of NE deficits, where the heavier Sahiwal had higher deficits than the Boran and zebu during lactation periods. No calving date was definitively better than the others because of prolonged NE deficits.

DEDICATION

To Kairuthi and those dearest to me.

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

Page

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF APPENDIX TABLES

LIST OF APPENDIX TABLES (continued)

LIST OF FIGURES

INTRODUCTION

Kenya is approximately 582,646 km^2 in size. Eighty percent of the country is classified as rangeland, supporting about 60% of the country's estimated 9.8 million cattle (Bernstein and Jacobs 1983), 70% of the estimated 8.5 million sheep and goats (Pratt and Gwynne 1977), 1.0 million camels and a considerable wildlife population (Ayuko 1978, Bernstein and Jacobs 1983). Currently all the livestock and wildlife on the rangeland depend almost entirely on the natural vegetation for their nutritional requirements for growth and production.

Kenya has limited exploited mineral resources, hence agriculture and tourism are the mainstay of the economy. Most of Kenya's rangelands receive less than 500 mm annual rainfall, and of the total land area, only 10% receives in excess of 1,000 mm annual rainfall (Morgan 1969). This 10% is the high potential agricultural land, where the bulk of the human population is concentrated and involved in intensive crop and livestock agriculture (Mutoka 1981).

In the last two decades, Kenya's population has had a sharp increase from approximately 8 million in 1962 to 15.8 million in 1980. This increase in population has increased the demand for food and, therefore, the demand for land and intensified agricultural production. This demand has necessitated the farming of marginal areas (semi-arid rangelands).

Prior to the recent and on-going land demarcation, consolidation and settlement programs, the majority of the range areas in Kenya were

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Citations in this thesis follow the form and style of the *Journal of Range Management*.

under communal grazing, usually overgrazed, and fire was an integral part of the pastoral livestock production system. In the Kenya National Livestock Development Policy (1980), an observation was made that "despite warnings as far back as 1929 on the overstocking conditions in pastoral areas, no satisfactory solution has been found to this problem yet." The above observation statement underscores the fact that grazing management, particularly in the pastoral areas, has not had a deserved serious consideration. Most of the range areas have been and are being subjected to overgrazing or to management systems that may or may not be beneficial to the grazing animals and sustained maximum rangeland productivity.

Fire has been a recurrent phenomenon in the development and maintenance of grazing lands in East Africa. Most of the intentional burning had been carried out during the dry periods in the traditional agricultural and animal husbandry patterns of the tribes of East Africa. Their goal was to extend grass growth into the dry season, encourage seed germination, remove dead herbage and check woody species (Lemon 1968, Ndawulu-Seyimba 1972, Harrington and Ross 1974, Kinyamario 1982).

Dense stands of bush severely reduce herbaceous production of rangelands and also much of the browse forage may not be easily accessible to the grazing livestock (Thomas and Pratt 1967), hence reducing forage production of rangelands. Afolayan (1978) observed that certain grass species are maintained in the habitat by burning and grazing while complete protection from burning and grazing enhances the growth of unpalatable grasses and shrubs. A monitoring program in the Serengeti, Tanzania, reported that most of the vegetation changes taking place there could be attributed to grass fires, although the removal of large trees throughout the woodlands is due to elephants (UNESCO 1979). Grass-burning is practiced by pastoralists to suppress bush encroachment and to take advantage of early regrowth. Whether fire is helpful or harmful depends upon a myriad of considerations, principally the economic resources of the livestock owner. In East Africa, fire is used because it is inexpensive, easy to implement and potentially one of the most useful tools available for bush management in grasslands and savannahs (Harrington and Ross 1974).

Seasonal distribution of rainfall in the range areas of Kenya is erratic. In Kenya, and indeed in most of the tropical savannahs, rangeland herbage is generally of high quality, if not adequate quantity, during and immediately following the rains (the growing season). As the vegetation matures into the dry season, both quality and quantity decline rapidly, particularly protein. The dry season herbage is usually stemmy, coarse and relatively unpalatable (McKay 1970, Afolayan and Fafunsho 1978), and the forage is of lower nutritive value than the green, young forage of the wet season. The use of fire to improve diet quality has been reported. Apart from influencing the botanical composition and accessibility of available herbage, burning enhances dietary crude protein and organic matter digestibility of forages for varying lengths of time (Lemon 1968, McKay 1970, Angell 1983, McGinty *et al.* 1983). The dietary benefits of fire are short-lived, typically lasting through the rapid growth periods following the burn (Hilmon and Hughes 1965, McAtee *et al.* 1979, Angell 1983, McGinty *et al.* 1983).

In the management of natural pastures, one of the objectives is to determine the best practical combination of regulated grass-burning to encourage grass growth and discourage bush encroachment, while at the same time permitting as much grazing as possible (Little and Ivens 1965). Similarly, one of the main objectives in livestock nutrition management is often to match the livestock production system with the forage production pattern. It is therefore important to establish the quantity and quality of the diets by month/season in order to match the animal maintenance requirements and to evaluate the need for supplementation when and if necessary.

The objectives of this study were:

(1) To evaluate the effects of burning on the seasonal dietary crude protein, organic matter digestibility and digestible energy of cattle and goats; and

(2) To determine the effects of diet quality on the optional choice of calving dates and weaning practices.

LITERATURE REVIEW

Burning

Herbage with low protein content forms the main diet of large ruminants in many parts of Africa for several months in a year. This poor nutritional environment, typical of the conditions which prevail during the dry months, is the result of seasonal distribution of rainfall (Elliot and Topps 1963). Virtually all areas where range and goat production are practiced are also characterized by high seasonal variation in precipitation and that even in years of "normal" rainfall, there are profound month-to-month variation in the available forage, from the standpoint of both quantity and quality (Malechek 1982). Dry tropical grasslands are characterized by rapid growth rates during the rainy season, followed by reduced yields and deterioration in quality in the dry months (Elliot and Topps 1963, Tiharuhondi *et al.* 1973, Afolayan and Fafunsho 1978). Reduced herbage quality impairs the productivity of range ruminants. Animal production under such circumstances then follows a typical response with rapid gains (much as compensatory growth) during the rainy periods followed by accelerated losses during the dry periods. The overall trend of these regular oscillations is only gradually upward with an undue amount of time required for growing animals to attain mature weights. The alternate loss and gain of body weights may not be desirable for breeding and raising slaughter stock on range forage. Several weeks may elapse before body losses which occur during the dry season are recovered, and net weight gains realized in growing and slaughter animals.

The accessibility and availability of high quality forage during the dry season is a practical aim of many livestock owners to minimize body weight losses. Over the years, local tribes in Kenya have been burning during the dry seasons and grazing the young grass and shrubs that appear late in the season or after rains, to increase the nutritive content and digestibility of the potentially consumable forage resources (Dougall 1962).

Burning may be a wasteful method of management as the bulk of the grass is burned and never utilized; a factor that is probably offset by the ensuing accessible higher quality forage among other benefits. Dougall (1962) reported that as grass grows to maturation, the overall pattern is a decrease in nitrogen concentration, indicating that the benefits of a burning treatment have to be captured early in the growing season. McKay (1970) reported high crude protein (CP) levels in cattle diets after burning of a good condition *Themeda triandra-Digitaria setivalva* grassland in the Kedong area of Kenya. He noted that the dietary CP in cattle diets had dropped to between 5 and 6% after 2.5 months post-burn growth. This is an indication that within a few weeks, any advantage in nutritional quality is lost after a burn. The duration of the rainy season and the amount and distribution of the rainfall will largely determine the expected growth of the vegetation, which in turn will influence the chemical composition of the forage (Dougall 1962, McKay 1970).

Nutritional Effects on Cattle Diets

Seasonal changes and burning are reported to have a marked influence on the quality, accessibility and availability of forage for the grazing animal. Forage selected by the grazing animal varies from that available. Galt *et al.* (1969) reported significant differences in forage species found in rumen samples as compared to the available forage species on the range, with the botanical composition varying between periods and to a lesser degree among sampling dates. Crude protein levels in diets of grazing animals are reported to be significantly higher than those in available forage (Van Dyne and Heady 1965, Jefferies and Rice 1965, McKay 1970). These differences are due to selectivity and preference for certain plant parts as well as certain plant species (McKay and Frandsen 1969, Rice *et al.* 1971). This selection process influences the nutritional quality of the diets (McKay 1970, Bedell 1971), Bredon *et al.* 1971).

Burning apparently removes dead plant material, resulting in greater accessibility of green plant phytomass to the grazing animal as well as changing the species composition of the herbage (Angell 1983). McGinty *et al.* (1983) reported on the *in vitro* digestible organic matter (IVDOM) content of steer diets grazing liveoak-shin oak savannah of the Edwards Plateau, Texas. It was noted that IVDOM from a spring burn paddock was greater than the control paddock due to higher percentage of grass in the diets from the burn, and the percent live phytomass of higher CP content was selected. This observation concurs with observations made elsewhere (Lemon 1968, Galt *et al.* 1969, Van Voorthuizen 1971, Angell 1983, Hart *et al.* 1983). McAtee *et al.* (1979) reported digestible energy (DE) and CP increase in gulf cordgrass (*Spartina spartinae*) following burning. Angell *et al.* (1986) also reported increased crude protein and digestible organic matter (DOM) in gulf cordgrass due to regrowth following burning.

Season and rainfall are major influences on the growth and maturing or vegetation, and their major influences are reflected in the quality of animal diets. Dietary crude protein and *in vitro* organic matter digestibility (IVOMD) are reported to decline with advance of season and maturity (Dougall 1962, Van Dyne and Heady 1965, Harris *et al.* 1968, Sims *et al.* 1971, Tiharuhondi *et al.* 1973, Sinclair 1974, Hart *et al.* 1983). Van Dyne and Heady (1965) reported an average CP decrease from 9.5 to 6.9% for cattle and sheep diets in an annual grassland in northern California from early to late summer. A slight decrease in energy content of the available forage was noted for the same period. Browse (leaves and twigs of trees and shrubs) and forbs generally contain higher levels of CP (and phosphorus) during the growing season than do grass (Rector and Huston 1976) and when available during the dry season (McKay 1970). Browse CP content is more consistent across seasons (Wilson 1969). Thus, although browse generally has lower digestibility than grasses, it provides supplements of protein and energy when the grasses are mature and of low nutritive value (Wilson 1969). Cattle have been observed browsing during herbage dormancy (Wilson 1969, McKay 1970, Dradu and Harrington 1972). The effects of browse are reflected in the CP, IVOMD and digestible energy (DE) of the diets.

Nutritional Effects on Goat Diets

Information pertaining to the nutritive value of goat diets under range conditions is limited. Goats differ from cattle and sheep in their diet selection and gastro-intestinal physiology (Huston 1978). In the goat, the rumen is simpler, but still contains food delaying mechanisms (Van Soest 1982). However, goats have low enough metabolic rate and high enough gut capacity (compared to other browsers) that they can afford to selectively retain the more slowly digesting parts of plants (cell wall), but a small mouth and low absolute intake requirement permit selection for the higher quality parts of plants (McDowell and Woodward 1982). Selective ruminant species may not have a high pressure for large rumen fill as grazers (Van Soest 1982), hence, they can select for rapidly digestible plant parts. Goats have faster rates of passage than cattle or sheep, which allows higher intakes, but less ability to digest fiber (McDowell and Woodward 1982). The differences offer explanation as to why the goats' elevated requirements can be satisfied under environmental conditions unsatisfactory for other animals (Maher 1945, Wilson 1957, Huston 1978, Shelton 1978) in that by use of their prehensile upper lip, they can discretely select more nutritive diet constituents (Rector 1983). Sidahmed *et al.* (1982) reported that Spanish goats grazing chaparral in California discriminated against plant parts that were low in nitrogen and high in cellulose and cell wall contents. Wilson (1957) has reported that the East African dwarf goats are not very selective in regards to plant species, but are very selective to stage of growth and height above the ground of the plant material.

Goats are browsers and grazers. However, literature on goats abounds with differing ideas concerning their feeding habits. Huston (1978) reported that browse proviced the major portions of goats' diets. Studies have shown that goats have a unique preference for shrubs and tree leaves (Cory 1927, Edwards 1948, Wilson 1957). Bryant *et al.* (1979) in a study on the dietary interrelationships among Angora goats, Spanish goats and white-tailed deer under excellent range condition on the Edwards Plateau of Texas, found that Angora goat diets were comprised of 48% grass and 40% browse on a yearlong average. These percentages remained relatively constant throughout the year with a tendency to drift back and forth from grass to browse. Spanish goat diets contained 45% grass and 42% browse throughout the year. Lopes and Stuth (1984) reported that browse was the dominant diet component, comprising 77 and 51% of goat diets on untreated and mechanically treated Post oak woodland, respectively, while on herbicide treated pastures, browse was a minor component. Grass and grasslike plants provided approximately 64% of the goat diets from the herbicide treated pastures. Wilson (1957) observed the browsing habits of the East African dwarf goat utilizing "Short grass" *Hyparrhenia filipendula* grassland community in the Teso district of Uganda, and found that trees and shrubs contributed 50%, grasses 33% and forbs 7% of goat diets.

Diets of goats grazing on an *Acacia* grassland community in Kenya, consumed 40 and 46% browse and grass, respectively (Ng'ethe and Box 1976). Diets of goats grazing a semi-arid *Casuarina cristata-Heterodeutrum oleifolium* woodland in western New South Wales, Australia, consisted largely of browse (Wilson *et al.* 1975). The leaves were a consistent component along with a large portion of herbaceous material. However, the studies by Wilson (1957) and Knight (1964) indicated that goats feed on all major categories of forage in East Africa depending on the availability and season. Thus, goats appear to have a superior adaptation to the dry tropics because of their ability to graze selectively and to willingly consume a wide variety of the vegetation (Shelton

1978).

Goats have a greater tendency than cattle and sheep to change their diets with changing seasons and achieving greater nutritional stability throughout the year (Edwards 1948, Huston 1978, Bryant *et al.* 1979). Values reported by Wilson *et al.* (1975) indicated that *in vitro* digestible organic matter of goat diets ranged from 43% in the late winter to 57% in mid-August, where the later peak was associated with higher amounts of grass in the diets. Dietary *in vitro* digestible nitrogen has been reported to be highest in sheep (1.26%), lowest in cattle (1.17%) and intermediate for goats (1.20%) (Squires 1982). Wilson (1969) reviewed browse in the nutrition of grazing animals and noted that browse has more consistent crude protein content than grasses, which are typically high in protein at the beginning of the growing period and low in protein when they mature. Likewise, browse has higher lignin content than grasses, hence lower organic matter digestibility (Wilson 1969). Crude protein in leaves and young shoots of trees/shrubs is generally higher that that of herbs and remains high throughout the dry season (Wilson and Bredon 1963).

Bryant (1977) worked with Angora and Spanish goats and found the highest dietary crude protein values for Angora and Spanish goats grazing a live oak-shin oak savannah occurred when plant growth was most rapid (April) while the lowest values occurred in late winter (February). He reported the crude protein values to be proportional to the grass content and inversely related with the browse content in the diets. Malechek and Leinweber (1972a) also reported lowest dietary crude protein levels in winter and highest values in early spring for goat diets in this type of vegetation. They attributed the high CP levels in spring to the increased consumption of forbs and immature browse leaves. The low dietary CP values occurred when the proportion of dry grass in the diets increased.

Seasonal shifts in diet selection were reported by Bryant *et al.* (1979) in a liveoak savannah, where forbs increased in Angora goat diets in the spring than the fall even though availability in both seasons was similar. Similarly, grass was significantly higher than browse in July diets and lowest in December diets, but browse was lower in July than in December; an indication of selection for grass in summer. Rector (1983) also reported highest percent (weight) forbs in summer and lowest percent in winter; highest percent browse in fall and lowest in summer; highest percent grass in spring and lowest in winter in Angora goats grazing in the live oak-shin oak savannah of the Edwards Plateau, Texas. Apparently, increased levels of CP are associated with increased amounts of young shoots of grass and browse in the diets, while increased levels of IVOMD and DE are associated with increased amounts of grass and forbs in the diets.

Livestock Production Systems

In Kenya, range livestock production and profitability are based on birth rates, amount of milk produced for both offspring and human consumption, the number of offspring weaned and their subsequent growth after weaning to market weights on natural pastures. The grazing animal is subjected to a continually changing pattern of food supply both in uantity and quality. At times, pasture growth is inadequate to meet even the animal requirement for maintenance, or there is a deliberate rationing of the feed supply to conserve pastures for more critical periods of the production cycle (Freer 1981). Forage is temporarily plentiful during and following the rains. The profitability then depends largely on the animals' ability to maximize intake. This makes the best use of the herbage before quality deteriorates. Systems based on breeding operations are generally more vulnerable to the changing forage supply than those involving stockers (Morley 1981).

Apart from mineral requirements, animals require energy and protein for body maintenance, activity, reproduction, production and growth. A substantial part of an animal's diet is used for supporting body processes which must proceed regardless of tissue or milk production. If this need is not met, tissue breakdown occurs, resulting in weight loss, reduced conception rates, and reduced offspring weight at birth and weaning (Maynard and Loosli 1969).

Dam Weights and Fertility

Reproduction as a phenomenon represents a series of events, namely ovulation, fertilization and gestation. Breeding programs can be adversely affected at a number of critical times in the life of the animal by undernutrition. The importance of dam weight and body condition at the time of breeding has been reported. Higher conception and birth rates have been reported in heavier cows than lighter cows (Trail *et al.* 1971, Pratt and Gwynne 1977, Topps 1977, Thorpe *et al.* 1981). Unless the females are in good condition, ovulation and fertility may be inhibited, and at parturition, a low plane of nutrition may be fatal not only to the unborn offspring, but also to the dam because of pregnancy and various metabolic disorders of parturition (Morley 1981).

Offspring Birth-weight and Weaning-weight

There is usually a positive correlation between birth and weaning weights under extensive range use conditions (Topps 1977). Improvement in nutrition of the pregnant cow is likely to be manifested in heavier weaner production. Heavier cows at parturition have been reported to wean heavier calves (Trail *et al.* 1971), but moderate and severe under-nutrition of the pregnant cow will decrease calf birth-weight (Topps 1977). Rebreeding success is also reduced by undernutrition. There is a critical feed quantity and quality level below which might result in the loss of the calf crop or in production of stunted calves (Pratt and Gwynne 1977).

Weaners and Fattening (Stockers) Stock

The weaned animals are highly vulnerable to low quality nutrition. In young animals growing from weaning to mature size, the daily energy demand increases with body weight, but when they reach mature sizes, the extent to which their potential energy demands are met depends on the diet quality, its digestibility and turnover rate in the gut (Freer 1981). The voluntary intake of many mature roughages by livestock, for example, might be inadequate to meet even the demands of maintenance. Young beef cattle require better quality feed for fattening and growth to maturity. The voluntary intake of ruminants under only low quality roughages is severely limited because of a slower rate of fermentation in the reticulo-rumen and the rate of passage of digesta, with protein being the most limiting (Topps 1977).

Timing

In arid and semi-arid regions, seasonal breeding is desirable so that offsprings are dropped early in the growing season and are weaned by the time the dry weather conditions are advanced (Pratt and Gwynne 1977). Carles and Riley (1984) reported highest weaning weights when calving was up to 2 months before the onset of the rains ($P/E_T = 0.5$), and lowest after the onset of rains in a zebu-European cross before herd in Kenya. Carles and Riley (1984) observed that in environments typical of Kenya's best rangelands, the dam's reserves can be adequate to offset the pasture deficiencies at the end of the dry season, during the early stages of calf growth. When weaning coincides with a period of ample grazing, growth rate in the 3 months post-weaning is not affected. When weaning coincides with steadily declining nutrition condition, reduced immediate post-weaning growth strongly reflects the absence of high quality forage (Sacker *et al.* 1971). Intermittent restrictions in food intake, whether they are imposed by management or a reflection of the seasonal variability, are characteristic of most animal production systems based on extensive grazing (Freer 1981). A "green-grass" loss, consisting of a substantial loss of weight in the first three weeks of rains is characteristic of the animals that are accustomed, during the dry season, to reduce intake of the dry material (Payne 1963). When the intake restriction is removed, it is often observed that animals exhibit a compensatory gain in weight (Freer 1981).

Beef cattle production is particularly vulnerable to choice of breeding date because the nutritional state must be adequate at the time of breeding as well as at the time of calving, and for some time subsequent in order to permit good growth of calves. When favorable nutritional conditions cannot be provided, calving may occur every other year rather than annually (Lamond 1969). Such unfavorable conditions apply in semi-arid regions with sharply defined periods of rainfall.

STUDY AREA

General Description

The study was conducted on the National Range Research Station (NRRS), Kiboko, situated about 170 km southeast of Nairobi, on the Nairobi-Mombasa highway. The station, with an approximate area of 30,000 ha, is bounded in the northwest by the Kiboko River, in the north by the Nairobi-Mombasa highway and by the Mbuinzau and Wikiamba volcanic cones to the south. The station lies between latitudes 2°10' and 2°25' S and longitudes 37°40' and 37°55' E. The station area is in ecological zone V, which comprises the bulk of Kenya's rangeland (Pratt *et al.* 1966), and has an altitude of 900 to 1100 m above sea level (Michieka and Van der Pouw 1977, Mwandotto 1978, Ndegwa 1983) (Fig. 1).

The station was formerly a game reserve, infested with tse tse flies, and later converted into a range research station in 1971 under a FAO/UNDP Kenya Range Management Project, with the objective of studying various aspects of range management, livestock husbandry and wildlife studies. Currently, the station area is used for grazing of cattle, sheep and goats. The major wildlife include eland, kongoni, giraffe, buffalo and gazelles. Plant and animal ecology and grazing management are the areas of emphasis in the current NRRS research program.

The study site is located approximately 6 km south of the NRRS headquarters (Fig. 2) in pasture 2 or a larger experimental unit known as GM2 (Fig. 3).

