PRODUCTIVITY LIMITATIONS AND POTENTIALS FOR DUAL-PURPOSE COW HERDS IN THE CENTRAL COASTAL (LEEWARD) REGION OF VERACRUZ, MEXICO

A Thesis

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by

Victor Antonio Absalon-Medina

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ABSTRACT

The objectives of this study were to systematically evaluate the productivity limitations from typical management and potentials from alternative management in dual-purpose cow herds owned by members of the Genesis farmer organization in the central coastal region of Veracruz, Mexico. The Cornell Net Carbohydrate and Protein System (CNCPS) model version 6.1 was the primary diagnostic tool applied to specific management group of cows in structured sets of simulations. A total of 60 simulations were conducted to evaluate the limitations from typical management and, based on this information, 102 additional simulations were conducted to estimate probable outcomes from alternative management options. Typical herd management was established from data in recent reports, a local agricultural experiment station herd, and with guidance from a panel of Mexican professionals working with herds in this region.

This case study clearly identified key biological (energetic) and management limitations affecting dual-purpose cattle herds in the central coastal region of Veracruz. It is believed to be the first published study for a tropical environment to systematically evaluate the interactions of energy balance, milk production, expected growth in immature cows and, indirectly, probable effects on calving interval for specified cow management groups. Cow management groups, defined by three age classifications (parities 1, 2 and >2), four forage seasons of calving (early rains, late rains, scarce rain, and little rain), and five sequential physiological stages of lactation (3 stages of lactation and 2 stages during the dry period), were evaluated across the production cycles.

Results showed accurate representation of typical lactation productivity scenarios for Genesis herds by the CNCPS model. Findings also revealed important

cow and herd vulnerabilities constraining milk production and, probably, reproductive performance (i.e., calf production) by the cow herd. Average CNCPS-predicted milk production outcomes based on chemical composition of feeds and typical feeding policy agreed with the overall Genesis herd performance and with milking performance by INIFAP's La Posta herd for crossbred cows from the same genetic group consuming forages grown in the same agroecozone. This outcome underwrites the accuracy of predicting sensible differential outcomes from alternative management strategies aimed at improving productivity and profit in dual-purpose herds like those in central coastal Veracruz.

Findings from the analysis of baseline scenarios suggested two key vulnerabilities constraining cow productivity: chronic energy deficits among dry cows of all ages and impeded growth among immature cows. Regardless of the forage season of calving, most, if not all, cows incur energy deficits in the last trimester of gestation. Negative feed energy balance prior to parturition reduces the pool of tissue energy, thus constraining milk production in the next lactation. Alternatively these energy deficits signify calving intervals that are longer than the averages considered in this study. Energy supplies often resulted in thin body condition scores and slow or arrested growth in young (immature) cows. Consequently, cows receiving typical management are frequently smaller and underweight for their age, which limits their feed intake capacity, milk production and the probability of early postpartum return to ovarian cyclicity.

Consequently, a management strategy was developed using affordable feeds, especially good quality harvested grass forage (e.g., grass hay, maize silage) to reduce identified risks of cow vulnerability. The substitution of harvested forage of good quality for grazing increased milk yields by about one-third over typical scenarios for underweight cows. When diets from first parturition properly supported cow growth and tissue repletion, milk production in second and third lactations was substantially improved, about 60%. Judiciously supplemented diets based on good quality grass that also incorporated legume forages starting at first calving were predicted to further increase productivity. About 80% more milk would be expected compared to the baseline nutritional regime (i.e., from group management with CNCPS monitoring and properly supplemented diets with good forage quality).

The incorporation of either good quality harvested grass or grass combined with forage legume into properly supplemented diets resulted in large increases in net margin across a (truncated) 3-lactation cow lifetime ($670 or $935). These profit increases of about 65% or 90% correspond to at least one additional lactation per cow of milk sales than from typical management. This expected outcome clearly represents a substantial economic incentive for farmers to reduce these production vulnerabilities. Additional expected economic benefits, unaccounted in this study, included increases in the expected average productive lifetime of cows, which means more calf sales, more total milk production and heavier cows at culling.

In conclusion, Genesis farmers, and probably many other dual-purpose herd owners in coastal Veracruz, apparently have large economic incentives to increase milk and calf sales and net incomes by implementing nutritional strategies like those considered in this study. Fundamental to this achievement is quality control of good quality forages, thrifty production of harvested forages, and their separate storage for feeding to management groups of cows guided by effective use of a nutrition tool like the CNCPS model.

BIOGRAPHICAL SKETCH

Victor Antonio Absalón-Medina was born on April 20, 1981 in Santiago Tuxtla, Veracruz, México, where he spent his childhood. He started a veterinary degree in 2000 at the Universidad Veracruzana Facultad de Medicina Veterinaria y Zootecnia. While he was studying for this degree he had an opportunity for an internship at the University of Wisconsin-La Crosse in 2002. In 2004 he served as a student volunteer for one year working with ranchers in the Sotavento and the Papaloapan regions of Veracruz, México. In 2005 he did another internship, this time at Mc Gill University Macdonald campus in Quebec, Canada. After graduating from veterinary school he was accepted into the MS program in the Department of Animal Science at Cornell University in August 2005.

To my beloved father,

Victor Augusto Absalón-Martínez

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1.0 Introduction

Mexico's Gulf state of Veracruz possesses abundant natural resources and food production potential. Lumber, coffee and dairy foods are produced in the mountain region. Many important crops are produced in the coastal zone, including cattle raised principally in dual-purpose systems, maize, sugar cane, black beans, honey, tobacco, timber and a variety of fruits (e.g., mango, banana, pineapple, citrus, papaya and watermelon).

Animal agriculture is a key component of the Veracruz economy. In addition to its position as Mexico's premier supplier of beef, predominantly from dual-purpose cattle herds (Roman-Ponce, 2005), Veracruz is also the country's fifth largest producer of milk (INEGI, 2004). Although there are about 65,000 cows in specialized (high input) dairy herds, most milk is produced by about 4 million dual-purpose cows whose bull calves are destined for the beef market (OEIDRUS, 2003). The Veracruz cattle inventory in 2004 yielded about 206 metric tons of beef carcass weight (OEIDRUS, 2004).