Climate

Makindu Meteorological Station and Kiboko Railway Station, both at

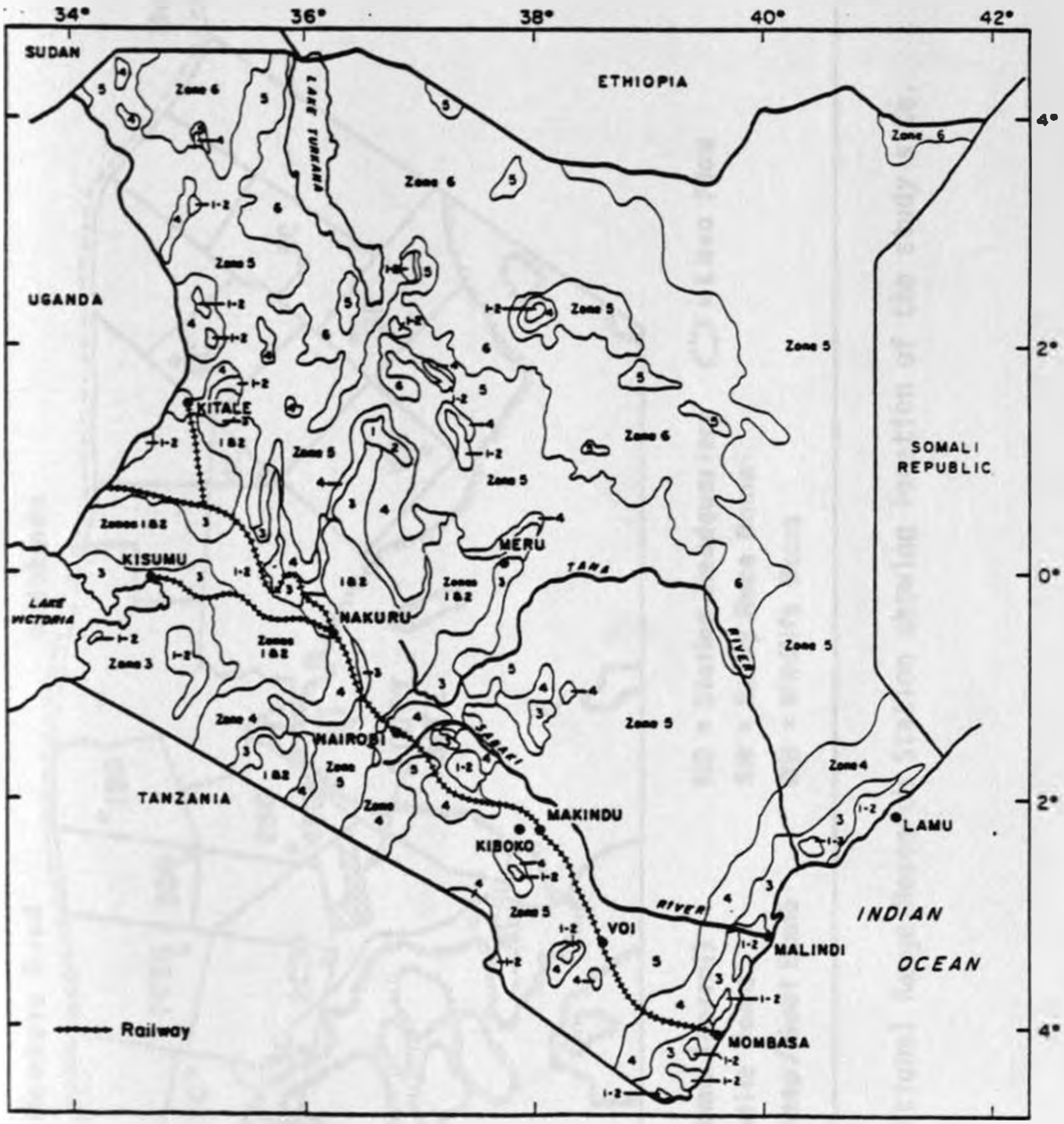

Fig. 1. Ecological zones of Kenya (after Pratt *et al.* 1966) and the geographical location of National Range Research Station, Kiboko, Kenya.

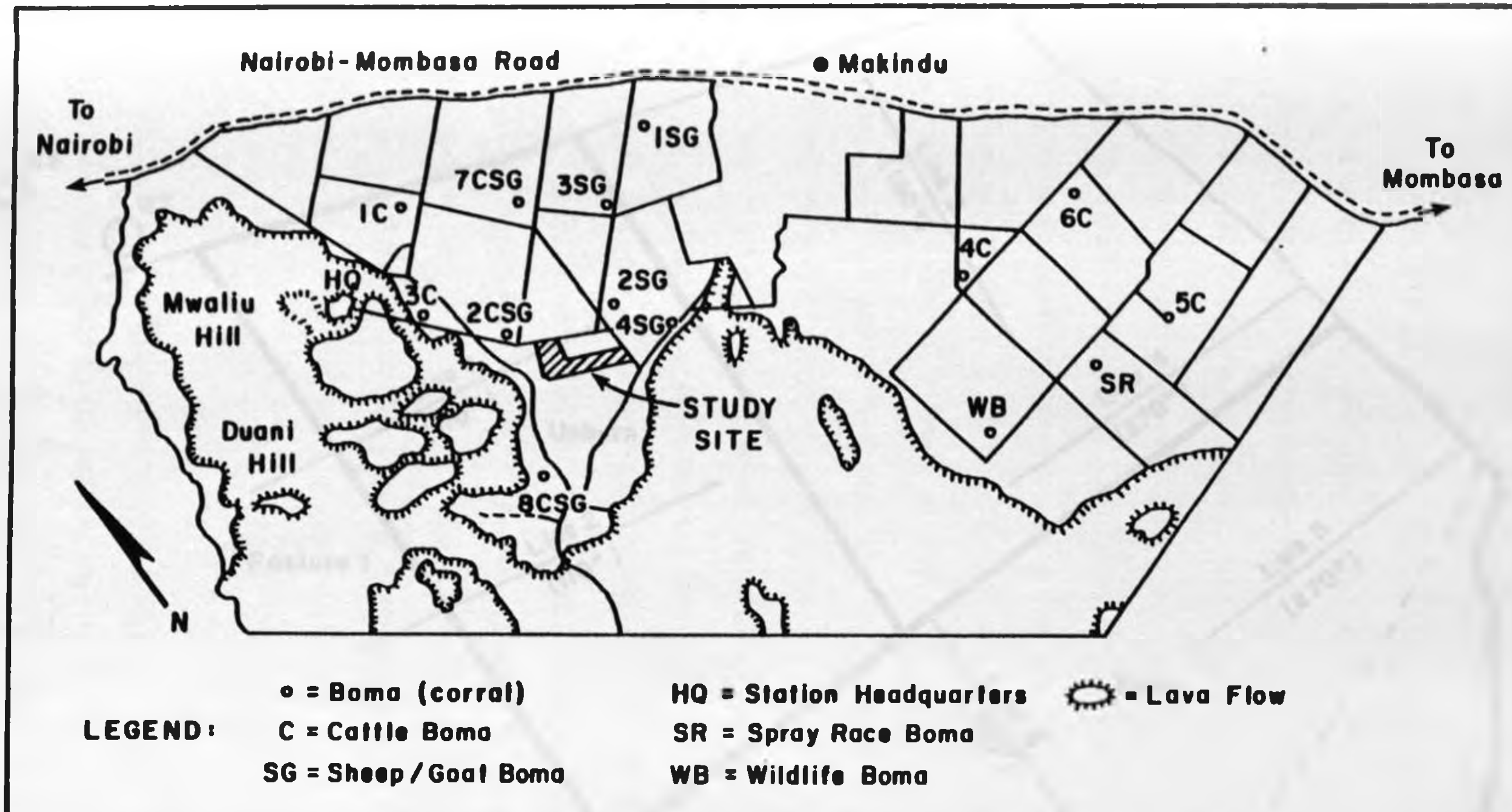

Fig. 2. Kiboko National Range Research Station showing location of the study site.

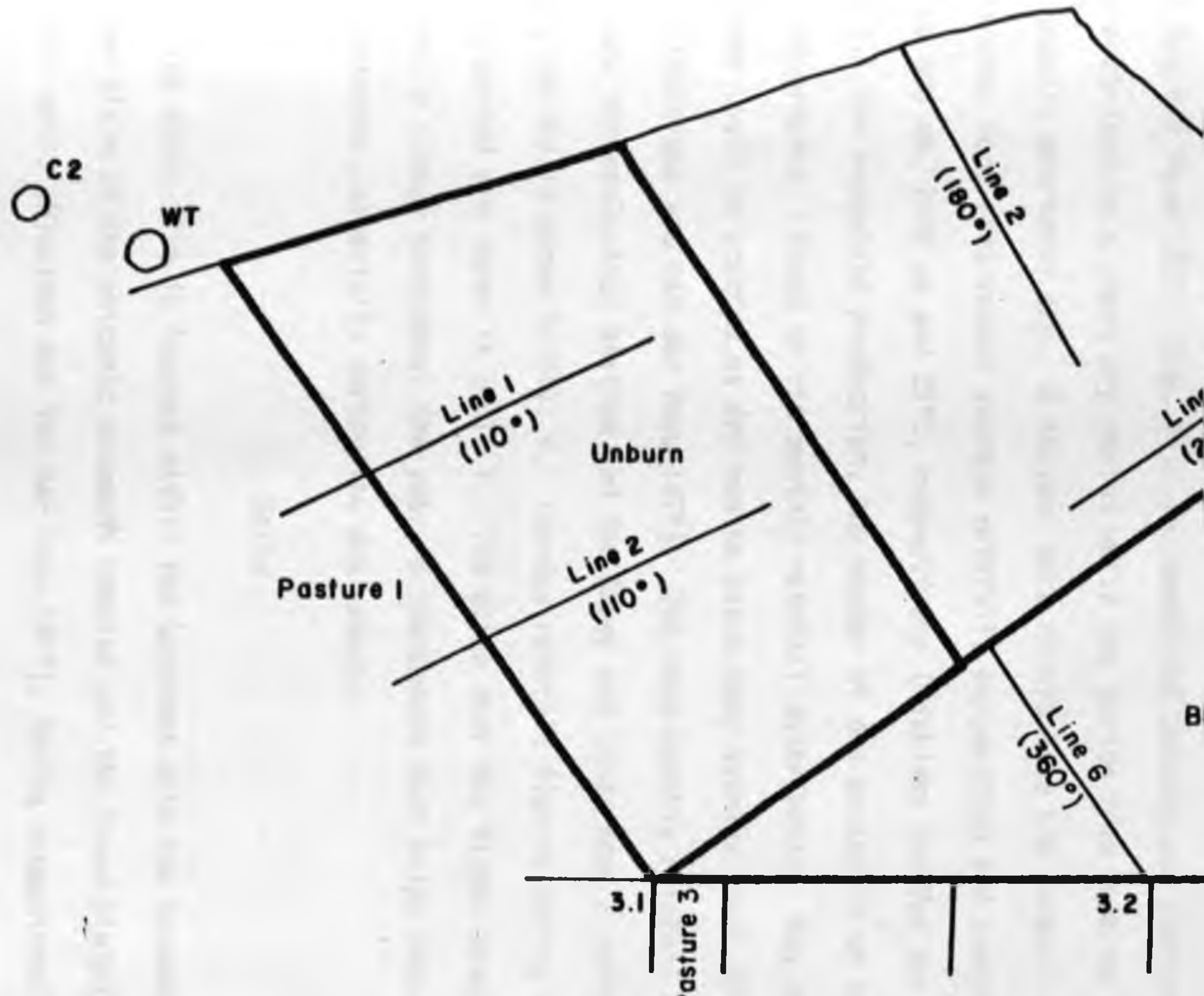

Fig. 3. The study paddocks of pasture 2, showing vegetation sampling
paddocks designated burn and unburn.

the periphery of NRRS, Kiboko, are the weather stations with long term weather records. Since the inception of the NRRS, weather stations have been established at different locations within the station.

The climate of Kiboko, and the general area, falls under the influence of the intertropical convergence zone (Whyte 1968), characterized by a biomodal rainfall distribution, with rainy seasons from the end of March to mid-May and from the end of October to mid-December (Michieka and Van der Pouw 1977) (Fig. 4). The months of January and February are characterized by a short dry period while the period from June to October is usually extremely dry. A 45-year data record from the general area indicates long term annual average rainfall, evaporation and temperature to be 600 mm, 2000 mm and 23°C, respectively (Michieka and Van der Pouw 1977). For rangeland production, the number of dry months is of particular importance. Based on the monthly rainfall distribution, May and October could be counted as dry months since they average about 30 mm or less (Michieka and Van der Pouw 1977). The mean monthly rainfall for Makindu Meteorological Station and for Sheep and Goats Boma 2 during the study period is shown in Fig. 4. Ten-day rainfall figures during the study period are shown in Table 1. The skies over the Kiboko area are generally cloudy throughout the year, a phenomenon that helps reduce air temperatures, especially during the dry seasons.

Soils

The study site is located within the basement with the basement system plain of the volcanic basement complex and the flood plains of the station soils (Michieka and Van der Pouw 1977), having predominantly

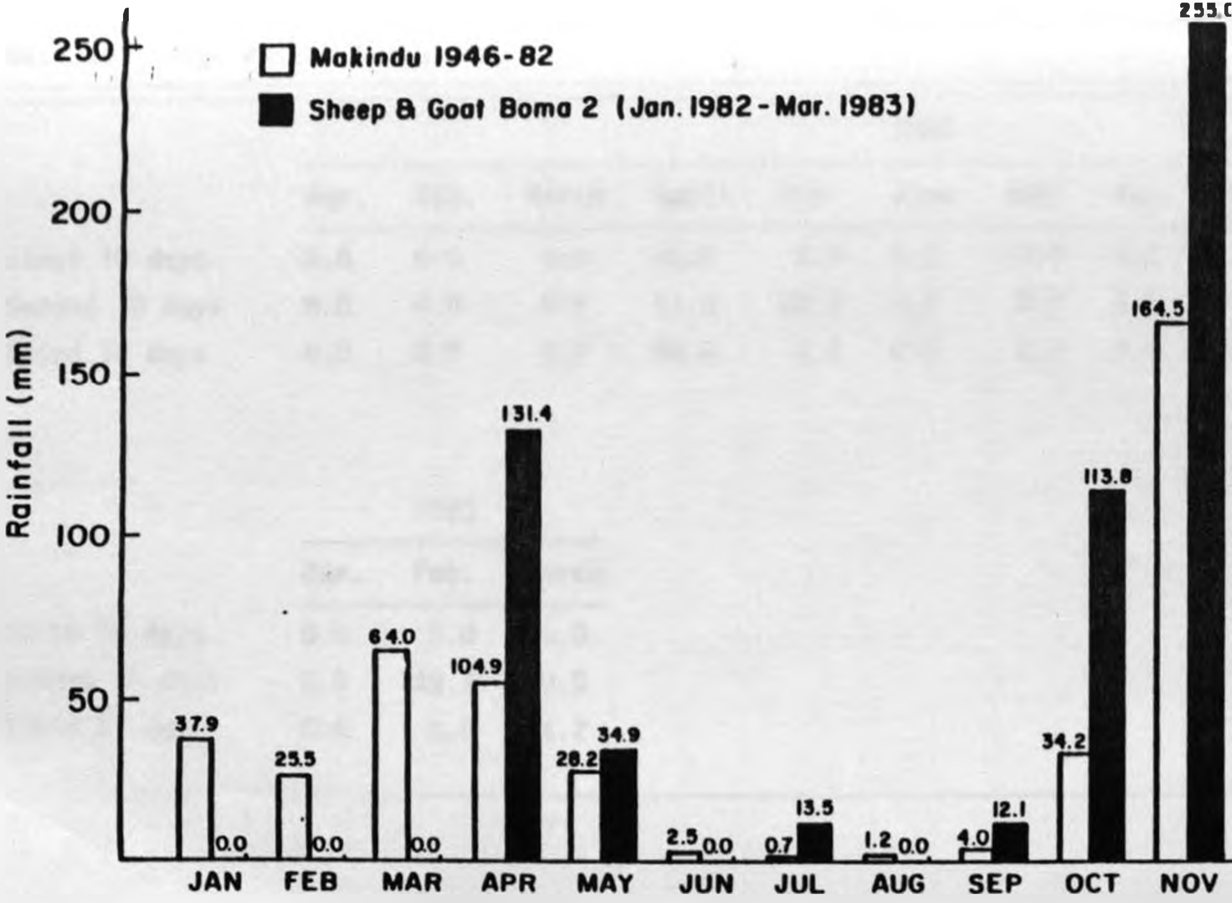

Fig. 4. Long term mean monthly rainfall for Makindu Meteorological Stat
fall at Sheep and Goat Boma 2 during the study period (Jan. 1982-March 1983).

Table 1. 10-day rainfall totals (mm) during the study period at Sheep a
National Range Research Station.

	1982								
	Jan.	Feb.	March	April	May	June	July	Aug.	S
First 10 days	0.0	0.0	0.0	45.6	2.3	0.0	13.5	0.0	
Second 10 days	0.0	0.0	0.0	57.0	26.2	0.0	0.0	0.0	
Third 10 days	0.0	0.0	0.0	28.8	6.4	0.0	0.0	0.0	1

	1983		
	Jan.	Feb.	March
First 10 days	0.0	0.0	0.0
Second 10 days	0.0	49.7	0.0
Third 10 days	0.0	0.0	14.2

developed from bonded gneissess. The soil types of the study site are ferrosols, which are well drained,friable to firm clay and sandy clays.

Vegetation

Michieka and Van der Pouw (1977) classified the vegetation of Kiboko into various categories based on physiognomic features, and classified the vegetation of the basement system plans as bushed grassland. Pratt *et al.* (1966) classified the area as wooded/bushed grassland savannah.

The study site vegetation is dominated in the tree layer by *Acacia senegal*, while *Hermania alhensis* dominates the shrub layer. Other tall woody species include *Acacia* sp. *Grewia* sp., *Commiphora* sp., *Cordia* sp., and *Balanites aegyptiaca*. *Solanum incanum, Hibiscus* sp., *Lantana* sp., and *Sida ovata* are the major subordinates of the shrub layer.

The herbaceous layer is dominated by *Digitaria macroblephara*, with *Bothriochloa insculpta, Chloris roxburghiana, Bothriochloa glabra, Microchloa kunthii, Sporobolus* sp., and *Panicum maximum* as major subordinate grass species. *Carex* sp. is the major grass-like species present during the rains. *Talinum portulacifolium* dominates the forb layer, with *Commelina benghalensis* and *Tephrosia villosa* as subordinate forbs.

MATERIALS AND METHODS

Experimental Paddocks

Two adjacent paddocks of Pasture 2 of the GM2 experimental unit were selected as the study site based on ocular similarity of their vegetation. The herbaceous vegetation similarity index (Sørensen 1948), as cited in Mueller-Dombois and Ellenburg (1974), for these paddocks ranged from 80 to 94%. These paddocks had not been under regular use by the station livestock or burned since 1972, but were under infrequent use by livestock and wildlife. In 1981, when the GM2 experimental unit was established, Pasture 2 was divided into three paddocks whereby the fire-lines served as boundaries. Two of these paddocks were the site of this study. One of the paddocks (Fig. 3) was burned on February 25, 1982, when the mean prevailing air temperature, relative humidity and wind speed were 33°C, 40% and 8.5 km/hour, respectively.

Vegetation Measurements

In each treatment paddock, two 600 m lines were established at random compass bearings and their locations marked with permanent posts. Twenty-five points were marked at 25 m intervals along each of these lines. Five out of the 25 points were randomly selected and marked with permanent posts. These five points were the transects from which vegetation data was collected. The compass bearings of these transects were randomly assigned with the herbaceous vegetation and the shrub/woody plant having different compass bearings (Table 2).

In November 1981, inventory of the herbaceous vegetation was taken to ascertain the frequency and density of the species before the February

Table 2. Permanent line, transect location and transect compass bearings for the vegetation inventory at Pasture 2 of GM2, National Range Research Station, Kiboko, Kenya.

Line	Line Compass Bearing	Vegetation Type	Treatment	Transect number, bearing and location				
				1[1]	2	3	4	5
1	110°		Unburned	3[2] - 50[3]	12 - 275	13 - 300	17 - 400	21 - 500
		Shrub/woody		40°[4]	262°	259°	230°	241°
		Herbaceous		70°	71°	138°	135°	235°
2	110°		Unburned	9 - 200	13 - 300	15 - 350	20 - 475	22 - 525
		Shrub/woody		110°	131°	203°	127°	133°
		Herbaceous		270°	262°	87°	212°	229°
5	270°		Burned	3 - 50	10 - 225	17 - 400	22 - 525	23 - 550
		Shrub/woody		200°	179°	270°	349°	286°
		Herbaceous		290°	249°	249°	320°	228°
6	360°		Burned	4 - 75	13 - 300	16 - 375	19 - 450	21 - 500
		Shrub/woody		243°	48°	94°	158°	218°
		Herbaceous		147°	200°	180°	75°	20°

[1] Transect number.
[2] Number of permanent transect locations on the line.
[3] Distance of transect post from the line post.
[4] Transect bearing for the vegetation type.

1982 burn of one of the paddocks. From each of the five transects per line, a 25 m tape was laid along the assigned compass bearing, and sampling was done at every meter starting from the 1 m point from the transect post. Point-centered quarter method (Cottam and Curtis 1956) was adapted for the evaluation method. The nearest herbaceous plant encountered in each quarter/quadrat was appraised (by species) for distance (cm). In May 1982, and approximately 3 months after the February burn, a second sampling of herbaceous vegetation was made.

During the short rains of October to December, 1982, shrub/woody plants inventory was done. This was at a time near the end of the study period to ascertain the differences in the vegetation after the February burn. The same lines and transects as for herbaceous vegetation were used except that the transect compass bearings were different (Table 2). The Point-centred quarter method (Cottam and Curtis 1956) was used to determine nearest plant species in each quadrant/quarter. Quadrants were placed at 25-meter intervals. Starting at 5-meters from the transect post along a 100-meter tape, vegetation was classified into two height classes, above 1 m and below 1 m, whereby the distance, canopy diameter, number of stems and height of each height class was recorded for the nearest plant species in the quadrat.

Animal Measurements

Four esophageally-fistulated heifers and two esophageally-fistulated goats were used to collect diet samples from the two treatments for two consecutive days per each sampling interval. The sampling intervals were twice monthly during the months of active vegetation growth and once monthly at other periods for a one year duration. However, this twice monthly schedule was not possible in November and December due to conflicting use of the animals for other experiments.

The sampling animals were penned and fasted overnight to avoid contamination of the extrusa samples during the morning sampling periods. The fistulated heifers and goats grazed alternately in the burned and unburned area after being fitted with extrusa collection bags (for heifers) (Cook 1964, Van Dyne and Torell 1964) and rectangular collection sacks (for goats) (Kamau 1984). Four heifer extrusa samples per treatment/paddock per sampling day were obtained. Likewise, two goat extrusa samples per treatment per day were obtained. A total of 12 diet samples per day, for a total of 24 samples for the two consecutive sampling days were obtained.

The diet samples from each heifer and goat were taken to the station headquarters, air-dried on wire-screen bottom racks for two days and later oven dried at 60°C for 24 hours. The dry samples were then ground in a Willey Mill to pass a 0.5 mm screen. Subsamples of the ground samples were stored in vials and shipped to the Range Nutrition Laboratory at Texas A&M University for chemical analysis.