Consequently, dual-purpose cattle herds constitute an important livelihood for the rural citizenry of Veracruz. Dual-purpose systems are the traditional method of cattle production in the tropics (Nicholson et al., 1994) with crosses between Zebu and European breeds used to produce milk and beef. However, farmers often lack technical assistance. Few managers keep formal records or have reproductive and health programs. Most herd owners, especially smallholders, rely on local inputs, especially labor and forages, and low-cost infrastructure and mechanization. Unsurprisingly, the least productive farms have the least access to inputs (e.g., land, feedstuffs, machinery, hired labor, information and technology).

Information to manage the productivity of dual-purpose cattle systems is relatively scarce, especially about the benefits and costs of alternative strategies

(Magaña-Monforte et al., 2006). The Mexican tropics typically have a six-month dry season, which limits the production of critical forage inputs. As a result, cows are more likely to become pregnant in the more nutrient-plentiful wet season. This scenario also probably limits the overall productive lifetime of cows that cannot quickly overcome post-partum anestrous from insufficient body tissue energy status for yearly calving. This seasonality leads to annual fluctuations in milk and beef production and farm sales. When live animal prices are high, as in 2004-05, farmers may liquidate their holdings of young stock, including heifers, for US trade, which jeopardizes herd recuperative capacity for restocking. Since 1999 between 800,000 and 1,300,000 Mexican calves have been exported annually to the US (Gallardo-Nieto et al., 2006; Appendix 8.1).

Government agricultural institutions such as the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) work with farmers to evaluate technologies to increase productivity and profitability. Targets for cattle producers are improved milk and beef production, shortened calving intervals, and younger age at first calving. One avenue of farmer participation, especially in Veracruz, is through membership in local associations called Grupo Ganadero para la Validación y Transferencia de Tecnología (GGAVATT, Cattlemen's Technology Testing and Transfer Group). Through this mechanism GGAVATT members and INIFAP researchers collaborate to evaluate and implement technology options adapted to members' farm settings. By participating (investing) in this business technology implementation process, GGAVATT members are enabled to be more competitive than other farmers (Appendix 8.2).

Another example of INIFAP's outreach program in Veracruz is the Día del Ganadero (Cattlemen's Field Day), an event that has been held annually for more than 30 years. This event currently introduces relevant information and new findings in support of herd and ranch management to more than 1,000 farmers. Topics include grazing management techniques and promising forage cultivars matched to local growing conditions and market opportunities. For example, intensive rotational grazing is expected to improve nutritional quality of pastures. In addition, new grass varieties frequently have greater nutritional quality and overall better performance than native ones (e.g., better growth rates in the dry season and under acid soil conditions). Most agree that GGAVATT members produce more milk and calves from their cattle systems than ranchers whose herds lack these nutritional management practices.

An INIFAP research project (Rueda et al., 2005) is currently evaluating dual-purpose cattle options in the states of Veracruz, Puebla and Nayarit. Objectives are to improve profitability through more efficient natural resource management by systematically evaluating herd productivity limitations, and to identify "best bet" nutritional management options to increase herd productivity and profits. Once determined, the most promising options would be tested by GGAVATT memberships in each location for potential incorporation into management protocols. Finally, options are to be assessed economically through partial budgeting procedures like those in Rueda et al. (2003). A correlated goal is to lower the cost of production.

1.1. Target climatic zone and clientele group.

The state of Veracruz comprises about 7.3 million ha, one-half of which is dedicated to livestock production, primarily in dual-purpose cattle systems (OEIDRUS, 2004; Appendix 8.3). Most land dedicated to livestock is found in Aw climatic zones[1]. About 60% of Veracruz's cattle inventory is reared in the predominant Aw_1 and Aw_2 climatic zones (derived from data from OEIDRUS, 2003).

The municipality of Medellín de Bravo exemplifies the rural cattle-based towns in this coastal region. Located about 30 km south of the port city of Veracruz at 19° 03' N and 96° 09' W, annual rainfall from 1996 to 2005 averaged about 1700 mm with large seasonal variation and mean annual temperature of 25 °C (*Centro de Previsión del Golfo de México*, 2006). In addition, the *Centro de Previsión del Golfo de México* provided detailed environmental information describing target climate zone (Aw_2), not only about rainfall but also about temperature, relative humidity and wind speed (Table 1).

The municipality of Medellín has two main rivers –the *Cotaxtla* and the *Jamapa*–. Most land is flat and the elevation of this region averages about 20 masl. The rainfall distribution, population and use of the land, are provided in Appendix 8.7 (Diaz and Cortina, 2006).

Table 1 Average monthly temperature (T), relative humidity (RH), rainfall (RF) and wind speed (WS) for the period 1996 to 2005 (Centro de Previsión del Golfo de México, 2006).

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T (°C)	21.5	22.6	24.0	25.9	27.7	28.1	27.8	27.8	27.7	26.4	24.3	22.1
RH (%)	84.3	83.9	82.9	81.7	81.5	83.2	83.6	83.6	83.3	83.2	83.4	81.5
RF (mm)	47.2	6.5	21.3	39.3	75.8	235.7	319.3	345.2	302.2	242.6	69.3	20.2
WS (kph)	34.1	35.8	34.9	34.8	31.7	29.7	27.9	27.9	31.1	33.4	34.1	36.7

Here about 25,000 ha, constituting about 80% of the total area of the municipality, are dedicated to about 1850 dual-purpose ranches with 25,000 animals (OEIDRUS, 2003). The rainy period of the year, typically from June and July (early

[1] Under Köppen's climate classification Aw_0, Aw_1 and Aw_2 zones have moist, warm conditions with summer rains, an extended dry period during winter, and average annual temperature >22 °C with coldest mean monthly temperature >18 °C.

rains) and August and September (late rains), follows a pronounced dry period from October through December (scarce rain) and little rainfall from January through May (little rain). This seasonal variation in rainfall results in large differences in supply and nutritional quality of forage (Figure 1), which was similarly illustrated by Baba (2007) for Yucatan beef systems. Correspondingly, there are large seasonal fluctuations in the annual pattern of calvings and, especially, in milk sales. Low or marginal nutrient intake by cows, aggravated during the dry season of forage scarcity, results in low body tissue energy status, prolonged calving intervals and slow growth of their calves from depressed milk production (Baba, 2007).