Chemical Analysis

The dry matter of each diet sample was estimated by oven drying approximately 0.5 gm in an oven for 12 hours at 120°C. The organic matter (OM) content of each diet sample was estimated by ignition of 0.5 g of the sample in a muffle furnace at 500°C for 4 hours. All estimates of the dietary components were computed on an organic matter basis.

Nitrogen (%N) was determined by the micro-Kjeldahl technique (AOAC

1975). Percent crude protein (CP) was estimated on an organic matter basis by multiplying percent nitrogen by a constant of 6.25.

In vitro organic matter digestibility (IVOMD) was determined by utilizing the fermentation stage of Tilley and Terry (1963) and the neutral detergent phase of Van Soest and Wine (1967). Standards of known *in vivo* organic matter digestibility were run with the diet samples to correct for variation in laboratory procedure and rumen inoculum to apparent digestibility.

Digestible energy (DE) (kcal/kg) of each diet sample was derived from the estimates of organic matter digestibility by multiplying percent organic matter digestibility by a conservative estimate of 4000 kcal/kg of organic matter (Rittenhouse *et al.* 1971).

Statistical Analysis

The treatment mean effect was burning. The year was divided into six seasons in relation to the rainfall pattern. A t-test analysis was utilized to analyse the diet quality data by treatments (burn and unburn) and season to detect differences between treatments at a 95% confidence level. A t-test analysis was utilized to analyse the vegetation parameters treatment effects.

Livestock Production Models

Projected weight profiles and physiological conditions of Sahiwal, Boran and East African zebu cows were utilized to project monthly forage intake and nutrient requirements. The dietary crude protein and organic matter digestibility values obtained in the chemical analyses by month and treatment were used to determine the monthly nutritional status of the animals. Model algorithm, equations and parameter inputs for forage intake, basal net energy requirements, crude protein requirements and their adjustments for body condition, environmental stress, milk production, travel, breed and production stage are in Appendix Figure 1 and Appendix Tables 19A and 19B.

RESULTS AND DISCUSSION

Herbaceous Vegetation

Burning does not only enhance the accessibility and dietary quality of the available forage species but also changes the botanical composition of the forage resource (Lemon 1968, McKay 1970, Angell 1983, McGinty *et al.* 1983). In this study, the pre-burn and post-burn frequcncy and density of the species was analysed to ascertain the pre-burn and post-butn differences between herbaceous vegetation in the burned and unburned paddocks (Tables 3, 4 and 5).

Pre-burn and Post-burn Frequency of Species

There was an inherent difference ($p = 0.0001$) in the pre-burn frequency of species when a chi-square test for homogeneity was performed, and likewise there was a highly significant difference ($P = 0.0001$) in the post-burn frequency of species for the two paddocks. Species with differences in their frequencies are indicated in Table 3. The dominant forage grass species were *Digitaria macroblephara, Chloris roxburghiana* and *Bothriochloa insculpta* in both pre-burn and post-burn periods regardless of the paddock.

Initially, the unburned paddock had more *Bothriochloa glabra, Bothriochloa insculpta, Carex* sp., *Eragrostis caespitosa, Sehemia nervosum* and *Themeda triandra,* but less *Chloris roxburghiana, Cynodon dactylon* and *Sporobolus pellucoides*. The burned paddock had more *Barleria* sp. and less *Tephrosia villosa* prior to the burn.

In the post-burn herbaceous vegetation, the burned paddock had a

Table 3. Percent frequency of pre-burn and post-burn herbaceous vegetation by species for the burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya.

Species	Pre-burn Nov. 1981		Post-burn May 1982		Burning effect[2]	Season effect[3]
	"Burn"[1]	Unburn	Burned	Unburned		
Grasses and grasslike						
Aristida adscensionis	0.31	0.50	2.03*	3.84	+	+
Bothriochloa glabra	0.51*[4]	4.23	0.71*	8.28	+	+
Bothriochloa insculpta $	4.80*	7.66	3.96	4.24	-	-
Carex sp.	1.74*	5.75	0.41	0	-	-
Cenchrus ciliaris	1.12	1.51	1.42	1.41	+	-
Chloris roxburghiana $	9.40*	3.13	6.50*	2.02	-	-
Cynodon dactylon	2.25*	0	-	-	-	0
Cyperus sp. $	-	-	4.57*	2.63	+	+
Digitaria macroblephara $	59.24	55.68	50.15	45.15	-	-
Echinochloa haploclada	-	-	0 *	1.11	0	+
Eragrostis caespitosa $	0.20*	0.91	0.30*	1.11	+	+
Eragrostis kiwuensis	0.10	0.50	0	0.51	-	0
Eustachys paspaloides	-	-	0.20	0.61	+	+
Heteropogon contortus	-	-	0	0.81	0	+
Microchloa kunthii	6.74	8.37	4.77*	8.59	-	+
Panicum maximum $	-	-	0.10	0.10	+	+
Sehemia nervosum	0 *	0.81	-	-	0	-
Pennisetum mezianum $	-	-	0.30*	1.82	+	+
Sporobolus pellucoides $	4.09*	1.21	1.83*	0.71	-	-
Sporobolus sp. $	-	-	4.98*	1.31	+	+
Themeda triandra $	0 *	1.51	0 *	1.52	0	0
Tragus berteronianus	-	-	2.03*	0.10	+	+
Others[5]	-	-	0.41	0.40	+	+

Table 3. Continued

Species	Pre-burn Oct. 1981		Post-burn May 1982		Burning effect[2]	Season effect[3]
	"Burn"[1]	Unburn	Burned	Unburned		
Forbs and sub-shrubs						
Acanthrosperma hispidum	-	-	0.51	0.20	+	+
Amaranthus sp.	-	-	2.34*	0.40	+	+
Athroisma psylloides	2.35	2.62	-	-	-	-
Barleria sp.	1.53*	0.10	0 *	4.34	-	+
Commelina benghalensis $	0.72	0.81	1.02	0.91	+	+
Cassia minosoides	-	-	1.73*	0.20	+	+
Heliotropium strigosum	-	-	1.42*	0.30	+	+
Indigofera sp.	-	-	1.12*	0	+	0
Justicia sp.	1.74	1.11	0.10*	1.21	-	+
Oxygonum sinuatum	-	-	0.30	0.20	+	+
Talinum portulacifolium $	-	-	1.12*	0	+	0
Tephrosia villosa $	0.72*	2.62	4.47	3.94	+	+
Others	0.72	0.20	0.81	0.40	+	+
Unknown	1.74	0.81	0.41*	1.62	+	+

[1] Was not burned until February 1982.
[2] 1981 "burn" vs 1982 burn total frequency proportions at P(|Z|) ≥ 1.960.
[3] 1981 unburn vs 1982 unburn total frequency proportions at P(|Z|) ≥ 1.960.
[4] Proportion of total frequency of the species is different for the treatments within sampling period at P(|Z|) ≥ 1.960.
[5] Includes the species whose treatments' combined total frequency counts was < 5 for the sampling period.
$ Desirable forage species (Casebeer and Koss 1970, Field 1975, Kamau 1984, Kibet 1984, Lusigi et al. 1984).

Table 4. Mean density (plants/m^2) of pre-burn herbaceous vegetation by species for the burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya, November 1981.

Forage class / Species	Treatment						
	Burned[1]			Unburned			α[4]
	n[2]	Mean	SE[3]	n	Mean	SE	
Grasses / Grasslike							
Aristida adscensionis	10	0.17	0.13	10	0.34	0.14	0.39
Bothriochloa glabra	10	0.38	0.27	10	3.19	1.36	0.07
Bothriochloa insculpta $	10	3.19	1.19	10	5.17	1.54	0.32
Carex sp.	10	1.12	0.39	10	4.46	0.94	0.006
Cenchrus ciliaris $	10	0.64	0.26	10	0.86	0.37	0.63
Chloris roxburghiana $	10	4.78	1.99	10	1.83	0.69	0.19
Cynodon dactylon	10	1.08	1.08		0	0	0.33
Digitaria macroblephara $	10	37.54	4.74	10	39.29	4.53	0.79
Eragrostis caespitosa $	10	0.23	0.23	10	0.71	0.64	0.51
Eragrostis kiwuensis	10	0.06	0.06	10	0.24	0.24	0.49
Microchloa kunthii	10	6.47	4.08	10	7.50	3.28	0.84
Sehima nervosum	10	0.0	0.0	10	0.38	0.38	0.33
Sporobolus pellucoides $	10	2.11	0.81	10	0.76	0.56	0.19
Themeda triandra $	10	0.0	0.0	10	0.88	0.45	0.07
Forbs and sub-shrubs							
Asparagus africanus	10	0.16	0.16	10	0.0	0.0	0.33
Athroisma psylloides	10	1.50	0.56	10	1.24	0.57	0.75
Barleria sp.	10	0.90	0.55	10	0.11	0.11	0.19
Commelina benghalensis $	10	0.38	0.33	10	0.59	0.24	0.60
Heliotropium strigosum	10	0.06	0.06	10	0.0	0.0	0.33
Justicia sp.	10	1.28	0.82	10	0.86	0.22	0.64
Hibiscus sp.	10	0.06	0.06	10	0.0	0.0	0.33
Ocimum americanum	10	0.19	0.19	10	0.07	0.07	0.57
Scilla indica	10	0.0	0.0	10	0.07	0.07	0.33
Tephrosia villosa $	10	0.44	0.26	10	1.59	0.47	0.04
Unidentified spp.	10	0.91	0.34	10	0.75	0.39	0.77

[1] Burning not done until February 1982 but area designed for burning treatment.

[2] Number of transects.

[3] Standard error of the mean.

[4] α - level of significance.

$ Important forage species (Casebeer and Koss 1970, Field 1975, Kamau 1984, Kibet 1984, Lusigi et al. 1984).

Table 5 . Mean density (plants/m^2) of post-burn herbaceous vegetation by species for the burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya, May 1982.

Forage class / Species	Burned			Unburned			α[3]
	n[1]	Mean	SE[2]	n	Mean	SE	
Grass/Grasslike							
Aristida adscensionis	10	1.32	0.53	10	1.90	1.19	0.67
Bothriochloa glabra	10	0.43	0.35	10	5.42	2.79	0.11
Bothriochloa insculpta $	10	2.46	1.13	10	2.76	1.52	0.87
Carex spp.	10	0.28	0.12	10	0.0	0.0	0.03
Cenchrus ciliaris $	10	.72	0.31	10	0.74	0.53	0.97
Chloris roxburghiana $	10	3.24	1.54	10	1.24	0.48	0.24
Cyperus sp. $	10	2.74	1.07	10	1.72	0.48	0.40
Dactylocterineum aegyptium	10	0.06	0.06		0.0	0.0	0.33
Digitaria macroblephara $	10	28.09	2.19	10	29.38	6.31	0.85
Echinochloa haploclada	10	0.0	0.0	10	0.52	0.52	0.33
Eragrostis caespitosa $	10	0.17	0.12	10	0.59	0.31	0.23
Enteropogon macrostachyus	10	0.0	0.0	10	0.05	0.05	0.33
Erogrostis cilianensis $	10	0.10	0.10	10	0.16	0.16	0.76
Eragrostis kiwuensis	10	0.0	0.0	10	0.23	0.23	0.33
Eragrostis superba	10	0.06	0.06	10	0.05	0.05	0.85
Eustachys paspaloides	10	0.10	0.07	10	0.37	0.20	0.24
Heteropogon contortus	10	0.0	0.0	10	0.51	0.51	0.33
Microchloa kunthii	10	4.07	3.55	10	5.27	1.52	0.76
Panicum maximum $	10	0.06	0.06	10	0.05	0.05	0.86
Pennisetum meziunum $	10	0.21	0.14	10	0.67	0.58	0.46
Sporobolus pellucoides $	10	0.97	0.54	10	0.30	0.23	0.28
Sporobolus sp. $	10	2.52	1.74	10	0.59	0.45	0.31
Themeda triandra $	10	0.0	0.0	10	0.89	0.51	0.09
Tragus berteronianus	10	1.27	0.68	10	0.08	0.08	0.11

[1]Number of transects.

[2]Standard error of the mean.

[3]α - level of significance.

$Important forage species (Casebeer and Koss 1970, Field 1975, Kamau 1984, Kibet 1984, Lusigi et al. 1984).

Table 5 . Continued

Forage class / Species	Burned			Unburned			α^3
	n^1	Mean	SE^2	n	Mean	SE	
Forbs and Sub-shrubs							
Acanthospermum hispidua	10	0.26	0.15	10	0.12	0.12	0.47
Becium sp.	10	0.0	0.0	10	0.13	0.13	0.33
Abutilon sp.	10	0.05	0.05	10	0.05	0.05	0.93
Barleria sp.	10	1.77	1.22	10	0.0	0.0	0.33
Amaranthus sp.	10	1.39	0.52	10	0.23	0.12	0.06
Athroisma psylloides	10	0.06	0.06	10	0.0	0.0	0.33
Cassia mimosoides	10	1.70	0.68	10	0.20	0.13	0.06
Commelina sp.	10	0.06		10	0.0	0.0	0.33
Commelina benghalensis $	10	0.53	0.18	10	0.61	0.23	0.79
Heliotropium strigosum	10	0.76	0.15	10	0.24	0.12	0.02
Hibiscus sp. $	10	0.15	0.08	10	0.0	0.0	0.33
Justicia sp.	10	0.06	0.06	10	0.69	0.46	0.21
Indigofera sp.	10	0.68	0.41	10	0.0	0.0	0.33
Oxygonum sinuatum	10	0.15	0.11	10	0.10	0.1	0.70
Sonchus sp.	10	0.06	0.06	10	0.0	0.0	0.33
Tephrosia villosa $	10	2.34	0.64	10	1.76	0.71	0.55
Talinum portulacifolium $	10	0.63	0.18	10	0.0	0.0	0.33
Targetes minuta	10	0.0	0.0	10	0.03	0.03	0.33
Trailina sp.	10	0.07	0.07	10	0.0	0.0	0.33
Unidentified sp.	10	0.40	0.22	10	1.60	1.60	0.47

[1]Number of transects.

[2]Standard error of the mean.

[3]α - level of significance.

$Important forage species (Casebeer and Koss 1970, Field 1975, Kamau 1984, Kibet 1984, Lusigi et al. 1984).

lower frequency of *Aristida adscensionis, Bothriochloa glabra, Eragrostis caespitosa, Echinochloa haploclada, Microchloa kunthii* and *Pennisetum mezianum* but a greater frequency of *Chloris roxburghiana, Cyperus* sp., *Sporobolus pellucoides, Sporobolus* sp. and *Tragus berteronianus* among the grass species. Likewise, the burned paddock had less *Barleria* sp. and *Justicia* sp. and more *Acanthrosperma hispidum, Amaranthus* sp., *Cassia mimosoides, Heliotropium ctrigosum, Indigofera* sp. and *Talinum portulacifolium* among the forbs and shrubs than the unburned paddock.

Burning had positive effects on the frequency of *Aristida adescensionis, Cyperus* sp., *Sporobolus* sp. and *Tragus berteronianus* and negative effects on the frequency of *Bothriochloa insculpta, Chloris roxburghiana, Digitaria macroblephara, Microchloa kunthii* and *Sporobolus pellucoides* among the grass species. Among the forbs and shrubs, burning had positive effects on the frequency of *Acanthrosperma hispidum, Amaranthus* sp., *Commelina benghalensis, Cassia mimosoides, Heliotropium strigosum, Indigofera* sp., *Talinum portulacifolium* and *Tephrosia vellosa* but negative effects on *Althroisma psylloides, Barleria* sp. and *Justicia* sp. Whereas it is apparent that burning had some effects on the frequency of some plant species, it appears that other natural factors (here referred to as season) might have influenced the increase or decrease in frequency of some plant species. However, it is apparent that burning increased the frequency of some non-grass herbaceous plant species at the expense of some important forage grass species, especially *Digitaria macroblephara, Bothriochloa insculpta, Chloris roxburghiana* and *Sporobolus pellucoides*.

Pre-burn and Post-burn Density of Species

A t-test analysis of the density of plant species revealed no differences ($\alpha \leq 0.05$) in major herbaceous forage species, between the burned and unburned paddocks during the two evaluation periods (Tables 4 and 5).

As in frequency, *Digitaria macroblephara* was the major dominant species in both pre-burn and post-burn periods regardless of paddock. Other forage species with high densities were *Chloris roxburghiana, Bothriochloa insculpta, Sporobolus pellucoides, Sporobolus* sp. and *Cyperus* sp. Burning generally enhanced the density of non-grass herbaceous vegetation at the expense of some of the desirable forage grass species, especially *Digitaria macroblephara, Chloris roxburghiana, Eragrostis ciliaris* and *Sporobolus pellucoides*. However, some important forbs/shrubs, especially *Talinum portulacifolium, Hibiscus* sp. and *Tephrosia villosa* had increases in density after burning.

In summary, from the observation in frequency and density, burning apparently enhanced the diversity of plant species, especially in the forb/subshrub category, thereby altering the botanical composition of the forage species as has been reported elsewhere (Lemon 1968, McKay 1970, Angell 1983, McGinty *et al.* 1983).

Post-burn Shrub/Woody Vegetation

Burning

Fire has been used in bushed/wooded grasslands to enhance accessibility of browse species through regeneration and to check the invasion of grasslands by shrubs and woody species (West 1965, Ndawulu-Seyimba 1972, Harrington and Ross 1974, Kinyamario 1982). Fire is a useful tool in the establishment and maintenance of correct balance between grass herbage and browse in the dry tropical savannah vegetation. However, the type of plant species, timing and frequency of burning, and the intensity of the fire will greatly influence the effectiveness of the burning treatment (West 1965).

In this study, there was a greater species diversity in the unburned paddock than in the burned paddock. Even though no shrub/woody vegetation data was collected before the burn, it was evident (from the burned, dead stems) that some plant/plant species, especially shrubs, had been effectively top-killed by the fire. The absence of some shrub/woody species, especially *Grewia bicolor, Grewia hexamita, Commiphora riparia, Commiphora rostrata, Hermania alhensis* and *Hibiscus aponeurus* in the above 1-meter height category of the burned paddock might have been due to foliar kill. Resprouts of some of these species and *Acacia* species were encountered in the below 1-meter height category.

Density of Shrub/Woody Species Above 1-Meter

The absolute density of shrub/woody plant species is shown in Table 6. Differences in species density were detected in *Acacia senegal* (α = 0.02), *Commiphora africana* (α = 0.03), *Commiphora riparia* (α = 0.004), *Grewia similis* (α = 0.02) and *Grewia villosa* (α = 0.01). However, the large standard error values (SE) and the absence of some species in one of the two paddocks might have been responsible for lack of paddock differences in most of the species. Generally, the unburned paddock had

Table 6. Absolute density (plants/ha) for shrub/woody species in burned and unburned *Acacia senegal* savannah pastures of GM2, Kiboko, Kenya, November 1982.

Height category / Species	Burned		Unburned		α[2]
	Mean	SE[1]	Mean	SE	
Above 1 meter					
Acacia drepanolobium	0.0		1.4	1.4	0.33
Acacia mellifera *	13.7	2.9	9.1	3.3	0.31
Acacia senegal *	65.7	19.9	159.5	31.2	0.02
Acacia tortilis *	22.6	6.1	21.9	4.6	0.93
Acalypha fruticosa	0.0	0.0	1.4	1.4	0.33
Albizia amara *	0.4	0.4	1.4	1.4	0.51
Balanites aegyptiaca *	3.9	2.5	9.5	3.8	0.23
Commiphora africana *	1.5	0.6	26.7	9.5	0.03
Commiphora riparia *	0.0	0.0	23.7	7.2	0.004
Commiphora rostrata	0.0	0.0	2.6	2.6	0.33
Commiphora sp.	0.6	0.6	0.0	0.0	0.33
Cordia gharaf *	4.1	3.0	10.6	3.2	0.16
Dalbergia melanoxylon	0.8	0.8	1.3	1.3	0.75
Duosperma kilimandscharicum	0.0	0.0	5.0	3.3	0.15
Grewia bicolor *	0.0	0.0	5.1	2.7	0.08
Grewia hexamita	0.0	0.0	3.0	1.7	0.10
Grewia similis *	0.2	0.2	12.8	4.3	0.02
Grewia villosa *	2.7	1.3	12.5	3.1	0.01
Hermania alhensis *	0.0	0.0	7.7	4.7	0.12
Hibiscus aponeurus *	0.0	0.0	4.3	2.2	0.06
Hoslundia opposita	0.0	0.0	2.7	2.3	0.25
Lantana viburnoides	0.4	0.4	11.2	5.2	0.06
Lippia sp.	0.4	0.4	1.0	1.0	0.66
Ormocarpum kirkii	0.0	0.0	1.0	1.0	0.33
Premna oliotrica	0.0	0.0	2.3	2.3	0.33
Solanum incanum *	0.8	0.8	41.8	20.8	0.08
Solanum sp.	0.4	0.4	4.2	2.8	0.21
Unidentified sp.	0.8	0.8	0.7	0.7	0.93

[1]Standard error of the mean.

[2]α - level of significance.

*Indicates important forage (browse) species (Kamau 1984, Lusigi et al. 1984).

Table 6. Continued

Height category / Species	Burned		Unburned		
	Mean	SE	Mean	SE	α^2
Below 1 meter					
Acacia mellifera	30.4	17.1	0.0	0.0	0.10
Acacia senegal	6.2	4.3	52.9	45.4	0.33
Acacia tortilis	49.8	21.7	0.0	0.0	0.03
Balanites aegyptiaca	0.0	0.0	38.2	32.9	0.26
Boscia angustifolia	0.0	0.0	6.5	6.5	0.33
Commiphora africana	0.0	0.0	22.0	12.3	0.09
Commiphora riparia	0.0	0.0	3.6	3.6	0.33
Cordia gharaf	0.0	0.0	5.1	5.1	0.33
Dalbergia melanoxylon	3.9	3.9	0.0	0.0	0.33
Grewia bicolor	6.9	6.9	13.0	13.0	0.68
Grewia similis	35.9	23.3	76.0	35.0	0.35
Grewia villosa	40.4	29.0	80.5	38.9	0.42
Hermania alhensis	457.2	85.1	1457.0	473.6	0.06
Hibiscus aponeurus	68.5	31.2	271.4	70.3	0.02
Hibiscus sp.	4.5	4.5	155.6	66.8	0.05
Lantana sp.	0.0	0.0	43.9	43.9	0.33
Lantana viburnoides	23.0	14.7	34.2	17.4	0.63
Lippia sp.	8.5	5.7	11.6	7.8	0.75
Malhania velutina	0.0	0.0	8.3	8.3	0.33
Ocimum americanum	0.0	0.0	175.0	143.9	0.24
Ocimum suave	7.9	5.3	10.1	7.1	0.80
Ormocarpum kirkii	0.0	0.0	8.3	8.3	0.33
Sida ovata *	0.0	0.0	710.	334.4	0.05
Solanum incanum	3007.9	1518.1	2159.9	736.9	0.62
Solanum sp.	17.4	17.4	34.4	20.6	0.54
Talinum portulacifolium *	2137.4	1214.0	1125.5	621.3	0.47
Unidentified sp.	82.7	77.7	185.5	86.7	0.39

[1]Standard error of the mean.