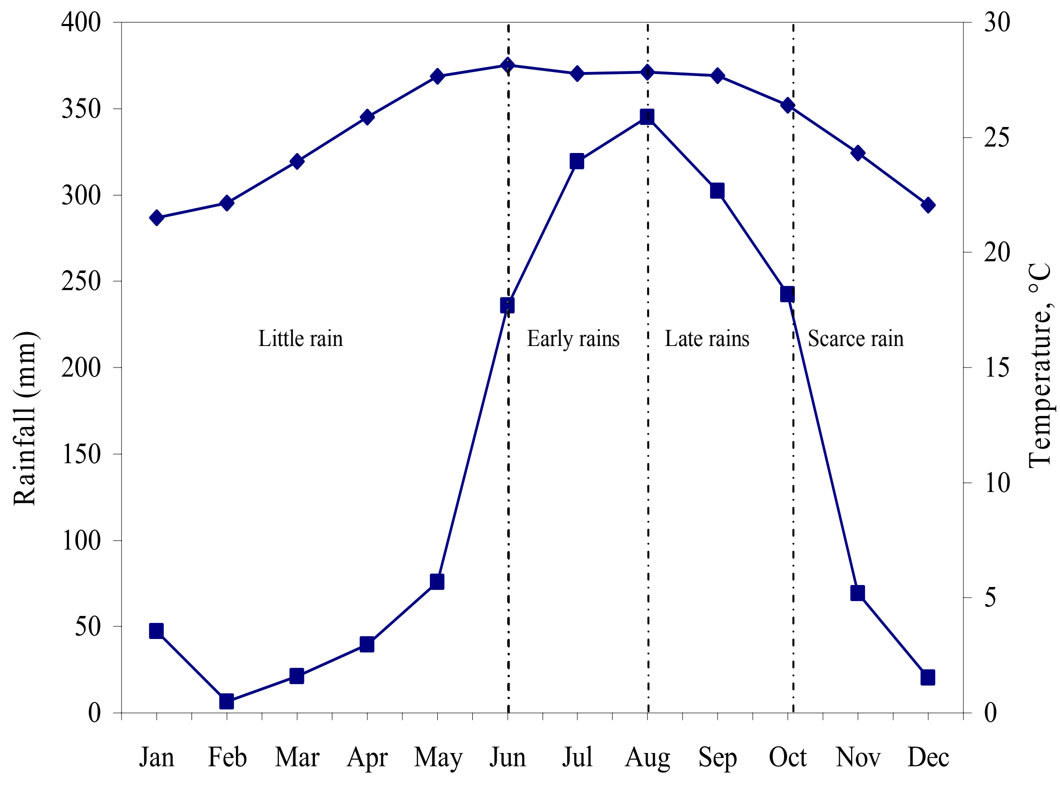


Figure 1 Mean monthly temperature (°C, ♦) and rainfall (mm, ■) in the Aw2 climatic zone of the municipality of Medellín de Bravo, Veracruz from 1996 to 2005 (Centro de Previsión del Golfo de México, Boca del Río Veracruz, 2006). Annual rainfall during this period ranged from 1500 to 1800 mm.

The GGAVATT Génesis, located in the municipality of Medellín de Bravo, has a membership of 18 ranchers with individual land holdings ranging from 24 ha to 283 ha which are stocked with about 1.0 animal unit (AU) per hectare (1 AU equals 450 kg of animal live weight) (Rodriguez-Morales et al., 2005; Appendix 8.4). Cattle on these ranches are mostly crossbreds between *Bos indicus* (Brahman, Sardo Negro) and *Bos taurus* (Brown Swiss, Holstein and Simmental) breeds (Appendix 8.5). The predominant genetic group is Brown Swiss x Brahman crossbreds. Ranchers manage dual-purpose herds and some cow-calf operations principally by grazing rarely fertilized pastures, with purchased hay fed during the low-rainfall months of the year. These GGAVATT (hereafter, Genesis) members have responded to professional advice by producing their own hay and maize silage for feeding during the seasons of scarce and little rainfall (Figure 1). Recommendations also have included grass and legume species substitutions and additions to the forage portfolio (e.g., the incorporation of *Brachiaria* spp.).

Systematic evaluation of dietary management for productivity improvement of Mexico's dual-purpose cattle systems is a national need, as identified in INIFAP's research portfolio (Rueda et al., 2003). Such evaluation should consider tradeoffs among productivity (milk and beef) potentials of alternative diets, seasons of calving, age groups of cows (parity) in a herd, and explicit physiological stages throughout an animal's calving interval. Systematic examination of productivity limitations and potentials should provide useful information and potential options for farmers to more effectively manage their input investments.

2.0 Literature Review

This section is focused on an assessment of cow productivity limitations and potentials in dual-purpose herds in the leeward region of the central coastal plain of

Veracruz. Emphasis is on information from the Gulf region of Veracruz, Mexico and from other countries, especially the Latin American tropics. Some studies address only the effect of chemical composition of forage on milk production or growth in a specific forage season (usually a rainy one) and in a specific age group of cows (often mature cows). The aim of this review (and research study) is to enable systematic accounting of cow age (parity), stage of lactation (e.g., days in milk), physiological status throughout the calving interval, and forage season of calving. These factors help define herd groupings of cows throughout the year that are subject to nutritional management using the Cornell Net Carbohydrate and Protein System or similar model.

2.1. Forage quality throughout the year.

Plant growth, chemical composition and digestion rates of tropical forages are known to vary with season of the year. Similar day length to night length and warm nights mean that tropical forages supply fewer nutrients than temperate ones (i.e., less daytime for photosynthesis, more nighttime for respiration). These plants may also produce secondary compounds that depress their digestibility. Therefore, the feeding quality of tropical grasses is typically less than for those grown in temperate locations (Sánchez et al., 1988; Van Soest, 1994).