[2]α - level of significance.

*Indicates important forage (browse) species (Kamau 1984, Lusigi et al. 1984).

more plants per hectare in nearly all species, an indication of a probable thinning effect of fire on shrubs/woody vegetation in a bushed/wooded grassland.

Density of Shrub/Woody Species Below 1-Meter

Nearly all plants of *Acacia mellifera, Acacia tortilis, Grewia bicolor, Grewia similis, Hermania alhensis, Hibiscus aponeurus* and *Solanum incanum* in the burned paddock were regenerations, thus indicating high top-kill of these species by the February burn. Burning apparently enhanced the density of *Acacia mellifera, Acacia tortilis* for this height category. *Talinum portulacifolium,* an important forage species was enhanced by burning.

Canopy Diameter of Shrub/Woody Species Above 1-Meter

Mean canopy diameter (meters) values are shown in Table 7. In this height category only *Acacia senegal* and *Solanum incanum* had significant paddock differences ($\alpha = 0.001$ and $\alpha = 0.03$, respectively). Nearly all the major browse species in the unburned paddock had larger canopies (diameter) than the species in the burned paddock where they occurred. Since only the live portions of the canopies were measured, burning may have reduced the canopy diameters of the species in the burned paddock.

Canopy Diameter of Shrubs/Woody Species Below 1-Meter

The mean canopy diameter (m) values are shown in Table 7. In this height category, there were no differences in species canopy diameter between the two paddocks. However, the absence of some of the species in

Table 7. Mean canopy diameter (meters) for shrub/woody species found in the burned and unburned *Acacia senegal* savannah pastures of GM2, Kiboko, Kenya, November 1982.

Height category / Species	Burned			Unburned			α^3
	n[1]	Mean	SE[2]	n	Mean	SE	
Above 1 meter							
Acacia drepanolobium	--	--	--	2	2.43	1.07	--
Acacia mellifera *	10	2.74	0.18	4	4.09	0.66	0.13
Acacia senegal *	10	2.70	0.10	10	3.71	0.22	0.001
Acacia tortilis *	8	2.31	0.14	8	2.29	0.18	0.91
Acalypha fruticosa	--	--	--	1	1.07	--	--
Albizia amara *	1	1.30	--	1	1.47	--	--
Balanites aegyptiaca *	3	1.75	0.37	5	3.15	0.83	0.26
Commiphora rostrata	--	--	--	1	2.60	--	--
Commiphora riparia *	--	--	--	6	1.84	0.09	--
Commiphora africana *	4	1.09	0.16	9	1.48	0.15	0.14
Commiphora sp.	1	0.74	--	--	--	--	--
Cordia gharaf *	5	3.56	0.87	7	2.28	0.34	0.15
Dalbergia melanoxylon	1	1.78	--	1	2.28	--	--
Duosperma kilimandscharicum	--	--	--	2	1.66	0.04	--
Grewia bicolor *	--	--	--	3	2.15	0.94	--
Grewia hexamita	--	--	--	3	4.61	0.53	--
Grewia similis *	1	1.08	--	6	1.31	0.08	0.32
Grewis villosa *	4	2.02	0.09	8	1.98	0.40	0.93
Hermania alhensis *	--	--	--	4	2.09	0.25	--
Hibiscus aponeurus *	--	--	--	3	1.18	0.59	--
Hoslundia opposita	--	--	--	2	1.52	0.47	--
Lantana viburnoides	1	1.20	--	7	1.04	0.18	0.77
Lippia sp.	1	1.18	--	1	0.60	--	--
Ormocarpum kirkii	--	--	--	1	2.40	--	--
Promna aliotrica	--	--	--	1	2.39	--	--
Solanum incanum *	1	0.30	--	8	1.10	0.10	0.03
Solanum sp.	1	1.77	--	2	1.49	0.38	0.74
Unidentified sp.	1	0.40	--	1	0.95	--	--

[1]Number of transect in which species occurred.
[2]Standard error of the mean.
[3]α - level of significance.
*Indicates important browse species (Kamau 1984, Lusigi et al. 1984).

Table 7. Continued

Height category / Species	Burned			Unburned			α[3]
	n[1]	Mean	SE[2]	n	Mean	SE	
Below 1 meter							
Acacia mellifera	4	0.53	0.16	--	--	--	--
Acacia senegal	2	0.69	0.32	2	0.30	0.28	0.45
Acacia tortilis	6	0.64	0.13	--	--	--	--
Balanites aegyptiaca	1	0.06	--	--	--	--	--
Boscia angustifolia	--	--	--	1	0.92	--	--
Commiphora africana	--	--	--	3	0.16	0.06	--
Cordia gharaf	--	--	--	1	0.24	--	--
Commiphora riparia	--	--	--	1	0.35	--	--
Dalbergia melanoxylon	1	0.57	--	--	--	--	--
Grewia bicolor	1	0.91	--	1	0.41	--	--
Grewia similis	3	0.34	0.14	5	0.59	0.23	0.65
Grewia villosa	4	0.24	0.06	4	0.41	0.07	0.13
Hermania alhensis	10	0.33	0.10	10	0.51	0.10	0.22
Hibiscus aponeurus	5	0.11	0.02	8	0.25	0.09	0.17
Hibiscus sp.	1	0.13	--	7	0.17	0.06	0.84
Lantana viburnoides	3	0.11	0.04	5	0.45	0.21	0.29
Lantana sp.	--	--	--	1	0.08	--	--
Lippia sp.	2	0.59	0.11	2	0.20	0.03	0.07
Sida ovata *	--	--	--	5	0.07	0.01	--
Malhania velutina	--	--	--	1	0.12	--	--
Ocimum americanum	--	--	--	2	0.09	--	--
Ocimum suave	2	0.19	0.06	2	0.25	0.21	0.82
Solanum incanum	10	0.61	0.40	10	0.43	0.12	0.67
Solanum sp.	1	0.23	--	3	0.15	0.08	0.67
Talinum portulacifolium *	5	0.15	0.02	6	0.45	0.18	0.16
Omorcarpum kirkii	--	--	--	1	0.05	--	--
Unidentified sp.	2	0.82	0.52	5	0.29	0.11	0.50

[1]Number of transect in which species occurred.
[2]Standard error of the mean.
[3]α - level of significance.
*Indicates important browse species (Kamau 1984, Lusigi et al. 1984).

any one of the paddocks might not give the true statistical representation of the mean canopy diameter comparison. However, due to the small values of canopy diameters of most of the browse species, whole species were completely accessible to the browsing goats and to some extend cattle. Lopes and Stuth (1984) delineated 0.3 m as the grazing depth of goats. The higher densities of this height category and the accessible height to the grazing/borwsing animals might have affected the botanical composition and diet quality of the animals.

Canopy Area of Shrub/Woody Species Above 1-Meter

The canopy area (m^2) per ha) values are shown in Table 8. In this height category, only *Commiphora africana* and *Grewia villosa* had canopy area (m^2 per ha) differences between the two paddocks, while differences for *Acacia senegal* and *Commiphora riparia* were highly significant (α = 0.001 and 0.006, respectively).

Acacia senegal had the highest canopy area. Other species with high canopy area in both paddocks were *Acacia mellifera* and *Acacia tortilis.* However, the unburned paddock tended to have higher canopy area than the burned paddock, hence, the burned paddock was a more open grassland than the unburned paddock. Appendix Table gives the details of the percent canopy cover of each species.

Canopy Area of Shrub/Woody Species Below 1-Meter

In this height category (Table 8), there was no difference in canopy area (m^2 per ha) between the two paddocks. *Hermania alhensis, Solanum incanum* and *Talinum portulacifolium* had the highest canopy area per

Table 8. Canopy area (m^2 per ha) for the shrub/woody species in the burned and unburned *Acacia senegal* savannah pastures of GM2, Kiboko, Kenya, November 1982.

Height category / Species	Burned		Unburned		α^2
	Mean	SE[1]	Mean	SE	
Above 1 meter					
Acacia drepanolobium	0	0	16.29	13.04	0.23
Acacia mellifera *	84.53	21.42	121.15	55.30	0.55
Acacia senegal *	367.56	98.56	1562.32	258.34	0.001
Acacia tortilis *	87.52	32.88	103.11	29.03	0.73
Acalypha fruticosa	0	0	1.58	1.58	0.33
Albizia amara *	0.52	0.52	2.30	2.30	0.47
Balanites aegyptiaca *	10.02	7.23	89.58	55.87	0.19
Commiphora africana *	1.64	0.83	57.88	23.11	0.04
Commiphora riparia *	0	0	70.07	22.61	0.006
Commiphora rostrata	0	0	13.81	13.81	0.33
Commiphora sp.	0.25	0.25	0	0	0.33
Cordia gharaf *	22.69	11.07	43.58	15.61	0.29
Dalbergia melanoxylon	0.79	0.79	3.30	3.30	0.47
Duosperma kilimandscharicum	0	0	10.78	7.19	0.15
Grewia bicolor *	0	0	32.18	28.08	0.27
Grewia hexamita	0	0	54.35	27.80	0.07
Grewia similis *	0.31	0.31	24.80	11.98	0.07
Grewia villosa *	8.91	4.52	51.64	18.41	0.05
Hermania alhensis *	0	0	27.88	19.40	0.17
Hibiscus aponeurus *	0	0	7.31	6.24	0.26
Hoslundia opposita	0	0	3.20	2.20	0.16
Lantana viburnoides	0.99	0.99	15.37	8.53	0.13
Lippia sp.	0.43	0.43	0.27	0.27	0.76
Ormocarpum kirkii	0	0	4.49	4.49	0.33
Premna oliotrica	0	0	10.33	10.33	0.33
Solanum incanum *	0.05	0.05	39.55	20.86	0.09
Solanum sp.	0.97	0.97	3.44	2.75	0.41
Unidentified sp.	0.10	0.10	0.47	0.47	0.46

[1]Standard error of the mean.

[2] - level of significance.

*Indicates important browse species (Kamau 1984), Lusigi et al. 1984).

Table 8. Continued

Height category / Species	Burned		Unburned		α^2
	Mean	SE[1]	Mean	SE	
Below 1 meter					
Acacia mellifera	15.46	13.85	0	0	0.28
Acacia senegal	2.25	1.83	1.90	1.9	0.89
Acacia tortilis	26.68	15.12	0	0	0.09
Balanites aegyptiaca	0	0	97.56	97.56	0.33
Boscia angustifolia	0	0	4.30	4.30	0.33
Commiphora africana	0	0	0.63	0.50	0.09
Commiphora riparia	0	0	0.36	0.36	0.33
Cordia gharaf	0	0	0.20	0.20	0.33
Dalbergia melanoxylon	1.0	1.0	0	0	0.33
Grewia bicolor	4.51	4.51	1.69	1.69	0.57
Grewia similis	14.68	10.57	31.00	18.61	0.45
Grewia villosa	72.10	71.47	11.92	6.89	0.42
Hermania alhensis	49.91	23.74	419.59	245.71	0.17
Hibiscus aponeurus	1.03	0.51	34.90	27.57	0.25
Hibiscus sp.	0.06	0.06	6.98	3.61	0.09
Lantana sp.	0	0	0.44	0.44	0.33
Lantana viburnoides	0.47	0.43	20.29	16.39	0.26
Lippia sp.	2.31	1.62	0.38	0.27	0.27
Malhania velutina	0	0	0.09	0.09	0.33
Ocimum americanum	0	0	1.56	1.43	0.29
Ocimum suave	0.24	0.19	1.05	1.05	0.47
Ormocarpum kirkii	0	0	0.02	0.02	0.33
Sida ovata *	0	0	4.87	2.97	0.12
Solanum incanum	453.34	273.46	359.81	128.48	0.76
Solanum sp.	0.70	0.70	1.32	1.24	0.67
Talinum portulacifolium *	44.70	24.89	117.52	75.55	0.38
Unidentified sp.	108.88	108.52	17.96	14.25	0.43

[1]Standard error of the mean.

[2] - level of significance.

*Indicates important browse species (Kamau 1984, Lusigi et al. 1984).

hectare in both paddocks. It is apparent that in spite of the large numbers of plants per hectare (absolute density) of this height category, their total canopy cover was relatively small, hence, most of the understory vegetation was dominated by grasses.

Nutritive Value of Cattle Diets

Seasonal Effects

The nutritional data of the diets were aggregated into six distinct seasons based on rainfall patterns. The nutritional parameters were analysed within season (Table 9). Detailed dietary nutritional data can be found in Appendix Tables 2-7.

The highest diet quality values occurred during the early short wet season (mid-October to mid-November). Both the long wet season and short set season (mid-March to late May and mid-November to mid-January, respectively) had the next highest levels of nutritional quality. These were the periods of active plant growth and reflected some carry-over effect of the abnormally rainy short wet season. During these seasons, the grazing animals would have been actively selecting for leafy, green plant material. Kibet (1984) reported the highest percentage of green leaves in diets of cattle in November than for the months of June to September from an adjacent pasture to this study site during the same period.

The short and late long dry seasons corresponded with the lowest levels of nutritional quality in diets of cattle. The early long dry season was intermediate to the very dry periods and the wet periods regardless of the dietary parameter due to the gradual decline in dietary

Table 9. Mean seasonal dietary crude protein (%) and organic matter dig
ted heifers grazing burned and unburned *Acacia senegal* savannah pastures at Ki

Season	Period	Burn n[1]	Burn Mean	Burn SE[2]	n
				Crude prot	
Long wet	Mid March to late May[3]	28	15.6	0.62	36
Early long dry	Early June to late July	22	11.1	0.17	22
Late long dry	Early Aug. to mid Oct.	15	8.6	0.26	16
Early short wet	Mid Oct. to mid Nov.	16	20.7	0.82	16
Late short wet	Mid Nov. to mid Jan.	16	13.7	0.31	16
Short dry	Mid Jan. to mid March	22	8.7	0.25	22
				Organic matter d	
Long wet	Mid March to late May[3]	28	74	0.51	36
Early long dry	Early June to late July	22	70	0.85	22
Late long dry	Early Aug. to mid Oct.	15	63	0.62	16
Early short wet	Mid Oct. to mid Nov.	16	76	0.37	16
Late short wet	Mid Nov. to mid Jan.	16	71	1.12	16
Short dry	Mid Jan. to mid March	22	68	0.69	22

[1]Number of samples analysed.

[2]Standard error of the mean.

[3]No March samples for the burn treatment due to lack of regrowth after the bur

quality with advance in plant maturity as has been observed by many researchers (Cook and Harris 1950, Pritchard *et al.* 1963, Terry and Tilley 1964, Cook and Harris 1968, Burzlaff 1971, Haggar and Ahmed 1971, Huston *et al.* 1981, Heitschmidt *et al.* 1982). Periods of advanced plant maturity have been documented by researchers as periods of low crude protein (CP) values (Cook and Harris 1968, Kothmann 1968, Burzlaff 1971, Sims *et al.* 1971, Huston *et al.* 1981, Heitschmidt *et al.* 1982), and lower digestibility (Pritchard *et al.* 1963, Terry and Tilley 1964, Burzlaff 1971, Haggar and Ahmed 1971). These dry periods coincide with seasons when plants shed most of their dead and senesced leaves. Thus grazing animals will have high stem to leaf ratios in their diets. In a concurrent study period, Kibet (1984) reported low levels of dietary quality in an unburned area adjacent to this study site, and that the low levels of dietary quality during the dry periods were indicators of reduced live plant material in the diets.

Burning Effects

Burning enhanced dietary CP of cattle throughout the long wet season and into the early long dry season. This positive effect of burning on dietary CP was lost during the late long dry season. However, when the rains began in October, the positive effect of burning was sustained until late November. Thus, burning did not allow cattle to select for higher dietary protein in the late dry season, late wet season, and short dry season. It is, therefore, apparent that the positive effects of a February burn on dietary protein lasted approximately 5.5 months and can be measured again for a short period in the early short wet season following the burn with adequate rainfall.

The long wet season was drier than the long term average, with March receiving no rains and May receiving no rains in the first 10 days (Fig. 4 and Table 1). The poorly distributed and limiting moisture conditions reduced the growth of fresh vegetative shoots after the February burn as would be expected to occur after a burn (West 1965, McKay 1970, McAtee *et al.* 1979), thus reducing animal selectivity for green leaves in both the burned and unburned paddocks. However, cattle selected diets higher in crude protein from the burned pasture than from the unburned pasture. The grazing animals were able to select for higher CP level in the burned (11.1% CP) than in the unburned (10.0%) 4 months after the February burn in spite of the low rainfall situation. These levels were much higher than the 5 to 6% reported by McKay (1970) in a *Themeda triandra-Digitaria setivalva* grassland in the Kedong area, Kenya, 2.5 months post-burn.

The dietary CP values during the late long season and short dry season were similar for both the burned and unburned paddocks. This was an indication of the lack of selectivity for green leaves and stems by the grazing animals due to the maturity of the herbage and plant dormancy during the rainfall deficient seasons.

The short rains of October to December again initiated new shoot growth. Dietary CP was again higher for the burned paddock than the unburned paddock during this period. However, the significant positive effect of burning lasted for approximately 1 month during the flush of growth. Other researchers (Hilmon and Hughes 1965, McAtee *et al.* 1979, McGinty *et al.* 1983, Angell *et al.* 1986) have reported shortlived high dietary CP content lasting through the rapid growth periods following burning. The continued high rainfall in December possibly carried over its effect in January and enabled cattle to continuously select for higher quality shoots in both the burned (11.8% CP) and unburned (11.4% CP) paddocks even though January was a dry month.

Burning had positive effects on dietary organic matter digestibility (OMD) during the long wet season (2 months) and the early short wet season (1 month), but had no effect ($\alpha = 0.05$) during the other four seasons. In contrast to the positive effect of burning on dietary CP during the early long dry season ($\alpha = 0.0001$), there was no strong positive effect of burning on OMD ($\alpha = 0.085$) in this season. During the early long dry season, there was limited leaf growth due to lack of sufficient soil moisture and little carry-over growth from the preceeding rainy season. Carry-over growth had been consumed by buffalos, Kongoni, elands and other wild graziers because the burned pasture was the only area in the vicinity with attractive greenery. This heavy utilization of the burned pasture by wildlife limited selectivity by livestock. Cattle may have, therefore, consumed high proportions of stems which have lower digestibility than leaves (Woie 1984) even though green on account of high consumption of *Digitaria macroblephara* (Kibet 1984).

Nutritive Value of Goat Diets

Seasonal Effects

The nutritional quality of goat diets followed a similar seasonal trend as cattle except that the variation from one season to the next was not as dramatic (Table 10 and Appendix Tables 8-13).

Table 10. Mean seasonal dietary crude protein (%) and organic matter di
ted goats grazing burned and unburned Acacia senegal savannah pastures at Kib

Season	Period	Burn			
		n[1]	Mean	SE[2]	n
				Crude prot	
Long wet	Mid March to Mid May[3]	4	17.4	0.71	4
Early long dry	Early June to late July	7	16.6	0.55	7
Late long dry	Early Aug. to mid Oct.	8	15.3	0.83	8
Early short wet	Mid Oct. to mid Nov.	8	23.3	0.84	8
Late short wet	Mid Nov. to mid Jan.	8	19.2	0.62	8
Short dry	Mid Jan. to mid March	12	16.4	0.58	12
				Organic matter di	
Long wet	Mid March to late May[3]	4	73	0.98	4
Early long dry	Early June to late July	7	68	1.56	7
Late long dry	Early Aug. to mid Oct.	8	63	2.60	8
Early short wet	Mid Oct. to mid Nov.	8	79	1.45	8
Late short wet	Mid Nov. to mid Jan.	8	71	0.67	8
Short dry	Mid Jan. to mid March	12	62	1.35	12

[1]Number of samples analysed.

[2]Standard error of the mean.

[3]No sampling done in March and April. Values are for May only.

Burning Effects

Burning had a positive effect on dietary CP in the early short wet season (α = 0.048). There was no apparent positive effect of burning for the other seasons. However, it is probable that a positive effect would have occurred during the long wet season had the samples for the April flush of growth been included in the analysis. There was a trend for high dietary CP in goat diets from the burned pasture during the long dry seasons, but in all seasons, goats selected for CP above their maintenance requirement (NRC 1981). It is apparent that burning does not significantly alter the dietary quality of goat diets, except during the initial flush of growth in response to the March and October rains and is short-lived. Diets from the burned pasture maintained higher trends of CP levels than the unburned pasture in almost all seasons of the study period. It is also apparent that burning increased seasonal variation in diet quality in the burned paddocks as compared to the unburned paddock. This seasonal variation within the burn treatment may be due to an increase in forb availability (Tables 5 and 6), especially *Talinum* sp. and *Hibiscus* sp., whose leaves and fruits are relished by goats.

Many research reports indicate that the nutritive quality of forages declines with advance in plant maturity and that the rate of decline varies between plant species and parts of plants within and between species (Pritchard *et al.* 1963, Terry and Tilley 1964, Bredon *et al.* 1967, Cook and Harris 1968, Daubenmire 1968, McKay 1970, Burzlaff 1971, Sims *et al.* 1971, Huston *et al.* 1981). Goats prefer browse (Harrington 1982, Rector 1983, Kamau 1984), but are not obligate browsers (Harrington 1982, McDowell and Woodward 1982). Thus, goats will graze depending on the availability and quality of the herbage. The ability of the goat to select and consume plant parts of high quality and to shift their diets with season is demonstrated by the high quality of their diets in all seasons.

Although dietary OMD content appeared to be higher in diets from the burned pasture through much of the year, differences (α = .024) could be detected during the late short wet season, when the dietary OMD content was higher for unburned pasture goat diets. During the other seasons, OMD of the diets was apparently similar (α - range of 0.1005 to 0.74). It is apparent that burning does not provide goats with a significantly greater opportunity for selection of more digestible forage. This agrees with the finding reported by other researchers that goats are able to select the nutrient-rich parts of grasses and browse of high digestibility (Arnold 1960, Malechek and Leinweber 1972b, Harrington 1982, McDowell and Woodward 1982). However, the low dietary digestible organic matter contents during the dry seasons would have indicated the consumption of mature forages and probably higher browse at this time when the grasses would have low CP content. At these seasons, goats would be inclined to select forages with higher CP content as has been reported by Malechek (1970), Field (1975) and Wilson *et al.* (1975).