A diagnostic study in the warm climate of Mediterranean Italy (Licitra et al., 1998) revealed large seasonal differences in cow performance associated with seasonal variation in forage quality. Pastures with high contents of neutral detergent fiber (NDF) and lignin and low crude protein (CP) content led to poorest cow performance. In Veracruz, Mexico (Juarez et al., 2002) tropical grasses grow and mature rapidly and incur rapid declines in nutritional quality with plant age (i.e., high NDF, high lignin and marginal CP). Therefore, cattle productivity in Veracruz's dual-purpose herds is undoubtedly constrained by seasonal limitations in the quantity and the quality of its forage supplies.

2.2. Research applications of the Cornell Carbohydrate and Protein System in the tropics.

The Cornell Carbohydrate and Protein System (CNCPS) is a mathematical model to predict cattle nutrient requirements (i.e., maintenance, growth, pregnancy, lactation and body tissue reserves), feed utilization, and nutrient excretion (Fox et al., 2004). This tool has been applied to temperate and to tropical herd production conditions (Juárez et al., 1999, Rueda et al., 2003, Reynoso-Campos et al., 2004; Baba, 2007).

Juárez et al. (1999) utilized the CNCPS model to evaluate the productivity potentials of 15 tropical grasses grown in Veracruz. These grasses varied in their chemical composition and NDF digestion rates to support milk production in dual-purpose herds. This research team concluded that the CNCPS can accurately predict nutritional requirements and probable cow performance with appropriate descriptions of animal and environmental inputs, the chemical composition of feeds and their digestion rates.

Rueda et al. (2003) evaluated strategies to improve productivity and economic returns from beef and dual-purpose cattle grazing *Brachiaria decumbens and Brachiaria brizantha* cv. Marandu grasses and *Pueraria phaseoloides* in Acre, Brazil. Milk production and post weaning growth of steers were evaluated using information describing seasonal variations in chemical composition and digestion rates of grazed forages. Subtle differences in forage chemical composition between seasons significantly affected the CNCPS-predicted dietary supply of metabolizable energy (ME) and thus animal growth rate throughout the year. The authors concluded that supplementation with sorghum grain to increase milk production or growth by 25% or

50% was less profitable than forage-only diets. Increasing the stocking rate (from 2 to 4 AU/ha) with careful fertilization resulted in greater net margins for farmers producing beef (growing cattle) but not for milk production.

Approaches, like those from Reynoso-Campos et al., (2004) and Baba, (2007) (CNCPS applications), that consider chemical composition of forages, animal and environmental inputs are fundamental to identifying bottlenecks on dual-purpose livestock production systems in the leeward (central coastal) region of Veracruz.

2.3. Dietary constraints on animal productivity.

A key determinant of cattle productivity and profit is the intake of energy (Nicholson et al., 1994; Reynoso-Campos et a., 2004; Baba, 2007). The intake of ME was more limiting than the intake of metabolizable protein (MP) for growing steers grazing *Brachiaria* grasses in Acre, Brazil (Rueda et al., 2003). Undergrazing pasturelands leads to overly mature grasses with low digestibility and depressed animal performance. Thus, managing the stocking rate in accordance with the plant growth rate is expected to facilitate herd productivity by providing better quality grazing and greater supply of ME for milk and growth. Deficits of dietary energy also constrain reproductive performance of cows and heifers.

Energy requirements of cows increase rapidly during the 60-day period preceding parturition. This rapid increase followed by high lactation demands during early lactation results in a negative body tissue energy balance (NEBAL). This deficit usually reaches its nadir about two weeks after calving in well-fed dairy cows. This NEBAL nadir has been related to the length of the postpartum interval to first ovulation (Butler, 2003). Thus, delays in re-initiation of ovarian cyclicity are related to the length and the extent of NEBAL. The quantity of adipose tissue reserves at various physiological stages of the calving interval is an important determinant of reproductive performance and overall herd productivity. Therefore, body condition score (BCS) is a valuable indicator and herd management tool for identifying and monitoring the nutritional and body tissue energy reserve statuses of cows (Herd et al., 1987). Extended calving intervals (CI), which leads to fewer calves to sell, often result from dietary energy deficiencies and misallocations of feed resources throughout the year. Consequently, Mexican smallholders frequently are unable to take advantage of calf marketing opportunities with US traders (Gallardo-Nieto et al. 2006). Poor diets of lactating cows result in too-heavy reliance on body tissue reserves to support milk production, which leads to long CI (Baba, 2007). As a result, cows may tend to get pregnant at the beginning of the rainy season with recovery of adipose tissue reserves from consumption of high quality forage, and with subsequent calvings frequently occurring during seasons of low forage supply and quality (e.g., October to February). For example, the monthly distribution of calvings in Genesis herds from September 2004 to August 2005 is shown in Figure 2 (Rodriguez-Morales et al., 2005). Calvings are distributed throughout the year with about 70% of cows calving from October through February (seasons of scarce and little rain).

Reynoso-Campos et al. (2004) developed a dynamic version of the CNCPS for monitoring and managing milk production, ME and MP balances, and fluctuations in body weight and BCS on a daily basis throughout calving intervals on dual-purpose cows in Veracruz, Mexico. This model systematically evaluated productive and reproductive performance of cows in established physiological stages (e.g., early lactation, mid lactation) and parities (primiparous, multiparous) during a calving interval.

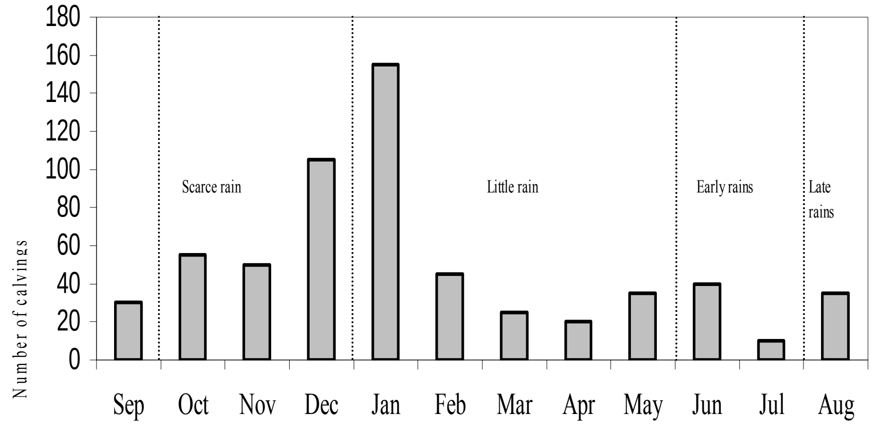


Figure 2 Monthly calvings in 18 Genesis herds from September 2004 to August 2005. Calvings frequently occur in October through February from conceptions in the forage-plentiful season when forage quality is high.

The authors concluded that accounting for tissue reserve fluxes is important for achieving productivity and profitability goals. In other words, accurate predictions of nutrient requirements, animal performance and body tissue status can help cattlemen to make decisions about optimal forage portfolios and when and how to supplement the cows' diet.

Body tissue energy balance is a key factor affecting the postpartum interval to re-initiation of ovarian cyclicity. Therefore, to obtain calving intervals of desirable length, effective herd management requires analysis and monitoring of cow energy balance and dietary supplementation to replenish catabolized tissue reserves. This means achieving BCS goals in key physiological stages of the calving interval. Well-managed schedules of tissue mobilization and repletion fluxes, including the achievement of BCS goals at each parturition (and short calving intervals) are necessary conditions for managing the productivity potentials of dual-purpose herds in the state of Veracruz.

Most research about tropical cattle performance focuses on mature cows. Less, if any, has been devoted to heifers or immature cows in first and second lactation that are still growing. Baba (2007) found in beef systems in Yucatan, Mexico that restrictions on *ad libitum* forage energy intake reduced growth of immature cows by one-third. Consequently, immature cows could not achieve target live weights without incurring longer calving intervals, which certainly restricts their productive life (i.e., fewer lactations and fewer calves). The author concluded that greater feed consumption would reduce the heavy reliance on body tissue energy reserves for milk production, which also portends shorter calving intervals (Baba, 2007).

In the lowland savannah of Colombia, three groups of weaned Brahman heifers (9 mo old) that were raised to a target body weight of 270 kg experienced effects of undernutrition from alternative stocking rates grazing a low-quality *Brachiaria humidicola* (chemical composition and digestion rates were not given) (Vera et al., 1993). Average daily gains were 0.097 kg, 0.215 and 0.259 kg. Once heifers reached the target body weight, all cows were transferred to a common low-quality *Brachiaria humidicola* paddock. The only supplementation that the cows received was minerals containing mainly 80 g/kg of phosphorus and other macro and micro nutrients. Results indicate that heifers reared under the highest stocking rate (lowest dietary quality) first calved 200 d later than the other heifer groups. Consequently, heifers consuming the low quality diet had shorter productive lifetimes with fewer calvings (~3) than better fed heifers (~4 calvings). Ages at first calving were 50 mo, 41 mo, 40 mo for heifers reared under high, medium and low stocking rates ($P < 0.001$).

In addition to insufficient management attention to growing animals, dry cows merit more attention, especially during the transition period from late gestation to early lactation. Management of "transition cows" in US dairy herds has received increased attention during the past 15 yr. Nonetheless, many commercial dairy farms incur metabolic disorders from a lack of understanding about the biology of metabolic regulation, immune function and stress in cows in this stage of the calving interval (Overton and Waldron, 2004).

Cows in the transition period experience homeorhetic changes (i.e., metabolic adaptations of the liver, body fat and other tissues) to support the increasing demands for macrominerals, glucose, amino acids and fatty acids. Thus, improper management during this period can precipitate several problems, such as depressed appetite, milk fever, fatty liver, displaced abomasum and mastitis, all of which reduce animal productivity and reproductive performance (Overton and Waldron, 2004).

Overton and Waldron (2004) identified several feeding strategies for the transition period. Better performance with fewer problems are observed from dividing dry cows into two groups to minimize overfeeding of nutrients during the early dry period and to facilitate metabolic adaptation with greater nutrient supplies during the late dry period. The latter seems to be more successful than other feeding strategies, such as dietary fat or conjugated linoleic acid additions or decreasing the cation-anion difference in the diet.

Further research that accounts not only for dietary constraints on milk production but also on growth of young cows and the transition period is needed for farmers to achieve herd productivity goals. Thus, systematic evaluation of herd management opportunities and options should include explicit consideration of growth to achieve body size goals. Cows obtaining body weights that are a larger proportion of their inherent mature size are able to consume more forage and possess larger adipose tissue reserves to support greater milk production (Urbina, 1999).

2.4. Alternative forages for increased herd productivity and profit in Veracruz, Mexico.

Recent studies have shown benefits from improved grasses or other forages (e.g. legumes) when they are integrated into dual-purpose cattle systems. Some cultivars, like Mulato grass (*Brachiaria ruziziensis* x *Brachiaria brizantha*), can tolerate higher stocking rates than native ones. Other reports indicate successful implementations of legumes and grasses in grazing systems in tropical Australia and Brazil (Shelton, 2004; Rueda et al., 2003). Intercropping forages is therefore another option to improve not only the quality of the diet but also to enhance soil nutrients, e.g., nitrogen (Shelton, 2004; Argel and Villarreal, 2003). Furthermore, the Centro Internacional de Agricultura Tropical (CIAT) has several research findings regarding cattle performance (i.e., milk production, growth) in intercropped pasture/legume cattle systems. These findings consist of improvements in productivity from better quality diets and profitability from lower cost forage supplementation.

Traditionally farmers in the leeward region of Veracruz feed commercial supplement only during the critical part of the dry season, especially in May when forage stocks have been exhausted. Greater feed stocks during the periods of scarce and little rain in Veracruz would be expected to improve milk production and shorten the prolonged calving intervals of cows. The following subsection is intended to provide relevant information about new forage species and management techniques (and their implications) for alternative feeding prospects to be considered in this study.

2.4.1. Alternative grass species providing more dietary energy.

Native grass species in Veracruz and other regions of Mexico relying on grass-based cattle systems typically supply insufficient dietary energy to meet the nutritional energy requirements of cattle to produce milk and beef for the current domestic and international markets. Therefore, the introduction of high-yielding improved grasses containing more energy to animals in dual-purpose systems is an important step towards greater market competitiveness. In addition, the features of these improved grasses include resistance to pests, disease, high rates of stocking, and extended drought.