Cattle Diets Vs Goat Diets

Goats had consistently higher dietary CP contents than cattle across all seasons in both the burned and the unburned pastures (Appendix Table 14). The dietary OMD values of goats were higher than those of cattle during the short wet season and lower during the short dry season in the burned pasture during the wet seasons and lower OMD during the dry season (Appendix Table 14). It is apparent that goats have a better ability to select for higher CP content than cattle regardless of the treatment, but are only able to select for higher digestibility during the wet periods, presumably during periods of active herbaceous vegetation growth. Detailed comparisons can be found in Appendix Tables 15-17.

In the absence of any analysis of the botanical composition (for forage classes), leaf:stem ratios, green:dead ratios, and plant parts of cattle and goat diets by season, the interpretation of the above Appendix Tables was by inferences to other research observations. Many researchers have reported differences in foraging behavior, dietary strategy, dietary preference and selectivity between cattle and goats.

While cattle have a high forage demand to be browsers and their intake requirement so great that there is insufficient high quality feed in the environment to sustain them, goats are small ruminants with a high metabolic rate relative to gut capacity. Goats must, therefore, eat high quality feed that can be digested quickly (Huston 1978, McDowell and Woodward 1982). The small mouths of goats are able to penetrate even thorny bushes, their mobile upper lips, and their low absolute intake requirements permit selection of higher quality plants and parts of plants (McDowell and Woodward 1982). Goats are also able to alternate their diets with changes in season and abailability (Fraps and Cory 1940, Wilson 1957, Knight 1964, Harrington 1982, McDowell and Woodward 1982, Rector 1983, Kamau 1984, Lopes and Stuth 1984); hence, goats are able to select for plants and parts of plants of high nutritional values (Field 1975, Malechek and Leinweber 1972b, Harrington 1982, Forwood and Owensby

1985). This enables goats to improve their nutrient intake even at times of nutritional stress. These above observations probably explain why goat dietary CP content was higher than for cattle, which are coarse grass feeders and rely mostly on perennial species. Cattle eat in bulk - their large mouths rendering them rather unselective to plant parts (Field 1975).

It is documented that goats are grazers when the grasses and forbs are actively growing (Malechek 1970, Harrington 1982, McDowell and Woodward 1982, Rector 1983, Kamau 1984) and change to browsing as the season advances, when the grasses are low in dietary quality. Since grasses (leaves and stems) are generally more digestible than browse (Wilson 1969), the OMD of the diets selected by goats were lower than that of cattle during the dry seasons.

Livestock Production Systems

Model Overview

The profitability of the beef enterprise in Kenya is based primarily on the birth rates, amounts of milk produced for both the offspring and human consumption, the number of calves weaned and the subsequent growth of weaners to breeding weights and market weights on natural pastures. The availability and quality of forage greatly affect the production and reproductive ability of beef cattle. Other factors like availability of quality water, feed conversion efficiency and diseases, among others, are important factors. The model discussed here was based on a cow-calf operation with January, May and October as the mean calving months.

The computer model algorithm was based on equations adapted from

Powell *et al.* (1984). The LOTUS-123 algorithm and equations are presented in Appendix Fig. 1 and Appendix Table 18. However, some assumptions had to be made on the parameter input values.

Assumptions. Except for the OMD (%) and CP (%) at high precipitation (i.e., during the study period), all other inputs were based on studies done elsewhere and personal communications with people who have been involved with the particular breeds of livestock. The inputs by month are presented in Appendix Tables 19A and 19B.

The following were the assumptions made in developing the parameter inputs:

1. Breed - The cattle breeds used in this study were Sahiwal, Boran and the small East African Zebu. These breeds do not appear in the "Breed Adjustment" consideration of Powell *et al.* (1984). The Brahman (*Bos indicus*) is a tropical/subtropical breed and was selected over the other breeds.

2. Precipitation level - The amount of rainfall and its distribution affects the monthly quantity and quality of the forage. Two precipitation levels were adopted, whereby the year of this study was regarded as having high precipitation and a below normal rainfall was regarded as low precipitation level.

3. Body weights - These were arbitrary averages based on various sources, i.e., for Sahiwal, the weights were based on Mwandotto (Personal communication), Semenye and Chabari (1980); for Boran, the weights were based on a combination of mean weights reported by Lampkin and Lampkin (1960a) and Semenye and Chabari (1980); zebu weights were based on a combination of mean weights reported by Semenye (1980) and King *et al.*

(1984). However, body weight losses during the dry periods and after calving were based on 12 to 14% reported by Kidner (1966b) and personal experience.

4. Body condition - These were adopted from Wiltbank (1985).

5. Production/physiological stage - Three mean calving months of January, May and October were adopted. The calves were allowed an 8-month suckling period.

6. Environmental condition - Hot and dry environment was adopted.

7. Travel - Most range livestock production is done on open range, with pastures being 20 ha or more and distances of greater than 1.6 km to water.

8. Milk production - The milk yield estimates were based on a combination of various sources and the author's experience. Guidelines for Sahiwal milk yields were based on Mwandotto (personal communication) and Saigaonkar *et al.* (1981). Boran milk yield guidelines were based on Lampkin and Lampkin (1960b). Zebu milk yield figures were those of the author.

9. Diet OMD and CP - The values for high precipitation scenario were from the data collected during the study period (March 1982-March 1983). Values for the low precipitation scenario were estimated by the author.

10. Average daily gain (ADG) of replacement heifers - Only mature cows were used in the model.

11. Forage intake - Forage availability was assumed to be unlimiting. The equation for organic matter intake was adopted from Olson (1984).

Energy and Protein Status

In the interpretation of the daily energy (mcal/day) and protein (kg/day) status of the cattle breeds for the three average calving months, the nutritional status of the breeds at various trimesters were evaluated in regard to rebreeding success, milk production and calf weaning weights, calf weights at birth, recovery of dams' bory condition and the growth of retained heifers in both high and low precipitation scenerios. The reported excess/deficit values for energy and protein were values in excess or short of breed's requirements for maintenance at various production levels.

Generally, under a high rainfall scenerio, the heavier, high milking breeds appeared to have higher values for excess energy and protein in almost all months regardless of the breeding regimen, hence had higher potential for probable weight gains, milk production, heavier calves at birth and at weaning. However, under low precipitation scenerio, where the forage quality was relatively low, the energy and protein deficits were apparently greater in the heavy, high milking Sahiwal than in Boran and zebu during the lactation period. The lighter breeds had greater energy and protein deficits, and lower excess energy and protein than the heavier breeds during the non-lactation periods. Net energy and crude protein balances for the breeds are summarized in Tables 11, 12, 13 and 14.

<u>High precipitation, January calf</u>. All breeds had excess daily energy requirements except during the month of March when Sahiwal and zebu breeds had negligible energy deficits (-0.1 mcal/day each) and again in August when the zebu breed had a deficit of -0.3 mcal/day. The

Table 11. Projected net energy (mcal/day) status (excess/deficit) by month for selected mean calving months of three breeds of cattle grazing unburned and burned *Acacia senegal* rangelands with above average forage quality and rainfall conditions.

Month	Sahiwal Breed	Boran Breed	E. African Zebu Breed
JANUARY CALF			
Jan.	4.2[1] (3.5)[2]	4.4 (3.8)	3.0 (2.5)
Feb.	1.5 (1.5)	2.0 (2.0)	0.9 (0.9)
March	-0.1 (0.5)	0.2 (0.7)	-0.1 (0.3)
April	5.4 (7.6)	4.8 (6.6)	3.3 (4.7)
May	6.4 (6.4)	5.7 (5.7)	3.6 (3.6)
June	5.4 (7.4)	4.2 (5.9)	2.7 (4.0)
July	2.3 (2.3)	1.2 (1.2)	0.5 (0.5)
Aug.	0.8 (0.8)	0.4 (0.4)	-0.3 (-0.3)
Sept.	1.2 (1.2)	0.8 (0.8)	0.2 (-0.2)
Oct.	6.2 (8.8)	4.9 (7.2)	3.3 (5.1)
Nov.	5.8 (7.7)	5.2 (7.0)	3.8 (5.2)
Dec.	3.6 (5.5)	3.1 (4.8)	1.8 (3.2)
MAY CALF			
Jan.	8.8 (8.1)	7.2 (6.6)	4.6 (4.1)
Feb.	4.2 (4.2)	3.0 (3.0)	1.3 (1.3)
March	2.6 (3.2)	1.8 (2.3)	0.4 (0.8)
April	7.4 (9.7)	6.0 (7.9)	3.4 (4.8)
May	4.5 (4.5)	4.4 (4.4)	2.4 (2.4)
June	2.9 (5.0)	2.7 (4.4)	1.0 (2.2)

Table 11. Continued.

Month	Sahiwal Breed	Boran Breed	E. African Zebu Breed
MAY CALF (continued)			
July	-0.3[1] (-0.3)[2]	-0.2 (-0.2)	-0.9 (-0.9)
Aug.	-1.3 (-1.3)	-0.6 (-0.6)	-1.2 (-1.2)
Sept.	-1.6 (-1.6)	-0.7 (-0.7)	-1.3 (-1.3)
Oct.	5.2 (7.6)	5.0 (7.2)	2.8 (4.5)
Nov.	6.0 (8.0)	5.5 (7.3)	3.1 (4.4)
Dec.	4.0 (5.9)	3.5 (5.3)	1.3 (2.5)
OCTOBER CALF			
Jan.	4.8 (4.1)	5.3 (4.7)	2.4 (2.0)
Feb.	2.5 (2.5)	2.9 (2.9)	1.0 (1.0)
March	2.0 (2.6)	1.6 (2.2)	0.2 (0.5)
April	7.1 (9.2)	6.1 (7.9)	3.3 (4.6)
May	8.0 (8.0)	6.5 (6.5)	3.6 (3.6)
June	7.8 (9.2)	6.1 (7.8)	3.9 (5.2)
July	2.4 (2.4)	1.3 (1.3)	0.3 (0.3)
Aug.	0.7 (0.7)	0.4 (0.4)	-0.7 (-0.7)
Sept.	0.1 (0.1)	-0.1 (-0.1)	-1.1 (-1.1)
Oct.	3.6 (6.3)	4.1 (6.5)	1.7 (3.3)
Nov.	3.4 (5.4)	3.4 (5.2)	1.6 (2.8)
Dec.	1.0 (2.9)	1.2 (2.8)	0.0 (1.1)

[1] Net energy balance for unburned paddock. [2]Net energy balance for burned paddock.

Table 12. Projected protein (kg/day) status (excess/deficit) by month for selected mean calving months of three cattle breeds grazing unburned and burned *Acacia senegal* rangelands with above average forage quality and rainfall conditions.

Month	Sahiwal Breed	Boran Breed	E. African Zebu Breed
JANUARY CALF			
Jan.	0.73[1] (0.76)[2]	0.75 (0.77)	0.60 (0.62)
Feb.	0.28 (0.24)	0.35 (0.32)	0.30 (0.27)
March	0.12 (0.17)	0.22 (0.26)	0.21 (0.23)
April	1.23 (1.87)	1.14 (1.67)	0.90 (1.31)
May	1.25 (1.22)	1.13 (1.10)	0.88 (0.86)
June	0.77 (1.03)	0.70 (0.92)	0.54 (0.71)
July	0.60 (0.70)	0.54 (0.62)	0.43 (0.49)
Aug.	0.46 (0.46)	0.43 (0.43)	0.33 (0.33)
Sept.	0.40 (0.40)	0.34 (0.34)	0.23 (0.23)
Oct.	1.93 (2.70)	1.69 (2.38)	1.28 (1.82)
Nov.	1.47 (1.88)	1.36 (1.74)	1.02 (1.32)
Dec.	1.15 (1.34)	1.05 (1.22)	0.78 (0.91)
MAY CALF			
Jan.	1.15 (1.17)	0.98 (1.00)	0.71 (0.72)
Feb.	0.61 (0.58)	0.51 (0.48)	0.33 (0.30)
March	0.46 (0.51)	0.37 (0.41)	0.22 (0.25)
April	1.52 (2.17)	1.28 (1.84)	0.88 (1.28)
May	1.04 (1.01)	0.99 (0.97)	0.73 (0.72)
June	0.51 (0.78)	0.53 (0.76)	0.39 (0.54)

Table 12. Continued.

Month	Sahiwal Breed	Boran Breed	E. African Zebu Breed
MAY CALF (continued)			
July	0.33[1] (0.42)[2]	0.39 (0.48)	0.30 (0.35)
Aug.	0.23 (0.23)	0.33 (0.33)	0.25 (0.25)
Sept.	0.17 (0.17)	0.26 (0.26)	0.20 (0.20)
Oct.	1.80 (2.56)	1.69 (2.37)	1.24 (1.74)
Nov.	1.47 (1.89)	1.37 (1.74)	0.99 (1.26)
Dec.	1.15 (1.34)	1.07 (1.24)	0.76 (0.88)
OCTOBER CALF			
Jan.	0.80 (0.81)	0.85 (0.87)	0.59 (0.60)
Feb.	0.43 (0.40)	0.49 (0.46)	0.34 (0.32)
March	0.35 (0.40)	0.37 (0.41)	0.26 (0.29)
April	1.41 (2.03)	1.25 (1.78)	0.88 (1.25)
May	1.42 (1.39)	1.21 (1.19)	0.86 (0.85)
June	0.96 (1.20)	0.78 (1.01)	0.56 (0.73)
July	0.65 (0.75)	0.53 (0.62)	0.33 (0.39)
Aug.	0.48 (0.48)	0.42 (0.42)	0.23 (0.23)
Sept.	0.36 (0.36)	0.31 (0.31)	0.14 (0.14)
Oct.	1.67 (2.48)	1.63 (2.37)	1.09 (1.57)
Nov.	1.21 (1.64)	1.14 (1.50)	0.81 (1.06)
Dec.	0.83 (1.02)	0.83 (0.99)	0.59 (0.70)

[1] Protein balance for unburned paddock. [2] Protein balance for burned paddock.

Table 13. Projected net energy (mcal/day) status (excess/deficit) by month for selected mean calving months of three cattle breeds grazing unburned and burned *Acacia senegal* rangelands with below average forage quality and rainfall conditions.

Month	Sahiwal Breed	Boran Breed	E. African Zebu Breed
JANUARY CALF			
Jan.	-3.2[1] (-2.7)[2]	-2.2 (-1.7)	-2.0 (-1.7)
Feb.	-3.7 (-3.2)	-2.6 (-2.1)	-2.6 (-2.2)
March	-3.0 (-1.9)	-2.2 (-1.3)	-1.9 (-1.2)
April	1.4 (4.1)	1.5 (3.7)	0.8 (2.5)
May	0.4 (3.0)	0.8 (2.9)	-0.1 (1.5)
June	0.4 (1.0)	0.1 (0.6)	-0.4 (-0.1)
July	-0.5 (0.1)	-1.1 (-0.6)	-1.3 (-1.0)
Aug.	-1.1 (-0.7)	-1.4 (-1.0)	-1.6 (-1.3)
Sept.	-0.7 (-0.7)	-0.9 (-0.9)	-1.2 (-1.2)
Oct.	-0.5 (0.0)	-1.0 (-0.6)	-1.3 (-1.0)
Nov.	2.8 (5.2)	2.4 (4.7)	1.6 (3.3)
Dec.	1.2 (2.4)	0.9 (2.0)	0.1 (0.9)
MAY CALF			
Jan.	1.4 (1.9)	0.8 (1.3)	-0.2 (0.2)
Feb.	-0.9 (-0.4)	-1.5 (-1.0)	-2.0 (-1.7)
March	-0.3 (0.8)	-0.7 (0.2)	-1.4 (-0.7)
April	3.4 (6.1)	2.5 (4.8)	0.9 (2.5)
May	-1.4 (1.1)	-0.7 (1.4)	-1.3 (0.2)
June	-2.0 (-1.4)	-1.5 (-1.0)	-1.9 (-1.5)

Table 13. Continued.

Month	Sahiwal Breed	Boran Breed	E. African Zebu Breed
MAY CALF (continued)			
July	-3.0[1] (-2.5)[2]	-2.4 (-2.1)	-2.5 (-2.2)
Aug.	-3.3 (-2.8)	-2.3 (-1.9)	-2.4 (-2.1)
Sept.	-3.5 (-3.5)	-2.4 (-2.4)	-2.5 (-2.5)
Oct.	-1.3 (-0.8)	-0.8 (-0.4)	-1.4 (-1.1)
Nov.	2.9 (5.4)	2.8 (4.9)	1.1 (2.7)
Dec.	1.6 (2.8)	1.4 (2.5)	0.0 (0.8)
OCTOBER CALF			
Jan.	-2.3 (-1.8)	-2.3 (-0.6)	-1.8 (-1.5)
Feb.	-2.1 (-2.0)	-2.8 (-1.0)	-1.9 (-1.6)
March	-0.8 (0.2)	-2.2 (0.1)	-1.5 (-0.8)
April	3.2 (5.8)	1.7 (4.9)	1.0 (2.5)
May	2.0 (4.5)	0.7 (3.8)	0.0 (1.6)
June	2.7 (3.3)	1.8 (2.3)	0.8 (1.1)
July	-0.4 (0.1)	-1.1 (-0.6)	-1.5 (-1.1)
Aug.	-1.4 (-0.9)	-1.5 (-1.0)	-2.0 (-1.7)
Sept.	-1.9 (-1.9)	-2.0 (-2.0)	-2.3 (-2.3)
Oct.	-3.3 (-2.8)	-2.2 (-1.7)	-2.4 (-2.1)
Nov.	0.3 (2.8)	0.8 (2.9)	-0.3 (1.2)
Dec.	-1.4 (-0.2)	-0.8 (0.2)	-1.3 (-0.7)

[1] Net energy balance for unburned paddock grazing. [2] Net energy balance for burned paddock grazing.

Table 14. Projected protein (kg/day) status (excess/deficit) by month f
months of three cattle breeds grazing unburned and burned *Acacia senegal* rang
forage quality and rainfall conditions.

Month	Sahiwal Breed		Boran Breed	
JANUARY CALF				
Jan.	-0.07[1]	(-0.03)[2]	0.04	(0.08)
Feb.	-0.10	(-0.08)	0.02	(0.03)
March	-0.02	(0.06)	0.09	(0.16)
April	0.98	(1.40)	0.93	(1.28)
May	0.33	(0.49)	0.37	(0.51)
June	0.22	(0.33)	0.25	(0.34)
July	0.16	(0.20)	0.18	(0.21)
Aug.	0.15	(0.17)	0.16	(0.17)
Sept.	0.17	(0.17)	0.14	(0.14)
Oct.	0.38	(0.50)	0.31	(0.42)
Nov.	1.28	(1.78)	1.18	(1.65)
Dec.	0.58	(0.69)	0.53	(0.63)
MAY CALF				
Jan.	0.35	(0.39)	0.29	(0.33)
Feb.	0.23	(0.25)	0.18	(0.20)
March	0.31	(0.39)	0.23	(0.31)
April	1.26	(1.69)	1.05	(1.43)
May	0.13	(0.30)	0.21	(0.35)
June	-0.02	(0.08)	0.07	(0.17)

Table 14. Continued.

Month	Sahiwal Breed	Boran Breed
MAY CALF (continued)		
July	-0.11[1] (-0.07)[2]	0.02 (0.06)
Aug.	-0.08 (-0.06)	0.06 (0.07)
Sept.	-0.04 (-0.04)	0.07 (0.07)
Oct.	0.29 (0.42)	0.33 (0.44)
Nov.	1.28 (1.79)	1.19 (1.65)
Dec.	0.58 (0.69)	0.55 (0.65)
OCTOBER CALF		
Jan.	0.03 (0.07)	0.04 (0.20)
Feb.	0.06 (0.08)	0.03 (0.18)
March	0.20 (0.29)	0.10 (0.31)
April	1.15 (1.57)	0.93 (1.39)
May	0.49 (0.65)	0.37 (0.58)
June	0.40 (0.51)	0.32 (0.41)
July	0.21 (0.25)	0.16 (0.19)
Aug.	0.16 (0.17)	0.13 (0.15)
Sept.	0.12 (0.12)	0.09 (0.09)
Oct.	0.05 (0.18)	0.17 (0.29)
Nov.	1.02 (1.53)	0.97 (1.41)
Dec.	0.27 (0.38)	0.45 (0.44)

[1] Protein balance for unburned paddock. [2]Protein balance for burned pad

Sahiwal breed had the highest excess energy values (except in the first 3 month of lactation), zebu had the lowest excess values and Boran was intermediate. Boran breed had the highest excess energy values in the first 3 months of lactation. During the dry months in February and March and July to September, all breeds had energy status that were slightly above their daily maintenance requirements, while some breeds had negligible deficits.

The estimated energy status for the zebu was slightly above of negligibly below maintenance requirements during the dry seasons (0.7, -0.1, 0.5, -0.3, 0.0 mcal NE/day in February, March, July, August and September, respectively), while Boran energy balance was 2.0 0.2, 1.2, 0.4, 0.8 mcal NE/day and Sahiwal had 1.5, -0.1, 2.3, 0.8, 1.2 mcal/day during the same periods. This illustrated that, with high precipitation and unlimited forage availability to the grazing animal, the heavier, high milk yield breeds were better suited than the smaller frame breeds since they had more excess net energy that would have been available for body weight gains and milk production. Overall, the cows with a January mean calving date and high precipitation, apparently had no net energy problems, hence had high possibilities of rebreeding success, high milk yield, heavy calves and body weight gain.

The January calves would be weaned in August, which corresponds with forage of the lowest nutritional value. Retained weaners of January calving cows might require some extra nutritional care, especially the replacement heifers. This would pose a major problem to subsistence pastoralists, who typically retain the weaners.

The trends for protein status were similar to energy status within and between breeds. There was no apparent protein deficit in a January calving date across all breeds. However, the weaners would probably require some supplementation for protein in August to mid-October.

High precipitation, May calf. All breeds had excess net energy requirements except during the dry months of July, August and September when the energy status were below requirements for the projected production levels. The highest excess energy values were during the wet months of April, October and November, and again in January (soon after weaning). The negative energy balance early in the lactation period (3rd to 5th month), indicates that the cows would probably have some nutritional stress and that milk yields would probably be depressed. The cows would probably utilize their energy reserves (fat mobilization) to meet the deficit (Carles and Riley 1984, Chestnutt 1984). The deficits would probably jeopardize the rebreeding success. Herbel *et al.* (1984) reported that rebreeding performance is strongly affected by the cows' nutrition. Wiltbank *et al.* (1965) also reported that the nutritional levels, before and after calving, influence pregnancy rates for the next year's calf crop. Generally, there were high nutritional balances after weaning and before calving, therefore, with a May mean calving date, there were prospects for heavy calves at birth, rapid recovery of body condition and a steady growth of the weaners.

There were no apparent protein deficits across all breeds at all stages of production. The lowest values for excess protein were during the months of January to March and June to September. During the latter period of lowest values, the cows were lactating and had energy deficits. Like in excess energy trends, the bigger frame, heavier breeds had had a general trend for higher excess protein values than the lighter breeds.

High precipitation, October calf. Apparently, the Boran exhibited a trend for highest excess energy values during the first 5 months of lactation (October to February) and the Sahiwal exhibited a trend for highest excess energy values for the rest of the year. The zebu breed had the lowest excess energy values all year. While the Sahiwal had no apparent energy deficit, the Boran had negligible deficit in September (-0.1 mcal/day) and zebu had deficits of -0.7 and -1.1 mcal/day in August and September, respectively. The low excess/or deficit energy situation occurred when the cows were dry but in their late pregnancy period which would probably affect calf weights at birth. Calves born in October would probably be lighter than calves born in January or May due to the dams' relatively lower nutritional status two to three months prior to calving. Prospects for rebreeding success, high milk yield, weaning heavy calves and recovery of dams' body condition were apparently good. However, since the mean weaning month was May (at the end of the long wet season), the weaned calbes would present some management problems in that high quality pastures or supplemental energy sources would probably be required to carry the weaners over the long dry season (June to mid-October).

There were no apparent protein deficits in any breed in this model. The heavier breeds had higher excess protein values. The lowest values for excess protein were towards the end of the long dry season, prior to the October calving dates.

Low precipitation, January calf. Unlike in the high precipitation scenerio where there were only 3 months of deficit or near deficit energy status in a January calving date, all breeds had energy deficits for periods of 7 to 9 months and a further 2 to 3 months of near deficit under a low precipitation scenerio. All breeds had their highest energy deficit during the first 3 months of lactation (-3.0 to -3.7, -2.2 to -2.6 and -2.0 to -2.6 mcal/day for Sahiwal, Boran and zebu, respectively). Table 13 summarizes the daily energy status of the three breeds during the year.

During the first 3 months of lactation, the heavier, higher milk yield Sahiwal breed tended to have greater energy deficits than the lighter Boran and zebu breeds, whose deficits were almost similar. Whereas the Sahiwal and the Boran had energy deficits only the first 3 months of lactation and in July to October, the zebu had a further additional 2 months of deficit in May and June. The May and June energy deficits for the zebu were negligible. The lighter breeds tended to have slightly greater energy deficits than the heavier breeds during the drier months of July to October.

The high energy deficits would probably depress milk yields in the first 3 months of lactation and to some extent jeopardize rebreeding success. After weaning, there was only one month of pronounced excess energy followed thereafter by months of energy deficits, hence the dams' body condition recovery and growth of weaners would be arrested.

All breeds had excess daily protein requirements in all months except for the Sahiwal, which had negligible deficits (-0.02 to -0.1 kg/day) during the first 3 months of lactation. The Boran and zebu breeds had negligible excess protein during the same period. Apparently, energy was more limiting than protein in a January calf under low rainfall scenerio, and would probably affect milk production in the first 3 months of lactation, especially for the Sahiwal breed.

Low precipitation, May calf. All breeds had energy deficits for periods of 8 to 9 months. The Sahiwal and the Boran breeds had 8 months of net energy deficits while the zebu had 9 months of deficits. The deficits were more pronounced in the months June to September during the early and mid-lactation periods. Generally the Boran and zebu breeds had lower and almost similar daily energy deficits than the Sahiwal for most of the lactation period. During the non-lactation period of February and March, the lighter breeds had higher energy deficits than the heavier breeds (-0.09 and -0.3 mcal/day for Sahiwal; -1.5 and -0.7 mcal/day for Boran; -2.0 and -1.4 mcal/day for zebu).

The Boran and zebu had no protein deficits in the months of June to September whereas the Sahiwal had negligible deficits of 0.1 to 0.04 kg/day. In all breeds, excess protein was more pronounced during the wet months of April and November, and the highest values were for Sahiwal breed. Again, energy was the most limiting factor in the May calf scenerio, and since the cows were lactating during the long dry season, milk production and rebreeding success would probably be impaired by these deficits.

Low precipitation, October calf. All breeds had net energy deficits for periods of 8 to 9 months. These deficits occurred during the October to March lactation period (Sahiwal and Boran had negligible excess energy values in November) and again in the months of July to September. During the later deficit period, the calves had been weaned. The deficits were more pronounced in the first 3 months of lactation and the mid-lactation periods. This would indicate probable depressed milk yields in all months except April and May, lighter calves at birth and at weaning, lower rebreeding success and impaired recovery of body condition after weaning. Since the calves were weaned in May, there would be a greater need for weaner pasters or some supplemental energy source for the weaners to carry them through the long dry season.

There were no protein deficits in any breed. The excess protein values were minimal during the months of energy deficiency except during the months of November and December.

Effects of burning on energy and protein status. In the high precipitation scenerio, burning had no advantageous effect on the energy status of the cattle breeds during the dry months of February and July to September. Burning had some marked positive effect in the months of April, June and October to December. In all the other months except in January, the burn exhibited a trend for slightly higher excess energy and lower deficits than the unburn. Although during this study period there was no advantage of the burn over the unburn in the month of May, there probably would have been a burn advantage if the rains were normal.

Burning had negative effects on protein status in February and May but had no advantage over the unburn in August and September. In April, June and October to December, burning had marked positive effects.

In the low precipitation scenerio and during the months of April, May, November and December, the burned paddock had highest excess energy and protein over the unburned paddock. These were the wet months. In all other months, the burned paddock had a trend of slightly higher values than the unburned. The excess and deficit values were almost similar during the dry months.

MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Burning had no significant effect on the frequency and density of almost all the herbaceous plant species, nor did it significantly affect the density and canopy of nearly all the woody plant species during the first year post-burn. However, burning enhanced the nutritional quality of livestock diets, especially cattle during the wet seasons, and prolonged the higher quality trend into the early dry season. Due to the accelerated decline in forage quality as the vegetation matures, burned pastures should be utilized as early as is practically possible so as to maximize the nutritional benefits of burning. Grazing management and grazing systems should be planned such that the heavier, higher milk yielding animals and weaners are afforded priority of utilizing the burned pastures if and when these pastures are ready for grazing.

When forage availability is not limiting under a high precipitation scenerio, cattle energy and protein requirements are adequately met for the January, May or October calving dates. However, during the dry season, there might be reduced forage intake due to the decline in forage quality, especially crude protein. Smith (1962) has documented declines in voluntary intake of forage during the dry season. The seasonal drop in crude protein and organic matter digestibility could be accentuated by the drop in organic matter intake so that the diets of mature herbage in the dry season might be deficient in both energy and protein, especially for the nursing cows and replacement heifers. Based on the nutritional status of cattle breeds, it would appear that January and October calving dates are more appropriate than May in that there is less or no stress on the cows due to milk yield. However, under a low precipitation scenerio, there appears to be no calving date that is definitively better than the others due to the many months of energy deficits, that would probably result in irregular and long calving intervals due to uncorrected body weight losses before the cow calves again (Kidner 1966b). Excessive body weight losses could be reduced by restricting the suckling period to six or seven months (Kidner 1966a). Breeds with smaller body frame and lower milk yields appear to be more suitable under low precipitation scenerio than the heavy Sahiwal breed.

Calf weaning weights and the subsequent growth of the weaners are important factors of the production system. Kidner (1966b), working with Boran X Red Poll calves in a relatively wetter Kitale area of Kenya, reported that there was no marked reduction in growth rates following weaning irrespective of the calving season. He also reported that severe reductions in growth rates occurred during the first dry season post-weaning. It would appear that January and October calves would have their growth rates somewhat impaired during the long dry season. However, Mwandotto *et al.* (1985) reported that calves of Sahiwal, Boran and East African zebu breeds born in July to December at Kiboko and Buchuma (Ecological Zone V), were slightly heavier (12 kg) than those born in January to June at 18 months of age. The October calving date would therefore appear to be more appropriate in that the additional nutritional stress on the dams due to milk production during the long dry season would be avoided.

The relatively lower nutritional quality of the forage under the low precipitation scenerio would usually be accompanied by reduced forage availability, thus compounding the estimated poor energy and protein balance. The subsistence and commercial livestock production systems should be evaluated with a view of addressing the energy and protein balance problem. Thus, under the subsistence production system, the possibility and economic feasibilities of early weaning of the calves, feeding with farm by-products or supplemental feeding should be evaluated in future research work. Under the commercial livestock production systems, the economics of early weaning of the calves versus the supplemental feeding of the dams and calves should be evaluated. A further study on the infrastructure and economics of "on-site" versus "off-site" production of the weaners and fattening stock would invaluably address the efficiency of beef production in Kenya.

SUMMARY AND CONCLUSIONS

Burning apparently enhanced the frequency and density of forbs and subshrub herbaceous species at the expense of important forage grasses, especially *Digitaria macroblephara, Bothriochloa insculpta, Chloris roxburghiana* and *Sporobolus pellucoides*. Some important forbs and subshrub forage species, especially *Talinum portulacifolium, Hibiscus* sp. and *Tephrosia villosa* were enhanced by burning. Burning, therefore, enhanced the diversity of plant species and thereby altered the botanical composition of available potential forage.

Even though there was no pre-burn shrub/woody vegetation data for a definitive comparison with the post-burn data, it was apparent that burning enhanced the regeneration of important browse species, especially *Acacia mellifera, Acacia tortilis, Grewai bicolor, Grewia similis* and *Solanum incanum*. Fire can therefore be used to enhance the accessibility of potential browse to the grazing/browsing animal. Since this was a one-year post-burn study, further and more extensive research on repeat prescribed burning under the various grazing regimen is recommended so as to ascertain the long term effect of fire on the density, cover and productivity of the various plant species and to properly relate these parameters to quantity and quality of potential animal diets.

Cattle and goats grazing burned and unburned paddocks had the highest dietary quality values during the wet seasons; and the values declined with advance of the drier seasons to their lowest during the dry seasons. Burning enhanced the crude protein of cattle diets during the wet seasons and into the early part of the dry seasons, but the positive effects were detectable only during the early part of the wet seasons when the vegetation was actively growing. Although burning had positive effects on the organic matter digestibility of cattle diets, the effects lasted for shorter periods than the effects on crude protein.

In goats, burning had effects on dietary crude protein and organic matter digestibility only during the early part of the wet season and no effects for the late wet and dry seasons. This demonstrates the ability of the goat to select for a high crude protein and digestibility diet than cattle irrespective of treatment.

The data demonstrates that in the first year post-burn, cattle were the main beneficiary of the burn as compared to goats. However, since this study was not done under a regular grazing pressure situation, further research under regular and proper range use conditions is recommended.

The cattle nutritional profile model adequately portrayed the nutritional balance for the breeds at various production levels. Under high precipitation and unrestricted forage intake, the heavier, higher milker breeds appeared to have higher excess net energy and crude protein values in almost all months regardless of the breeding regimen, hence had greater potential for weight gains, increased milk yield and production of heavier calves. The October calving date would be more appropriate than other dates since the cows would not be lactating during the long dry season when forage quality is relatively low. However, under low precipitation, net energy and crude protein deficits were greater in heavier, higher milker Sahiwal than in Boran or zebu breeds during the lactation periods, hence had higher prospects for reduced milk yield and rebreeding success. The high milk producing cows were penalized more than the lower milkers during these periods. The lighter breeds had greater crude protein and net energy deficits than the heavier breeds during the non-lactation periods under low precipitation, where there was no apparent calving date determined to be appropriate due to the prolonged net energy deficits.

Burning had no advantageous effect on net energy balances during the dry months of February and July to September, but had marked advantage during the wet months of April, June, October and December. During the other months, the burn exhibited a trend for slightly higher excess net energy balance and low deficits than the unburn under high precipitation. Grazing the burned paddocks during the wet season, when appropriate, would enhance rebreeding success and milk production.

The highest excess net energy values in the burn over the unburn occurred during the wet months of April, November and December under low precipitation. The burned paddocks could be appropriately grazed so as to enhance rebreeding success in April and December for cows calving in January and October.

The result of this study suggests some burning-plant-animal relationships that should be explored further in more extensive and intensive research work to enhance the efficiency of beef production in tropical savannahs. However, it is noted that nutritional models used in this study did not consider many parameter variables of pests and disease, mineral nutrition, land terrain, hours of grazing, herding management, etc.; factors that would affect intake and should be considered for a more complex model.

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APPENDIX

Appendix Table 1. Percent canopy cover of shrub/woody species in burned and unburned *Acacia senegal* savannah pastures of GM2, Kiboko, Kenya, November 1982.

Height category / Species	Burned		Unburned		α^2
	Mean	SE[1]	Mean	SE	
Above 1 meter					
Acacia drepanolobium	0	0	0.16	0.13	0.23
Acacia mellifera *	0.84	0.21	1.21	0.55	0.55
Acacia senegal *	3.67	0.98	15.62	2.58	0.001
Acacia tortilis *	0.87	0.33	1.03	0.29	0.73
Acalypha fruticosa	0	0	0.01	0.01	0.33
Albizia amara *	0.005	0.005	0.02	0.02	0.46
Balanites aegyptiaca *	0.1	0.07	0.89	0.56	0.19
Commiphora africana *	0.02	0.008	0.58	0.23	0.04
Commiphora riparia *	0	0	0.7	0.23	0.006
Commiphora rostrata	0	0	0.14	0.14	0.33
Commiphora sp.	0.002	0.002	0.0	0	0.33
Cordia gharaf *	0.23	0.11	0.43	0.16	0.29
Dalbergia melanoxylon	0.008	0.008	0.03	0.03	0.47
Duosperma kilimandscharicum	0	0	0.11	0.07	0.15
Grewia bicolor *	0	0	0.32	0.28	0.27
Grewia hexamita	0	0	0.54	0.28	0.07
Grewia similis *	0	0	0.25	0.12	0.07
Grewia villosa *	0.09	0.04	0.52	0.18	0.05
Hermania alhensis *	0	0	0.28	0.19	0.17
Hibiscus aponeurus *	0	0	0.07	0.06	0.26
Hoslundia apposita	0	0	0.03	0.02	0.16
Lantana viburnoides	0.01	0.01	0.15	0.08	0.13
Lippia sp.	0.004	0.004	0.003	0.003	0.76
Ormocarpum kirkii	0	0	0.04	0.04	0.33
Promna oliotrica	0	0	0.10	0.10	0.33
Solanum incanum *	0.0005	0.0005	0.39	0.21	0.09
Solanum sp.	0.01	0.01	0.03	0.03	0.41
Unidentified sp.	0.001	0.001	0.005	0.005	0.46

Appendix Table 1. Continued.

Height category / Species	Burned		Unburned		α^2
	Mean	SE[1]	Mean	SE	
Below 1 meter					
Acacia mellifera	0.15	0.14	0	0	0.28
Acacia senegal	0.02	0.02	0.02	0.02	0.89
Acacia tortilis	0.27	0.15	0	0	0.09
Balanites aegyptiaca	0	0	0.97	0.97	0.33
Boscia angustifolia	0	0	0.04	0.04	0.33
Commiphora africana	0	0	0.006	0.006	0.23
Commiphora riparia	0	0	0.004	0.004	0.33
Cordia gharaf	0	0	0.002	0.002	0.33
Dalbergia melanoxylon	0.01	0.01	0	0	0.33
Grewia bicolor	0.04	0.04	0.02	0.02	0.57
Grewia similis	0.15		0.31		0.45
Grewia villosa	0.72	0.71	0.12	0.07	0.42
Hermania alhensis	0.50	0.24	4.19	2.46	0.17
Hibiscus aponeurus	0.01	0.005	0.35	0.27	0.25
Hibiscus sp.	0.0006	0.0006	0.07	0.04	0.09
Lantana sp.	0	0	0.004	0.004	0.33
Lantana viburnoides	0.005	0.004	0.20	0.16	0.26
Lippia sp.	0.02	0.02	0.004	0.003	0.27
Malhania velutina	0	0	0.0009	0.0009	0.33
Ocimum americanum	0	0	0.01	0.01	0.29
Ocimum suave	0.002	0.002	0.01	0.01	0.47
Ormocarpum kirkii	0	0	0.0002	0.0002	0.33
Sida ovata *	0	0	0.05	0.03	0.12
Solanum incanum	4.53	2.73	3.60	1.28	0.76
Solanum sp.	0.007	0.007	0.01	0.01	0.67
Talinum portulacifolium *	0.45	0.25	1.17	0.75	0.38
Unidentified sp.	1.09	1.08	0.18	0.14	0.43

[1]Standard error of the mean.

[2]α - level of significance.

*Indicates important browse species (Kamau 1984, Lusigi *et al.* 1984).

Appendix Table 2. Monthly dietary crude protein (CP) (%), organic matter digestibility (OMD) (%) and digestible energy (DE) (kcal/kg) of fistulated heifers grazing burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya.

Month	Year	Treatment		Nutritional component		
			n[1]	CP	OMD	DE
March	1982	Unburn	-	-	-	-
		Burn	-	-	-	-
April	1982	Unburn	15	14.1*[1]	72*	2899*
		Burn	15	17.6	75	3019
May	1982	Unburn	13	13.4 NS	72 NS	2900 NS
		Burn	13	12.2	72	2879
June	1982	Unburn	14	10.1*	70*	2805*
		Burn	14	11.4	73	2920
July	1982	Unburn	8	9.8*	65 NS	2818 NS
		Burn	8	10.7	65	2619
Aug.	1982	Unburn	8	9.0 NS	64 NS	2541 NS
		Burn	8	8.9	63	2522
Sept.	1982	Unburn	8	8.1 NS	62 NS	2480 NS
		Burn	7	8.1	62	2485
Oct.	1982	Unburn	8	19.3*	73*	2905*
		Burn	8	23.7	77	3064
Nov.	1982	Unburn	8	15.5*	72*	2894*
		Burn	8	17.7	75	2980
Dec.	1982	Unburn	8	13.6 NS	67 NS	2683 NS
		Burn	8	14.2	70	2781
Jan.	1983	Unburn	14	11.4 NS	72 NS	2899 NS
		Burn	14	11.8	71	2835
Feb.	1983	Unburn	8	8.8 NS	68 NS	2723 NS
		Burn	8	8.5	68	2914
March	1983	Unburn	8	8.4 NS	66 NS	2658 NS
		Burn	8	7.9	66	2623

[1] Number of samples.

* Means significantly different between treatment means within month and nutritional parameter (= 0.05).

NS Means not significantly different between treatment means for the same month and nutritional parameter ($\alpha = 0.05$).

Appendix Table 3. Mean dietary crude protein (%) of fistulated heifers grazing burned and unburned *Acacia senegal* savannah pastures on various sampling dates at Kiboko, Kenya.

Day	Year	Burn			Unburn			Significance
		n[3]	Mean	SE[4]	n	Mean	SE	
March 26-27	1982[2]	-	-	-	8	7.2	0.2	-[1]
April 17-18	1982	8	15.1	0.3	8	12.1	0.3	*
April 29-30	1982	7	20.6	0.6	7	16.5	0.5	*
May 14-15	1982	6	14.4	0.5	7	12.4	0.6	*
May 28-29	1982	7	12.2	0.4	6	14.3	0.6	*
June 15-16	1982	6	11.2	0.4	8	10.2	0.6	NS
June 30-July 1	1982	8	11.5	0.3	8	10.0	0.3	*
July 30-31	1982	8	10.7	0.2	8	10.0	0.2	*
Aug. 30-31	1982	8	9.0	0.4	8	9.0	0.1	NS
Sept. 28-29	1982	7	8.1	0.3	8	8.1	0.2	NS
Oct. 27-28	1982	8	23.7	0.5	8	19.1	0.2	*
Nov. 16-17	1982	8	17.8	0.3	8	15.5	0.4	*
Dec. 20-21	1982	8	14.2	0.2	8	13.6	0.6	NS
Jan. 4 & 6	1983	8	13.1	0.6	8	12.5	0.3	NS
Jan. 27-28	1983	6	9.9	0.4	6	9.8	0.1	NS
Feb. 14-15	1983	8	8.5	0.2	8	8.8	0.2	NS
March 17-18	1983	8	7.9	0.4	8	8.4	0.3	NS

[1] No satistical comparison.
[2] No sampling. There was no growth after the burn for the burn treatment.
[3] Number of samples.
[4] Standard error of the mean.
* Significant at $P < 0.05$.
NS Not significant at $P < 0.05$.

Appendix Table 4. Mean dietary organic matter digestibility (%) of fistulated heifers grazing burned and unburned *Acacia senegal* savannah pastures on various sampling dates.

Day	Year	Burn			Unburn			Significance
		n[3]	Mean	SE[4]	n	Mean	SE	
March 26-27	1982[1]	-	-	-	8	64	0.4	-[2]
April 17-18	1982	8	74	0.8	8	71	0.4	*
April 29-30	1982	7	78	0.3	7	74	1.5	*
May 13-14	1982	6	73	0.3	6	70	0.7	*
May 28-29	1982	7	71	0.4	7	74	0.6	*
June 15-1	1982	7	74	0.3	6	71	1.0	*
June 30-July 1	1982	8	73	0.5	8	69	0.3	*
July 30-31	1982	8	65	0.7	8	65	0.3	NS
Aug. 30-31	1982	8	63	1.0	8	64	0.6	NS
Sept. 28-29	1982	7	63	0.8	7	62	0.4	NS
Oct. 27-28	1982	8	77	0.2	8	73	0.3	*
Nov. 16-17	1982	8	75	0.5	8	72	0.3	*
Dec. 20-21	1982	8	70	0.6	8	67	2.1	NS
Jan. 4 & 6	1983	8	72	0.2	8	72	2.7	NS
Jan. 27-28	1983	6	70	1.9	6	73	2.7	NS
Feb. 14-15	1983	8	68	0.6	8	68	0.5	NS
March 17-18	1983	8	66	0.8	8	66	0.7	NS

[1] No sampling done in March for the burn treatment.
[2] No statistical comparison.
[3] Number of samples.
[4] Standard error of the mean.
NS Not significant at $P < 0.05$.
* Significant at $P < 0.05$.

Appendix Table 5. Dietary digestible energy (kcal/kg) of fistulated heifers grazing burned and unburned *Acacia senegal* savannah pastures on various sampling dates at Kiboko, Kenya.