Cultivars from the *Brachiaria* spp. exemplify grasses that are well adapted (suited) to tropical conditions. The CIAT has developed several species of *Brachiaria* that have been well accepted by farmers because of enhanced productivity and profitability. Greater ME supplies from *Andropogon gayanus* have resulted in more milk and beef production compared to other forage species (i.e. *Cynodon plectostachyus*).

A Veracruz research team (Juarez et al., 2002) has provided the chemical composition of an array of candidate forages with recommendations for managing each one. These authors recommend that productivity increases are enabled only when farmers know, and utilize, forage chemical composition and digestion rate information to predict probable nutrient requirements and to manage output potentials.

Several studies (Argel et al., 2006; Cuadrado et al., 2005; Pinzon and Santamaria, 2005b; Enríquez, 2003; Meléndez, 2003; and Guiot, 2000 [unpublished]) indicated that the *Brachiaria ruziziensis* x *Brachiaria brizantha* cv. Mulato is well-adapted to dual-purpose systems in Mexico, Panama and Colombia. Reasons were that it has a deeper rooting system, which makes it more resistant to frequent grazing, and better productivity in marginal soils compared to other options such as *Brachiaria brizantha* cv. Toledo.

Argel et al. (2006) noted that the chemical composition and digestibility of Mulato grass grown during rainy months under lowland conditions ranges from 9 to 16% of CP and from 55% to 62% *in vitro* dry matter digestibility at plant ages of 23 d to 30 d. The authors did not indicate geographical location. In a study during the rainy season in Cerete, Colombia, Mulato grass outperformed *Brachiaria decumbens* cv., Basilisk under similar grazing conditions (9.8% of CP *vs*. 8.3%, respectively [$P < 0.05$]) (Cuadrado et al., 2005). In addition, the author did not report any other performance measurements besides CP. However, in other studies in Honduras the authors have reported that the NDF content of Mulato grass is about 50% (Argel et al., 2006).

At CIAT's experimental station in Quilichao, Colombia, crossbred cows were randomly assigned to diets with three grass alternatives (*B. decumbens* cv. Basilisk, *B. brizantha* cv. Toledo and cv. Mulato). Cows consuming Mulato cultivar produced more milk (8.1 kg/d) than those consuming the other grasses (7.6 and 6.5 kg/d, respectively [$P < 0.05$]; CIAT, 2000).

A research study conducted at two locations (Gualaca, Panama [Pinzon and Santamaria 2005b] and Cerete, Colombia [Cuadrado et al., 2005]) evaluated growth of Zebu crossbred steers. In Panama steers were allowed to graze each paddock (3.5 AU/ha) for three days and then each paddock was allowed 21 d of recovery throughout the year. In Colombia animals grazed about two days in each paddock (3.5 AU/ha) followed by 22 d for recovery during the rainy months, and three days of grazing with 33 d for recovery during the dry season. Average daily gains were about 400 g at each location. Similar average daily gains (435 g) were observed in steers grazing Mulato cultivar (4 AU/ha) in Huimanguillo, Tabasco, Mexico.

In Isla, Veracruz, Mexico, two groups of steers were randomly assigned to either Mulato or *Brachiaria decumbens* (Signal grass) paddocks stocked with 4 AU/ha. Steers grazing Mulato grass grew most rapidly (301 g/d *vs*. 219 g/d, [significance was unreported]). Perhaps the average daily gains are not surprising, but when grasses were compared in terms of productivity Mulato grass showed superior average annual liveweight gain per hectare of 555 kg *vs*. 219 kg for Signal grass (Enriquez, 2002 [reported in Guiot and Melendez, 2003]).

Similar results were found in milk production from cows grazing Mulato grass compared to Signal grass in the Gulf region of Mexico. Daily milk production was similar (10.7 kg *vs*. 12.1 kg for crossbreds but unknown stage of lactation). However, because Mulato grass supported a higher stocking rate (4 AU/ha *vs*. 1.6 AU/ha) more daily milk production was obtained per unit of land (42.8 kg/ha *vs*. 19.4 kg/ha) (Melendez, 2003).

In another study in Veracruz (Juanita) one group of lactating Brown Swiss x Zebu cows (stage of lactation and age of cows not reported) were allowed to rotationally graze paddocks containing several grass species, such as *Andropogon gayanus*, *Digitaria decumbens*, *Paspalum notatum*, *Brachiaria humidicola*, *Brachiaria decumbens* and Mulato cultivar. On average the group of cows grazed for about seven days in each paddock except the Mulato one, where cows were allowed to graze for about three more days. Results indicated that cows grazing Mulato paddocks yielded 6.9 kg/d compared to 4.9 kg/d for the ones grazing paddocks containing the other forages (Guiot, 2000 [unpublished]).

In a field study in Colombia, 12 lactating dairy cows (location, breed, age, stage of lactation and chemical composition of grasses not reported) rotationally grazed five Signal grass paddocks of 0.75 ha with a stocking rate of 3.2 AU/ha. Each paddock was grazed for about 3 days. Cows under these conditions were able to maintain an average daily milk production of 5 kg from once-daily milking. Some cows were milked twice daily, yielding an average daily production of 8.8 kg. After those cows completed 15 d of grazing Signal grass they were switched to Mulato paddocks with same management. Cows milked once daily increased average daily milk production to 6.5 kg and cows twice daily yielded 11.3 kg. The total improvement in the average daily milk production for this forage species substitution was 22.9 kg (Plazas, 2002 [reported in Guiot and Melendez, 2003]). Studies of dual-purpose systems from Central America have also reported improvements in average daily milk production (from 1 kg to 2 kg) when Mulato cultivar was substituted for typical forages (Guiot and Melendez, 2003).

Feed quality is probably the most limiting factor for cattle production in tropical Latin America. Low forage quality and insufficient dietary intake of energy and other key nutrients causes cows to produce less milk and beef under these conditions compared to cows consuming forages of higher quality to better meet the cow's energy demands.