Day	Year	Burn			Unburn			Significance
		n[3]	Mean	SE[4]	n	Mean	SE	
March 26-27	1982[1]	-	-	-	8	2559	16	-[2]
April 17-18	1982	8	2945	31	8	2845	14	*
April 29-30	1982	7	3104	12	7	2961	62	*
May 13-14	1982	6	2902	13	6	2808	24	*
May 28-29	1982	7	2860	16	7	2979	23	*
June 15-16	1982	6	2942	11	6	2852	38	*
June 30-July 1	1982	8	2903	20	8	2769	13	*
July 30-31	1982	8	2619	27	8	2618	12	NS
Aug. 30-31	1982	8	2522	38	8	2541	23	NS
Sept. 28-29	1982	7	2485	31	8	2480	16	NS
Oct. 27-28	1982	8	3064	7	8	2905	13	*
Nov. 16-17	1982	8	2980	19	8	2894	11	*
Dec. 20-21	1982	8	2781	26	8	2683	79	NS
Jan. 4 & 6	1983	8	2866	87	8	2879	109	NS
Jan. 27-28	1983	6	2794	75	6	2925	109	NS
Feb. 14-15	1983	8	2717	22	8	2723	22	NS
March 17-18	1983	8	2623	32	8	2658	27	NS

[1] No sampling for the burn treatment.
[2] No statistical comparison.
[3] Number of samples.
[4] Standard errof of the mean.
NS Not significant at $P < 0.05$.
* Significant at $P < 0.05$.

Appendix Table 6. Mean dietary crude protein (CP) (%), organic matter digestibility (OMD) (%) and digestible energy (DE) (kcal/kg) of fistulated heifers grazing burned and unburned *Acacia senegal* savannah pastures on various sampling dates at Kiboko, Kenya.

Sampling dates	Burn						
		Dietary parameter					
		CP		OMD		DE	
	n[1]	Mean	SE[2]	Mean	SE	Mean	SE
March 26-27, 1982[3]							
April 17-18, 1982	8	15. d[4]	0.3	74 c	1	2945 c	31
April 29-30, 1982	7	20.6 b	0.6	78 a	0	3104 a	12
May 13-14, 1982	6	14.4 a	0.5	73 cd	0	2902 cd	13
May 28-29, 1982	7	12.2 fg	0.4	71 cde	0	2860 cde	16
June 15-16, 1982	6	11.2 gh	0.4	74 c	0	2942 c	11
June 30-July 1, 1982	8	11.5 gh	0.3	73 cd	1	2903 cd	20
July 30-31, 1982	8	10.7 hi	0.2	65 gh	1	2619 gh	27
Aug. 30-31, 1982	8	9.0 jk	0.4	63 hi	1	2522 hi	38
Sept. 28-29, 1982	7	8.1 k	0.3	62 i	1	2485 i	31
Oct. 27-28, 1982	8	23.7 a	0.5	77 ab	0	3064 ab	7
Nov. 16-17, 1982	8	17.8 c	0.3	75 bc	0	2980 bc	19
Dec. 20-21, 1982	8	14.2 dc	0.2	70 fe	1	2781 ef	26
Jan. 4 & 6, 1983	6	13.1 ef	0.6	72 cde	2	2866 cde	87
Jan. 27-28, 1983	8	9.9 ij	0.5	70 dfe	2	2794 def	75
Feb. 14-15, 1983	8	8.5 k	0.2	68 fg	1	2717 fg	22
March 17-18, 1983	8	7.9 k	0.4	66 gh	1	2623 gh	32

Appendix Table 7. Mean seasonal dietary digestible energy (DE) (kcal/kg) of fistulated heifers grazing burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya.

Season	Period	Burn			Unburn			α^4
		n[1]	Mean	SE[2]	n	Mean	SE	
Long wet	Mid-March to late May[3]	28	2954	20	36	2824	24	0.001
Early long dry	Early June to late July	22	2811	34	22	2734	24	0.085
Late long dry	Early Aug. to mid-Oct.	15	2505	25	16	2511	16	0.84
Early short wet	Mid-Oct. to mid-Nov.	16	3022	15	16	2899	8	0.0001
Late short wet	Mid-Nov. to mid-Jan.	16	2824	45	16	2781	70	0.61
Short dry	Mid-Jan. to mid-March	22	2704	28	22	2755	38	0.29

[1] Number of samples analysed.
[2] Standard error of the mean.
[3] No March samples for the burn treatment due to lack of regrowth after the burn.
[4] Level of significance.

Appendix Table 8. Monthly dietary crude protein (CP) (%), organic matter digestibility (OMD) (%) and digestible energy (DE) (kcal/kg) of fistulated goats grazing burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya.

Month	Year	Treatment	n[1]	Nutritional component		
				CP	OMD	DE
May	1982	Unburn	4	18.1 NS	72 NS	2879 NS
		Burn	4	17.4	73	2915
June	1982	Unburn	3	17.2 NS	63 NS	2509 NS
		Burn	3	17.1	70	2814
July	1982	Unburn	4	13.0*	68 NS	2713 NS
		Burn	4	16.2	66	2659
Aug.	1982	Unburn	4	12.6 NS	62 NS	2492 NS
		Burn	4	13.6	65	2614
Sept.	1982	Unburn	4	15.2 NS	55 NS	2216 NS
		Burn	4	17.1	62	2460
Oct.	1982	Unburn	4	22.3*	77 NS	3089 NS
		Burn	4	25.4	80	3186
Nov.	1982	Unburn	4	19.8 NS	72 NS	2893 NS
		Burn	4	21.3	78	3120
Dec.	1982	Unburn	4	16.4*	75*	3003*
		Burn	4	18.2	70	2810
Jan.	1983	Unburn	8	19.3 NS	69 NS	2719 NS
		Burn	8	19.6	68	2765
Feb.	1983	Unburn	4	15.5 NS	56 NS	2256 NS
		Burn	4	14.9	61	2434
March	1983	Unburn		16.4 NS	62 NS	2496 NS
		Burn		15.5	57	2286

[1] Number of samples.

NS - Means not significantly different between treatment means within month and nutritional parameter ($\alpha = 0.05$).

* Means significantly different between treatment means within month and nutritional parameter ($\alpha = 0.05$).

Appendix Table 9. Mean dietary crude protein (%) of fistulated goats grazing burned and unburned *Acacia senegal* savannah pastures on various sampling dates at Kiboko, Kenya.

Day	Year	Burn			Unburn			Significance
		n[1]	Mean	SE[2]	n	Mean	SE	
May 14-15	1982	2	16.7	1.6	2	18.7	0.0	NS
May 28-29	1982	2	17.8	0.3	2	17.5	0.4	NS
June 30-July 1	1982	3	17.1	1.3	3	17.2	1.5	NS
July 30-31	1982	4	16.2	0.4	4	13.0	1.2	*
Aug. 30-31	1982	4	13.6	0.5	4	12.6	0.9	NS
Sept. 28-29	1982	4	17.1	0.9	4	15.2	0.8	NS
Oct. 27-28	1982	4	25.5	0.5	4	22.3	0.5	*
Nov. 16-17	1982	4	21.3	0.5	4	19.8	0.8	NS
Dec. 20-21	1982	4	18.2	0.6	4	16.4	0.2	NS
Jan. 4 & 6	1983	4	20.3	0.9	4	20.3	1.1	NS
Jan. 27-28	1983	4	19.0	0.4	4	18.2	0.8	NS
Feb. 14-15	1983	4	15.0	0.4	4	15.5	0.7	NS
March 17-18	1983	4	15.5	0.6	4	16.4	0.2	NS

[1] Number of samples.

[2] Standard error of the mean.

NS Not significant at $P < 0.05$.

* Significant at $P < 0.05$.

Appendix Table 10. Mean dietary percent organic matter digestibility (%) of fistulated goats grazing burned and unburned *Acacia senegal* savannah pastures on various sampling dates at Kiboko, Kenya.

Day	Year	Burn			Unburn			Significance
		n[1]	Mean	SE[2]	n	Mean	SE	
May 14-15	1982	2	72	1.0	2	73	0.7	NS
May 28-29	1982	2	74	1.8	2	71	0.9	NS
June 30-July 1	1982	3	70	1.1	3	63	3.1	NS
July 30-31	1982	4	66	2.4	3	68	1.5	NS
Aug. 30-31	1982	4	64	2.6	4	62	1.0	NS
Sept. 28-29	1982	4	62	4.7	4	55	1.6	NS
Oct. 27-28	1982	4	80	1.2	4	77	2.1	NS
Nov. 16-17	1982	4	78	2.8	4	72	2.5	NS
Dec. 20-21	1982	4	70	0.8	4	75	0.5	*
Jan. 4 & 6	1983	4	71	1.1	4	72	0.8	NS
Jan. 27-28	1983	4	67	1.2	4	64	1.5	NS
Feb. 14-15	1983	4	61	1.7	4	57	1.2	NS
March 17-18	1983	4	57	0.9	4	62	2.1	NS

[1] Number of samples.

[2] Standard error of the mean.

NS Not significant at $P < 0.05$.

* Significant at $P < 0.05$.

Appendix Table 11. Mean dietary digestible energy (kcal/kg) of fistulated goats grazing burned and unburned *Acacia senegal* savannah pastures on various sampling dates at Kiboko, Kenya.

Day	Year	Burn			Unburn			Significance
		n[1]	Mean	SE[2]	n	Mean	SE	
May 13-14	1982	2	2877	38	2	2916	29	NS
May 28-29	1982	2	2953	70	2	2843	39	NS
June 30-July 1	1982	3	2814	45	3	2713	61	NS
July 30-31	1982	4	2659	96	4	2713	61	NS
Aug. 30-31	1982	4	2614	106	4	2492	38	NS
Sept. 28-29	1982	4	2460	188	4	2216	62	NS
Oct. 27-28	1982	4	3186	46	4	3089	83	NS
Nov. 16-17	1982	4	3119	113	4	3893	101	NS
Dec. 20-21	1982	4	2810	30	4	3003	18	*
Jan. 4 & 6	1983	4	2867	44	4	2874	30	NS
Jan. 27-28	1983	4	2664	47	4	2256	47	NS
March 17-18	1983	4	2286	34	4	2496	82	NS

[1] Number of samples analysed.

[2] Standard error of the mean.

NS Not significant at $P < 0.05$.

* Significant at $P < 0.05$.

Appendix Table 12. Mean dietary crude protein (CP) (%), organic matter digestibility (OMD) (%) and digestible energy (DE) (kcal/kg) of fistulated goats grazing burned and unburned *Acacia senegal* savannah pastures on various sampling dates at Kiboko, Kenya.

Sampling dates	Burn						
	Dietary parameter						
		CP		OMD		DE	
	n[1]	Mean	SE[2]	Mean	SE	Mean	SE
May 13-14, 1982	2	16.7 def[3]	1.6	72 bcd	1	2877 bcd	38
May 28-29, 1982	2	17.8 de	0.3	74 abc	2	2953 abc	70
June 30-July 1, 1982	3	17.1 def	1.3	70 cd	1	2814 dc	45
July 30-31, 1982	4	16.2 ef	0.4	66 cde	2	2659 cde	96
Aug. 30-31, 1982	4	13.6 g	0.5	65 de	3	2614 de	106
Sept. 28-29, 1982	4	17.1 def	0.9	62 ef	5	2460 ef	188
Oct. 27-28, 1982	4	25.4 a	0.5	80 a	1	3186 a	46
Nov. 16-17, 1982	4	21.3 b	0.5	78 ab	3	3119 ab	113
Dec. 20-21, 1982	4	18.2 cde	0.6	70 cd	1	2810 cd	30
Jan. 4 & 6, 1983	4	20.3 bc	0.9	71 bcd	1	2867 bcd	44
Jan. 27-28, 1983	4	18.0 cd	0.4	67 cde	1	2664 cde	47
Feb. 14-15, 1983	4	14.9 fg	0.4	61 ef	2	2434 ef	67
March 17-18, 1983	4	15.5 fg	0.6	57 f	1	2286 f	34

Appendix Table 12. (Continued)

Sampling dates	n[1]	Unburn					
		Dietary parameter					
		CP		OMD		DE	
		Mean	SE[2]	Mean	SE	Mean	SE
May 13-14, 1982	2	18.7 bed[3]	0	73 abc	1	2916 abc	29
May 28-29, 1982	2	17.5 cdef	0.4	71 bc	1	2843 bc	37
June 30-July 1, 1982	3	17.2 cdef	1.5	63 d	3	2509 d	126
July 30-31, 1982	4	13.0 gh	1.1	68 cd	2	2713 cd	61
Aug. 30-31, 1982	4	12.6 h	0.9	62 d	1	2492 d	38
Sept. 28-29, 1982	4	15.2 fg	0.8	55 e	2	2216 e	62
Oct. 27-28, 1982	4	22.3 a	0.5	77 a	2	3089 a	83
Nov. 16-17, 1982	4	19.8 abc	0.8	72 abc	3	2893 abc	101
Dec. 20-21, 1982	4	16.4 def	0.2	75 ab	0	3003 ab	18
Jan. 4 & 6, 1983	4	20.3 ab	1.1	72 abc	1	2874 abc	30
Jan. 27-28, 1983	4	18.2 bcdc	0.8	64 d	2	2564 d	58
Feb. 14-15, 1983	4	15.5 cfg	0.7	56 e	1	25.56 e	47
March 17-18, 1983	4	16.4 def	0.2	62 d	2	2496 d	82

[1] Number of samples analysed.
[2] Standard error of the mean.
[3] Mean values followed by the same letter within treatment and dietary parameter are not significant at 0.05 level.

Appendix Table 13. Mean seasonal dietary digestible energy (DE) (kcal/kg) of fistulated goats grazing burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya.

Season	Period	Burn			Unburn			α[4]
		n[1]	Mean	SE[2]	n	Mean	SE	
Long wet	Mid-March to late May[3]	4	2915	39	4	2879	29	0.49
Early long dry	Early June to late July	7	2725	62	7	2625	71	0.31
Late long dry	Early Aug. to mid-Oct.	8	2537	104	8	2353	62	0.15
Early short wet	Mid-Oct. to mid-Nov.	8	3153	58	8	2991	71	0.1004
Late short wet	Mid-Nov. to mid-Jan.	8	2838	27	8	2939	29	0.024
Short dry	Mid-Jan. to mid-March	12	2439	54	12	2462	52	0.76

[1] Number of samples analysed.
[2] Standard error of the mean.
[3] No sampling done in March and April. Values are for May only.
[4] Level of significance.

Appendix Table 14. Mean seasonal dietary crude protein (%), organic matter digestibility (%) and digestible energy (kcal/kg) of fistulated heifers and goats grazing burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya.

Season	Period	Burn[1]						
		Cattle			Goats			α^3
		n	Mean	SE	n	Mean	SE	
					Crude protein			
Long wet	Mid-March to late May[2]	28	15.6	0.62	4	17.4	0.71	0.29
Early long dry	Early June to late May	22	11.1	0.17	7	16.6	0.55	0.0001
Late long dry	Early Aug. to mid-Oct.	15	8.6	0.26	8	15.3	0.83	0.0001
Early short wet	Mid-Oct. to mid-Nov.	16	20.7	0.82	8	23.3	0.84	0.0569
Late short wet	Mid-Nov. to mid-Jan.	16	13.7	0.31	8	19.2	0.62	0.0001
Short dry	Mid-Jan. to mid-March	22	8.7	0.25	12	16.4	0.58	0.0001
					Organic matter digestibility			
Long wet	Mid-March to late May	28	74	0.51	4	73	0.98	0.4886
Early long dry	Early June to late July	22	70	0.85	7	68	1.56	0.2364
Late long dry	Early Aug. to Oct.	15	63	0.62	8	63	2.60	0.7611
Early short wet	Mid-Oct. to mid-Nov.	16	76	0.37	8	79	1.45	0.0609
Late short wet	Mid-Nov. to mid-Jan.	16	71	1.12	8	71	0.67	0.7813
Short dry	Mid-Jan. to mid-March	22	68	0.69	12	62	1.35	0.0001
					Digestible energy			
Long wet	Mid-March to late May	28	2954	20	4	2914	39	0.4894
Early long dry	Early June to late July	22	2810	34	7	2725	62	0.2326
Late long dry	Early Aug. to mid-Oct.	15	2505	25	8	2537	104	0.7705
Early short wet	Mid-Oct. to mid-Nov.	16	3022	15	8	3153	58	0.0609
Late short wet	Mid-Nov. to mid-Jan.	16	2824	45	8	2838	27	0.7815
Short dry	Mid-Jan. to mid-March	22	2704	28	12	2461	54	0.0001

Appendix Table 14. (Continued)

Season	Period	Unburn						
		Cattle			Goats			α[3]
		n	Mean	SE	n	Mean	SE	
					Crude protein			
Long wet	Mid-March to late May[1]	36	12.3	0.57	4	18.1	0.38	0.0001
Early long dry	Early June to late May	22	10.0	0.20	7	14.8	1.16	0.0001
Late long dry	Early Aug. to mid-Oct.	16	8.5	0.16	8	13.9	0.77	0.0001
Early short wet	Mid-Oct. to mid-Nov.	16	17.4	0.55	8	21.1	0.65	0.0005
Late short wet	Mid-Nov. to mid-Jan.	16	13.1	0.35	8	18.4	0.90	0.0004
Short dry	Mid-Jan. to mid-March	22	8.9	0.18	12	16.7	0.48	0.0001
					Organic matter digestibility			
Long wet	Mid-March to late May	36	71	0.74	4	72	0.72	0.5342
Early long dry	Early June to late July	22	68	0.60	7	66	1.78	0.1791
Late long dry	Early Aug. to Oct.	16	63	0.4	8	59	1.6	0.0415
Early short wet	Mid-Oct. to mid-Nov.	16	72	0.22	8	75	1.78	0.2312
Late short wet	Mid-Nov. to mid-Jan.	16	70	1.76	8	73	0.73	0.0575
Short dry	Mid-Jan. to mid-March	22	69	0.95	12	61	1.30	0.0001
					Digestible energy			
Long wet	Mid-March to late May	36	2824	29	4	2879	29	0.5407
Early long dry	Early June to late July	22	2737	24	7	2625	71	0.1784
Late long dry	Early Aug. to mid-Oct.	16	2511	16	8	2354	62	0.0407
Early short wet	Mid-Oct. to mid-Nov.	16	2899	8	8	2991	71	0.0829
Late short wet	Mid-Nov. to mid-Jan.	16	2781	70	8	2938	29	0.0502
Short dry	Mid-Jan. to mid-March	22	2755	38	12	2438	52	0.0001

[1] Goat samples are for May only.
[2] Goat samples are for May only.
[3] Level of significance.
n = Number of samples analysed.
SE = Standard error of the mean.

Appendix Table 15. Mean monthly dietary crude protein (%) of fistulated heifers and goats grazing burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya.

Month	Burn							Unburn						
	Cattle			Goats			α[3]	Cattle			Goats			α
	n[1]	Mean	SE[2]	n	Mean	SE		n	Mean	SE	n	Mean	SE	
May 1982	13	13.2	0.42	4	17.4	0.71	0.0002	13	13.42	0.48	4	18.1	0.38	0.0001
June 1982	14	11.4	0.23	3	17.1	1.25	0.0001	14	10.1	0.29	3	17.2	1.46	0.0001
July 1982	8	10.7	0.17	4	16.2	0.42	0.0003	8	9.8	0.21	4	13.0	1.05	0.0019
Aug. 1982	8	9.0	0.39	4	13.6	0.51	0.0003	8	9.0	0.13	4	12.6	0.93	0.0003
Sept. 1982	7	8.1	0.29	4	17.1	0.94	0.0016	8	8.1	0.15	4	15.2	0.84	0.0001
Oct. 1982	8	23.7	1.47	4	25.4	0.96	0.0384	8	19.3	0.19	4	22.3	0.46	0.0001
Nov. 1982	8	17.7	0.25	4	21.3	0.45	0.0001	8	15.5	0.41	4	19.8	0.81	0.0003
Dec. 1982	8	14.2	0.44	4	18.2	0.23	0.0001	8	13.6	0.58	4	16.4	0.18	0.0076
Jan. 1983	14	11.8	0.57	8	19.6	0.50	0.0001	14	11.4	0.42	8	19.3	0.76	0.0001
Feb. 1983	8	8.5	0.20	4	14.9	0.39	0.0001	8	8.8	0.23	4	15.5	0.71	0.0015
March 1983	8	7.9	0.37	4	15.5	0.56	0.0001	8	8.4	0.31	4	16.4	0.18	0.0001

[1] n = Number of samples analysed.

[2] SE = Standard error of the mean.

[3] α = Level of significance.

Appendix Table 16. Mean monthly dietary organic matter digestibility (%) of fistulated heifers and goats grazing burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya.

Month	Burn							Unburn						
	Cattle			Goats			α^3	Cattle			Goats			α
	n[1]	Mean	SE[2]	n	Mean	SE		n	Mean	SE	n	Mean	SE	
May 1982	13	72	0.3	4	73	1.0	0.2481	13	72	0.8	4	72	0.7	0.7612
June 1982	14	73	0.3	3	70	1.1	0.0073	14	70	0.5	4	63	3.1	0.0006
July 1982	8	65	0.7	4	66	2.4	0.7022	8	65	0.3	4	68	1.5	0.0587
Aug. 1982	8	63	1.0	4	65	2.6	0.3305	8	64	0.6	4	62	0.9	0.2933
Sept. 1982	7	62	0.8	4	62	4.7	0.8801	8	62	0.4	4	55	1.6	0.0214
Oct. 1982	8	77	0.2	4	80	1.2	0.0769	8	73	0.3	4	77	2.1	0.011
Nov. 1982	8	75	0.5	4	78	2.8	0.3079	8	72	0.3	4	72	2.5	0.9762
Dec. 1982	8	70	0.6	4	70	0.8	0.5046	8	67	2.1	4	75	0.5	0.0270
Jan. 1983	14	71	1.4	8	69	1.2	0.4218	14	72	1.9	8	70	1.7	0.1238
Feb. 1983	8	68	0.6	4	61	1.7	0.0005	8	68	0.5	4	56	1.2	0.0001
March 1983	8	65	0.8	4	57	0.9	0.0001	8	66	0.7	4	62	2.1	0.1409

[1] n = Number of samples analysed.

[2] SE = Standard error of the mean.

[3] α = level of significance.

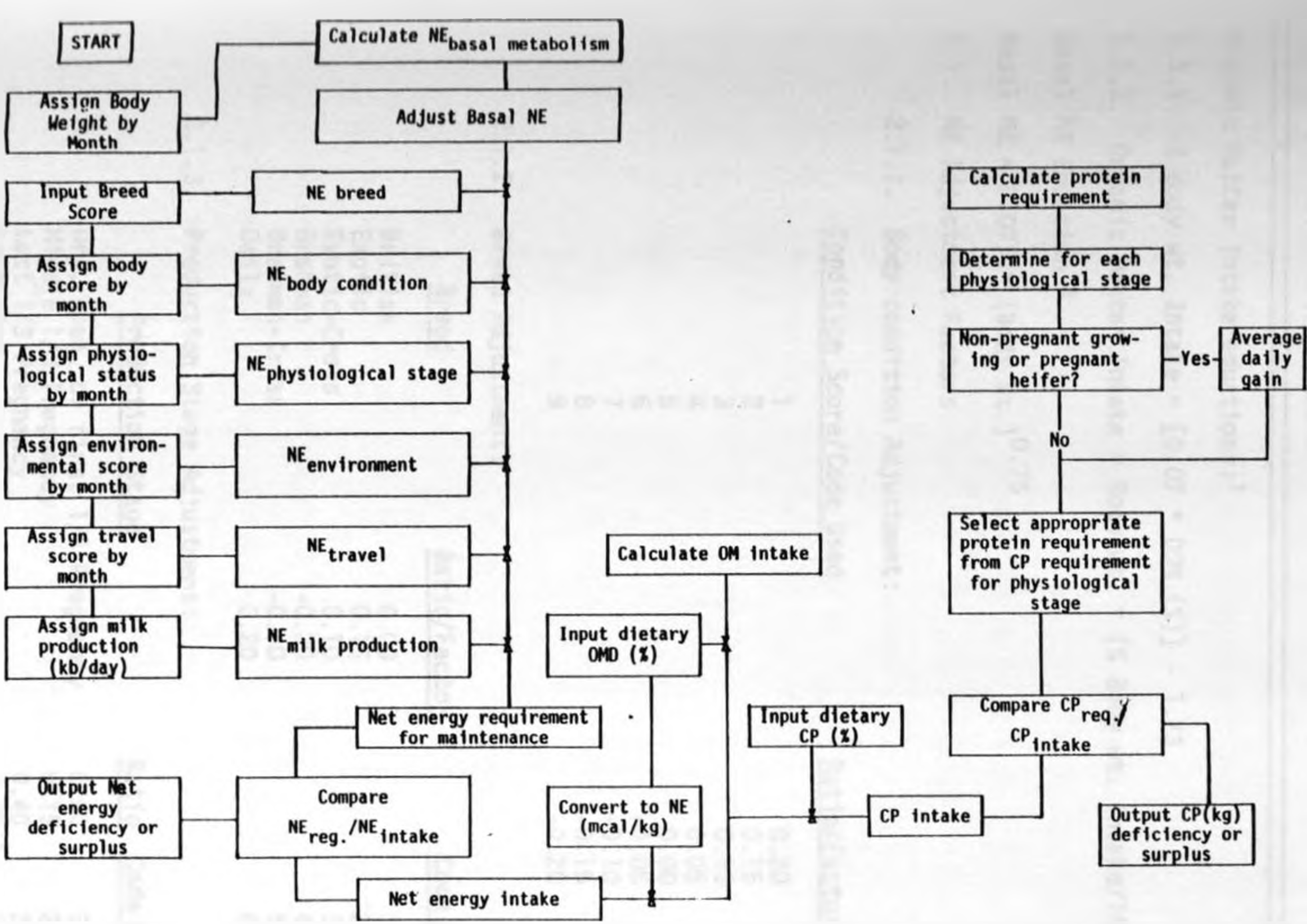
Appendix Table 17. Mean monthly digestible energy (kcal/kg) of fistulated heifers and goats grazing burned and unburned *Acacia senegal* savannah pastures at Kiboko, Kenya.

Month	Burn							Unburn						
	Cattle			Goats			α[3]	Cattle			Goats			α
	n[1]	Mean	SE[2]	n	Mean	SE		n	Mean	SE	n	Mean	SE	
May 1982	13	2879	12	4	2915	39	0.4397	13	2900	29	4	2879	29	0.7119
June 1982	14	2920	13	3	2814	45	0.0073	14	2805	21	3	2509	126	0.1412
July 1982	8	2619	27	4	2659	96	0.7103	8	2618	12	4	2713	61	0.2216
Aug. 1982	8	2522	38	4	2614	106	0.4613	8	2541	23	4	2492	38	0.267
Sept. 1982	7	2485	31	4	2460	188	0.9033	8	2480	16	4	2216	62	0.0214
Oct. 1982	8	3064	7	4	3185	46	0.0768	8	2905	13	4	3089	83	0.1134
Nov. 1982	8	2980	19	4	3119	113	0.3080	8	2894	11	4	2893	101	0.9959
Dec. 1982	8	2781	26	4	2810	30	0.5053	8	2683	79	4	3003	18	0.0068
Jan. 1983	14	2835	58	8	2765	49	0.4217	14	2899	75	8	2719	66	0.1233
Feb. 1983	8	2717	22	4	2434	67	0.0202	8	2733	22	4	2256	47	0.0007
March 1983	8	2623	32	4	2286	34	0.0001	8	2658	27	4	2496	82	0.0372

[1] Number of samples analysed.

[2] Standard error of the mean.

[3] level of significance.



Appendix Fig. 1. Generalized flow chart of the cattle nutritional profiles model (CNP).

Appendix Table 18. Equations for organic matter intake, net energy equirements for maintenance and crude protein requirements used in the attle nutritional profiles model.

. Organic Matter Intake equations:[1]

1.1.1. % Body wt. Intake = [0.07 * DOM (%)] - 1.73

1.1.2. Organic Matter Intake = Body wt. * (% Body wt. Intake/100)

. Basal NE Equation:[2]

$$\text{Basal NE} = 0.077 * (\text{Body wt.})^{0.75}$$

2.1. NE Adjustment Factors

2.1.1. Body condition Adjustment:

Condition Score/Code Used	Ratio/Factor
1	0.20
2	0.15
3	0.10
4	0.05
5	0.00
6	-0.05
7	-0.10
8	-0.15
9	-0.20

2.1.2. Breed Adjustment:

Breed	Ratio/Factor	Code Used
British	0.00	1
Exotic	0.15	2
Exotic-Cross	0.10	3
Brahman	-0.20	4
Brahman-Cross	-0.10	5
Daily	0.20	6

2.1.3. Production Stage Adjustment:

Production Stage	Ratio	Code Used
Dry, open, or first 1/3 Pregnancy	0.00	1
Middle 1/3 Pregnancy	0.15	2
Last 1/3 Pregnancy	0.40	3
Lactating	0.30	4
Nonpregnant and Growing Heifer	0.00	5
Pregnant Heifer	0.00	6

Appendix Table 18. Continued.

2.1.4. Milk Production Adjustment:

Milk Adjustment = 0.33 * kg of milk supply

2.1.5. Travel Adjustment:

Distance/Area	Ratio/Factor	Code Used
Confinement	0.00	1
Small Paddock/Pasture	0.10	2
Large Pasture, Water < 1.6 km	0.20	3
Large Pasture, Open Range, Water > 1.6 km	0.30	4

2.1.6. Environmental Stress Adjustment:

Environment	Condition of Animal	Ratio/Factor	Code Used
Cold, Wet	1, 2, 3	0.40	1
	4, 5, 6	0.30	2
	7, 8, 9	0.20	7
Dry, Cold	1, 2, 3	0.20	11
	4, 5, 6	0.15	12
	7, 8, 9	0.10	13
Comfortable	1 - 9	0.00	4
Hot, Dry	1, 2, 3	0.02	3
	4, 5, 6	0.04	5
	7, 8, 9	0.08	6
Hot, Humid	1, 2, 3	0.05	8
	4, 5, 6	0.10	9
	7, 8, 9	0.15	10

2.2. The Resulting Final NE_m equation is:

NE_m = Basal NE + (Basal NE * Breed Adj.) + (Basal NE * Condition Score Adj.) + (Basal NE * Environment Adj.) + (Basal NE * Production Stage Adj.) + Milk Adj. + (Basal NE * Travel Adj.)

2.2.1. NE equation for growing heifer:

$$NE_{gain} = [(0.056 * ADG) + (0.01265) * (ADG)^2] * [\text{Body wt. at Neutral}]^{0.75}$$

Appendix Table 18. Continued.

3. Crude Protein Requirements Equations:[3]

Production Stage and Animal Class	Primary Equation to Predict kg of Crude Protein/Day
Nonpregnant, growing Heifer	0.0737 + (0.0012 * Body wt.) + (0.3149 * ADG)
Dry, Open Cow, First 1/3 Pregnancy Cow, Middle 1/3 Pregnancy Cow	0.0929 + (0.0007 * Body wt.)
Last 1/3 Pregnancy Cow	0.19 + (0.000636 * Body wt.)
Lactating Cow	-0.0207 + (0.0011 * Body wt.) + 0.0763 * kg milk/day)
Pregnant Heifer	-0.234 + (0.0015 * Body wt.) + (0.795 * ADG)

[1] Percent body weight intake equation adopted from Olson (1984).

[2] Basal NE equation and NE Adjustments adopted from Powell *et al.* (1984).

[3] Crude protein requirement equations adopted from Powell *et al.* 1984.

Appendix Table 19A. Projected mean monthly parameter inputs for Sahiwal, Boran and East African Zebu breeds; January, May and October average calving months in an above average rainfall year.

Calving date	Breed	Parameter	MONTH/PARAMETER INPUT					
			Jan.	Feb.	March	April	May	June
Jan.	Sahiwal	Breed score[1]	4	4	4	4	4	4
		Body weight (kg)	410	395	400	415	425	410
		Body score[2]	5	5	5	5	5	5
		Physiological stage[3]	4	4	4	4	4	4
		Environmental score[4]	4	6	5	3	4	4
		Travel score[5]	4	4	4	4	4	4
		Milk production (kg)	5.0	4.7	4.5	3.5	2.5	1.5
		Diet OMD (%)	72[6](71)[7]	68(68)	65(66)	72(75)	72(72)	70(73)
		Diet CP (%)	11.4(11.8)	8.8(8.5)	7.9(8.1)	14.1(17.6)	13.4(13.2)	10.1(11.4)
		Average daily gain (kg)	0	0	0	0	0	0
Jan.	Boran	Breed score	4	4	4	4	4	4
		Body weight (kg)	360	350	340	345	350	340
		Body score	5	5	4	4	5	4
		Physiological stage	4	4	4	4	4	4
		Environmental score	4	6	5	3	4	4
		Travel score	4	4	4	4	4	4
		Milk production (kg)	3.0	2.8	2.4	1.4	0.8	0.5
		Diet OMD (%)	72(71)	68(68)	65(66)	72(75)	72(72)	70(73)
		Diet CP (%)	11.4(11.8)	8.8(8.5)	7.9(8.1)	14.1(17.6)	13.4(13.2)	10.1(11.4)
		Average daily gain (kg)	0	0	0	0	0	0
Jan.	E. African Zebu	Breed score	4	4	4	4	4	4
		Body weight (kg)	275	265	260	265	268	260
		Body score	5	4	4	4	4	4
		Physiological stage	4	4	4	4	4	4
		Environmental score	4	6	5	3	4	4
		Travel score	4	4	4	4	4	4
		Milk productin (kg)	2.0	1.8	1.4	0.8	0.5	0.3
		Diet OMD (%)	72(71)	68(68)	65(66)	72(75)	72(72)	70(73)
		Diet CP (%)	11.4(11.8)	8.8(8.5)	7.9(8.1)	14.1(17.6)	13.4(13.2)	10.1(11.4)
		Average daily gain (kg)	0	0	0	0	0	0
May	Sahiwal	Breed score	4	4	4	4	4	4
		Body weight (kg)	405	395	410	425	420	405
		Body score	5	5	5	5	5	5
		Physiological stage	2	3	3	3	4	4
		Environmental score	4	6	5	3	4	4
		Travel score	4	4	4	4	4	4
		Milk production	0	0	0	0	5	4.7
		Diet OMD (%)	72(71)	68(68)	65(66)	72(75)	72(72)	70(73)
		Diet CP (%)	11.4(11.8)	8.8(8.5)	7.9(8.1)	14.1(17.6)	13.4(13.2)	10.1(11.4)
		Average daily gain (kg)	0	0	0	0	0	0

Appendix Table 19A. Continued.

Calving date	Breed	Parameter	MONTH/PARAMETER INPUT					
			Jan.	Feb.	March	April	May	June
		Breed score	4	4	4	4	4	4
		Body weight (kg)	350	345	350	365	360	345
		Body score	5	4	5	5	5	4
		Physiological stage	2	3	3	3	4	4
		Environmental score	4	6	5	3	4	4
May	Boran	Travel score	4	4	4	4	4	4
		Milk production	0	0	0	0	3.0	2.8
		Diet OMD (%)	72(71)	68(68)	65(66)	72(75)	72(72)	70(73)
		Diet CP (%)	11.4(11.8)	8.8(8.5)	7.9(8.1)	14.1(17.6)	13.4(13.2)	10.1(11.4)
		Average daily gain (kg)	0	0	0	0	0	0
		Breed score	4	4	4	4	4	4
		Body weight (kg)	260	255	260	265	260	240
		Body score	4	3	4	4	4	3
		Physiological stage	2	3	3	3	4	4
		Environmental score	4	6	5	3	4	4
May	E. African Zebu	Travel score	4	4	4	4	4	4
		Milk production (kg)	0	0	0	0	2.0	1.8
		Diet OMD (%)	72(71)	68(68)	65(66)	72(75)	72(72)	70(73)
		Diet CP (%)	11.4(11.8)	8.8(8.5)	7.9(8.1)	14.1(17.6)	13.4(13.2)	10.1(11.4)
		Average daily gain (kg)	0	0	0	0	0	0
		Breed score	4	4	4	4	4	4
		Body weight (kg)	390	385	395	410	430	420
		Body score	5	4	5	5	5	5
		Physiological stage	4	4	4	4	4	2
		Environmental score	4	6	5	3	4	4
Oct.	Sahiwal	Travel Score	4	4	4	4	4	4
		Milk production (kg)	3.5	2.5	1.5	1.0	0.5	0
		Diet OMD (%)	72(71)	68(68)	65(66)	72(75)	72(72)	70(73)
		Diet CP (%)	11.4(11.8)	8.8(8.5)	7.9(8.1)	14.1(17.6)	13.4(13.2)	10.1(11.4)
		Average daily gain (kg)	0	0	0	0	0	0
		Breed score	4	4	4	4	4	4
		Body weight (kg)	350	340	345	350	360	350
		Body score	5	4	4	5	5	5
		Physiological stage	4	4	4	4	4	2
		Environmental score	4	6	5	3	4	4
Oct.	Boran	Travel score	4	4	4	4	4	4
		Milk production (kg)	1.4	0.8	0.5	0.3	0.1	0
		Diet OMD (%)	72(71)	68(68)	65(66)	72(75)	72(72)	70(73)
		Diet CP (%)	11.4(11.8)	8.8(8.5)	7.9(8.1)	14.1(17.6)	13.4(13.2)	10.1(11.4)
		Average daily gain (kg)	0	0	0	0	0	0

Appendix Table 19A. Continued.

Calving date	Breed	Parameter	MONTH/PARAMETER INPUT					
			Jan.	Feb.	March	April	May	June
Oct.	E. African Zebu	Breed score	4	4	4	4	4	4
		Body weight (kg)	235	230	235	245	255	260
		Body score	3	3	3	4	4	5
		Physiological stage	4	4	4	4	4	2
		Environmental score	4	6	5	3	4	4
		Travel score	4	4	4	4	4	4
		Milk production (kg)	0.8	0.5	0.3	0.2	0.1	0
		Diet OMD (%)	72(71)	68(68)	65(66)	62(75)	72(72)	70(73)
		Diet CP (%)	11.4(11.8)	8.8(8.5)	7.9(8.1)	14.1(17.6)	13.4(13.2)	10.1(11.4)
		Average daily gain (kg)	0	0	0	0	0	0

[1], [2], [3], [4], [5] See Appendix Table 18 for codes on breed score body condition score, physiological/production stage score, environmental and travel score adjustments.

[6] Values not inside parentheses are for the unburned paddock.

[7] Values inside parentheses are for burned paddock.

Appendix Table 19A. Continued.

Calving date	Breed	Parameter	MONTH/PARAMET			
			July	Aug.	Sept.	Oc
		Breed score	4	4	4	4
		Body weight (kg)	395	365	350	360
		Body score	5	4	3	4
		Physiological stage	4	4	2	3
		Environmental score	5	6	6	5
Jan.	Sahiwal	Travel score	4	4	4	4
		Milk production (kg)	1.0	0.5	0	0
		Diet OMD (%)	65(65)	63(63)	62(62)	73(77
		Diet CP (%)	9.8(10.7)	9.0(9.0)	8.1(8.1)	19.3(
		Average daily gain (kg)	0	0	0	0
		Breed score	4	4	4	4
		Body weight (kg)	325	320	310	320
		Body score	3	3	3	3
		Physiological stage	4	4	2	3
		Environmental score	5	6	6	5
Jan.	Boran	Travel score	4	4	4	4
		Milk production (kg)	0.3	0.1	0	0
		Diet OMD (%)	65(65)	63(63)	62(62)	73(77
		Diet CP (%)	9.8(10.7)	9.0(9.0)	8.1(8.1)	19.3(
		Average daily gain (kg)	0	0	0	0
		Breed score	4	4	4	4
		Body weight (kg)	255	240	230	250
		Body score	3	3	2	3
		Physiological stage	4	4	2	3
		Environmental score	5	6	6	5
Jan.	E. African Zebu	Travel score	4	4	4	4
		Milk production (kg)	0.2	0.2	0	0
		Diet OMD (%)	65(65)	63(63)	62(62)	73(77
		Diet CP (%)	9.8(10.7)	9.0(9.0)	8.1(8.1)	19.3(
		Average daily gain (kg)	0	0	0	0
		Breed score	4	4	4	4
		Body weight (kg)	390	365	340	350
		Body score	5	4	3	3
		Physiological stage	4	4	4	4
		Environmental score	5	6	6	5
May	Sahiwal	Travel score	4	4	4	4
		Milk production	4.5	3.5	2.5	1.5
		Diet OMD (%)	65(65)	63(63)	62(62)	73(77
		Diet CP (%)	9.8(10.7)	9.0(9.0)	8.1(8.1)	19.3(
		Average daily gain (kg)	0	0	0	0

Appendix Table 19A. Continued.

Calving date	Breed	Parameter	July	Aug.	Sept.	Oct.	Nov.	Dec.
			MONTH/PARAMETER INPUT					
		Breed score	4	4		4	4	4
		Body weight (kg)	335	320	300	315	340	360
		Body score	3	3	3	3	4	5
		Physiological stage	4	4	4	4	4	4
		Environmental score	5	6	6	5	3	3
May	Boran	Travel score	4	4	4	4	4	4
		Milk production	2.4	1.4	0.8	0.5	0.3	0.1
		Diet OMD (%)	65(65)	63(63)	62(62)	73(77)	72(75)	67(70)
		Diet CP (%)	9.8(10.7)	9.0(9.0)	8.1(8.1)	19.3(23.7)	15.5(17.7)	13.6(14.2)
		Average daily gain (kg)	0	0	0	0	0	0
		Breed score	4	4	4	4	4	4
		Body weight (kg)	230	225	220	230	245	255
		Body score	2	2	2	2	3	3
		Physiological stage	4	4	4	4	4	4
		Environmental score	5	6	6	5	3	3
May	E. African zebu	Travel score	4	4	4	4	4	4
		Milk production (kg)	1.4	0.8	0.5	0.3	0.2	0.1
		Diet OMD (%)	65(65)	63(63)	62(62)	73(77)	72(75)	67(70)
		Diet CP (%)	9.8(10.7)	9.0(9.0)	8.1(8.1)	19.3(23.7)	15.5(17.7)	13.6(14.2)
		Average daily gain (kg)	0	0	0	0	0	0
		Breed score	4	4	4	4	4	4
		Body weight (kg)	395	375	370	375	385	395
		Body score	5	4	4	4	4	5
		Physiological stage	3	3	3	4	4	4
		Environmental score	5	6	6	5	3	3
Oct.	Sahiwal	Travel score	4	4	4	4	4	4
		Milk production (kg)	0	0	0	5.0	4.7	4.5
		Diet OMD (%)	65(65)	63(63)	62(62)	73(77)	72(75)	67(70)
		Diet CP (%)	9.8(10.7)	9.0(9.0)	8.1(8.1)	19.3(23.7)	15.5(17.7)	13.6(14.2)
		Average daily gain (kg)	0	0	0	0	0	0
		Breed score	4	4	4	4	4	4
		Body weight (kg)	340	345	340	340	330	340
		Body score	4	4	4	4	4	4
		Physiological stage	3	3	3	4	4	4
		Environmental score	5	6	6	5	3	3
Oct.	Boran	Travel score	4	4	4	4	4	4
		Milk production (kg)	0	0	0	3.0	2.8	2.4
		Diet OMD (%)	65(65)	63(63)	62(62)	73(77)	72(75)	67(70)
		Diet CP (%)	9.8(10.7)	9.0(9.0)	8.1(8.1)	19.3(23.7)	15.5(17.7)	13.6(14.2)
		Average daily gain (kg)	0	0	0	0	0	0

Appendix Table 19A. Continued.

Calving date	Breed	Parameter	MONTH/PARAMETER INPUT					
			July	Aug.	Sept.	Oct.	Nov.	Dec.
Oct.	E. African Zebu	Breed score	4	4	4	4	4	4
		Body weight (kg)	245	235	225	225	230	230
		Body score	4	3	3	3	3	3
		Physiological stage	3	3	3	4	4	4
		Environmental score	5	6	6	5	3	3
		Travel score	4	4	4	4	4	4
		Milk production (kg)	0	0	0	2.0	1.8	1.4
		Diet OMD (%)	65(65)	63(63)	62(62)	73(77)	72(75)	67(70)
		Diet CP (%)	9.8(10.7)	9.0(9.0)	8.1(8.1)	19.3(23.7)	15.5(17.7)	13.6(14.2)
		Average daily gain (kg)	0	0	0	0	0	0

[1], [2], [3], [4], [5] See Appendix Table 18 for codes on breed score body condition score, physiological/production stage score, environmental and travel score adjustment.

[6] Values not inside parentheses are for the unburned paddock.

[7] Values inside parentheses are for burned paddock.

Appendix Table 19B. Projected parameter inputs for Sahiwal, Boran and East African Zebu cattle breeds with January, May and October mean calving months in a below average rainfall year.

Calving date[1]	Breed[2]	Parameter[3]	MONTH					
			Jan.	Feb.	March	April	May	June
		Diet OMD (%)	60[4](61)[5]	59(60)	60(62)	66(70)	63(67)	62(63)
		Diet CP (%)	7.3(7.5)	7.1(7.1)	7.5(7.9)	14.0(16.0)	8.5(9.0)	7.2(8.0)
			MONTH					
			July	Aug.	Sept.	Oct.	Nov.	Dec.
		Diet OMD (%)	60(61)	59(60)	58(58)	61(62)	67(71)	63(65)
		Diet CP (%)	6.7(6.9)	6.5(6.5)	6.3(6.3)	8.7(9.8)	15.6(18.4)	9.7(10.2)

1 Mean calving dates same as in Appendix A.

2 Breeds are same as in Appendix A.

3 The parameter and parameter inputs are same as in Appendix A except OMD and CP.

4 Values not inside parentheses are for unburned paddock.

5 Values inside parentheses are for burned paddock.

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