Researchers and farm advisors need to develop management strategies focusing on animal groupings differentiated by age and stage of lactation of cows, breed type, environmental inputs and chemical composition and digestion rates of the feedstuffs in the diet to precisely account for all the probable nutritional requirement of such cows. With this basic kind of information gathered and organized into an effective managerial protocol for technical application or implementation in target farms or in target agroecozones, farmers will have a better chance to improve animal productivity and profitability.

2.4.2. Legume species to improve nutrient intake.

The integration of legumes into dual-purpose systems has been successful in some cases (Shelton, 2004; Ramirez-Restrepo and Barry, 2005). Diet digestibility is improved by a rapid particle breakdown and consequently greater voluntary feed intake is expected (Ramirez-Restrepo and Barry, 2005). Legumes have secondary compounds that make more protein available in the abomasum, which improve milk production and growth through absorption of essential amino acids (Shelton, 2004;

Ramirez-Restrepo and Barry, 2005). In addition, legumes fix atmospheric nitrogen by means of symbiosis with bacteria of the genus *Bradyrhizobium*, which enhances soil fertility. Some legumes have the ability to search for water through a deep root system, which enhances the moisture in the topsoil (Shelton, 2004). Therefore, the production of milk and beef may be improved by integrating legumes into dual-purpose systems.

A study in Carimagua, Colombia was designed to evaluate growth patterns of young steers (genetic group of crossbred not reported) grazing *Panicum maximum* cv., Tanzania or *Brachiaria brizantha* cv., Toledo or a combination of these forages plus *Pueraria phaseoloides* (tropical kudzu) (chemical composition and digestion rates not reported). Paddocks with only the Toledo cultivar had a stocking rate of 2.5 AU/ha where animals had an average daily gain of 202 g and an average annual beef production of 184 kg/ha. Likewise paddocks with only Tanzania cultivar had a stocking rate of 2.0 AU/ha where animals grew 403 g/d with an average annual beef production of 294 kg/ha. Intercropped paddocks were able to maintain similar stocking rates (2.2 AU/ha). However, animals consuming intercropped pastures containing Toledo cultivar grew 505 g/d with an average annual beef production of 405 kg/ha. Furthermore, animals consuming intercropped pastures containing Tanzania cultivar grew 534 g/d with an average annual beef production of 429 kg/ha (Perez and Perez, 2002). This study suggested that intercropped paddocks are able to maintain similar stocking rates with improved animal performance.

Several studies reported the benefits from intercropping other legume species, such as *Arachis pintoi,* with *Brachiaria* spp in tropical conditions with crossbred cattle (CIAT, 1991; Quan et al., 1996; Ugalde, 1998; CIAT, 2000; Morales, 1989; Morales et al., 2001; Morales et al., 2001; Morales et al., 2003; Morales et al., 2004). In general, *Arachis pintoi* has good compatibility with *Brachiaria*, *Panicum* and

Cynodon spp. since it tolerates shade when intercropped with taller species. It can yield 2 to 5 metric tons of dry matter per year. On average, after five years of planting *Arachis pintoi* can constitute 50% of the forage offered during the rainy season and 20% during the dry months (Rincón et al., 2003).

In Colombia, reports show improvements up to 35% in average daily gains when *Arachis pintoi* was intercropped with *Brachiaria humidicola* and *Brachiaria dictyoneura*. These reports indicated that *Arachis pintoi* has high digestibility and content of crude protein. During the rainy season leaves and stems contain 18% and 10% CP, respectively, with 62% digestibility. During the dry season leaves and stems have similar digestibility. Cattle grazing this combination of forages during the rainy season had greater average daily gains (450 g) than those grazing only *Brachiaria* spp., (350 g; CIAT, 1991).

In Costa Rica, two trials of two lots of Jersey replacement heifers each showed better average daily gains when the quantity of commercial concentrate was reduced from 2 kg to 1.5 kg and the heifers had 5 h daily access to *Arachis pintoi* cv., Porvenir than those receiving 2 kg/d of commercial concentrate without *A. pintoi* 595 g and 537 g vs. 554 g and 444 g, (trial one and trial two [$P < 0.05$]) respectively. Findings indicate that not only was this protocol less expensive but that heifers grew more rapidly (adapted from Quan et al., 1996). Ugalde (1998) in Costa Rica demonstrated that using green banana and *A. pintoi* (chemical composition and digestion rates not reported) in a cut-and-carry system to replace between 56% and 78% of the commercial concentrate maintained the average daily milk production in dairy cows (between 10 and 14 kg, stage of lactation, age, crossbred type not reported).

The association of legumes and pastures has potential for improving herd productivity. However, without proper management of the paddocks it is very difficult to maintain the desired pasture/legume ratio under grazing conditions (CIAT, 2000;

Morales, 1989). The typical recommendation when *A. pintoi* is associated with *Digitaria decumbens* is to allow regrowth for 55 d before again grazing because the growth rate of the legume is slower than that of the grass. Therefore, although farmers would sacrifice nutrient content in the grasses to be grazed, they may obtain greater productivity than from grass-only pastures. In addition, nitrogen fertilization is largely unnecessary when farmers utilize associations of legumes and grasses (0.45:0.55 ratio), (Morales et al., 2001).

In addition, tree and shrub legumes have been shown to be a good feed resource for the dry months because they have better re-growth capacity than herbaceous legumes. At three months of regrowth, *Cratylia argentea* (cratylia) showed a CP content (23%) similar to other legume species such as *Gliricidia sepium* (25%) and *Leucaena leucocephala* (27%). In addition, the digestibility of cratylia (48%) was similar to other legumes (51% and 53%, respectively) (Lascano et al., 2002).

In Quilichao, Colombia, improvements in average daily milk production were observed in lactating dairy cows (age, stage of lactation and breed type not described) under grazing conditions. One of the supplemental forages consisted of 25% sugar cane and 75% cratylia and the other one consisted of 100% sugar cane. Results showed that cows consuming the mix of forages increased their average daily milk production compared to those cows consuming only sugar cane (8.2 kg *vs*. 6.6 kg [$P < 0.05$]) (Lascano et al., 2002).

The experimental station of CIAT (Quilichao, Cauca) in Colombia evaluated cratylia as supplemental forage for lactating dairy cows (stage of lactation, age and breed type not reported). The trial consisted of evaluating cratylia in cut-and-carry systems *vs*. cratylia grown in strips (1 meter between plants) in association with *Brachiaria decumbens* (Lascano et al., 2002). Cows grazing an association of forages had higher average daily milk production compared to cows under the cut-and-carry system (7.5 kg vs. 6.7 kg [dry season] and 7.3 kg vs. 6.6 kg [rainy season]). However, cows grazing only *Brachiaria decumbens* had an average daily milk production of 6.1 kg (dry season) and 6.3 kg (rainy season). The authors mentioned that cows consuming an association of forages can improve their average daily milk production by 14% to 17% ($P < 0.05$). In addition, when cratylia was used in cut-and-carry systems the authors recommended to sun-dry (wilt) it 24 h prior to feeding and/or to mix it with molasses to make it more palatable.

Shrubs or herbaceous legumes have their own advantages and disadvantages but successful association with forages directly depends on how well they are managed. For example, these forages should be allowed to regrow until they reach their optimal nutritional status before being grazed. Palatability problems can be managed by sun drying or mixing with other feedstuffs.

The identification of efficient and profitable diets can be achieved more rapidly with an *ex ante* (beforehand) evaluation of “best-bet” forage options by using a simulation tool to predict the probable nutritional requirements and expected productivity of cows managed by physiological status and age (parity). This management approach should also take into account environmental inputs and breed characteristics to accurately predict nutritional requirements. Management also requires information about chemical composition and digestion rates of the forages to be evaluated and other dietary ingredients. Armed with this information farmers in the leeward region of Veracruz would be able to better manage the profitability of their ranches through productivity-related decision making.

2.4.3. Feeding strategies for low rainfall seasons of the year.

Intensification of dual-purpose systems throughout the entire year is needed for farmers to capitalize on increasing market demands for milk and beef. Farmers should be able to maintain stable productivity, establishing goals for seasons throughout the year. Several studies (Morales et al., 2003; Morales et al., 2004; Fujisaka et al., 2005; Holmann et al., 2006) reported the benefits of introducing new forage species to dual-purpose systems, concluding that farmers adopting new technologies will be able to achieve competitive and sustainable livestock systems.

A diagnostic study conducted in Honduras and Nicaragua indicated farm characteristics, milk production by season of the year and feeding management protocols. In addition, crossbreds for both locations were reported (age and physiological stage of cows not reported); Brown Swiss x Brahman crossbreds was the major breed group in Honduras and ¾ Holstein x Zebu (Zebu breed not reported) cows was the primary breed group on Nicaraguan farms. The authors reported that the average daily milk production during the rainy months was 6.8 kg and 6.5 kg, respectively (Fujisaka et al., 2005). However, during the dry months only farmers with access to other inputs (e.g. silage, hay, cut-and-carry forage) were able to maintain productivity throughout the year. Therefore, in order to maintain a certain volume of product, i.e. milk, farmers will have to adopt different management techniques.

There are several options for low and middle income farmers; one example of a low-cost strategy for the dry season is the cut-and-carry system, which uses one source of energy (e.g., sugar cane) and one source of protein (e.g., cratylia). Another economical strategy would be the establishment of forage spp., of maize and sorghum for cut-and-carry. In addition, there are more specialized options such as production of silage or hay. These last options seem quite expensive but when farmers belong to associations, they can produce these feedstuffs less expensively than the price of commercial products because, for example in Mexico, as GGAVATT members, they are allowed to obtain subsidized machinery and equipment from the government for hay and earless corn silage production.

The results from feeding cattle high quality hay or corn silage including the ears are more milk/beef output by assuring adequate supplies of forage. In addition to it being more economical for farmers themselves to produce these inputs, the nutritional quality is superior to the commercial products. Increases of 35% and 67% in milk production have been observed during the dry months when corn silage of good quality was offered in Honduras and Costa Rica, respectively. Furthermore, increases of 35% and 32% in milk production were observed during the same period when hay was offered in Honduras and Costa Rica, respectively (Fujisaka et al., 2005). The authors concluded that it is less expensive to produce and offer hay in both cases. In addition, there is more milk production when hay was used in lieu of earless corn silage in both cases than to buy commercial product. Another interesting finding was that the average cost of the commercial hay was twice or more as expensive as farm-made hay. Thus, farmers have an opportunity to improve productivity and profitability through hay-making their own forages in the leeward region of Veracruz.

Costa Rican studies have found farm improvements when the hay from grasses is associated with legumes. In a dairy farm, one lot of late lactation cows under grazing conditions was able to maintain the same average daily milk production (10.8 kg) when 35% of a supplement (3 kg of concentrate/cow/day) was substituted for 1 kg hay (80% *Digitaria swatzilandes* and 20% *Arachis pintoi*) (Morales et al., 2003).

In another trial, Costa Rican researchers measured the growth response of housed steers to the quality of two different hays, *Arachis pintoi* associated with other grass vs. commercial hay (*Digitaria decumbens* cv., Transvala). Seventy percent of the diet consisted of either one hay or the other and the remaining 30% consisted of fish flour, poultry bedding and molasses. The commercial hay had a CP of 4.2% and 50.5 of IVDMD. On the other hand, hay of *Arachis pintoi* showed 14.1% of CP and 59% of IVDMD. The animals consuming the first diet had better growth performance (1.5 kg/d) than the animals consuming the second diet (0.397 kg/d). The authors concluded that the association of *Arachis pintoi* with grass in the hay lowered the cost of production since better average daily gains could be obtained from better quality feedstuffs and the animals needed less time to reach the average target weight (Morales et al., 2003, Morales et al., 2004).

The efforts of research centers have resulted in new varieties of forages that are better adapted to tropical environments, have better nutritional quality, are more efficient in terms of productivity, and are more profitable. We are also learning that the combination of pastures and legumes has potential benefits for dual-purpose systems, such as increased capacity of paddocks (more AU/ha), better nutritional quality feedstuffs, less use of nitrogen fertilization of soils, more outputs and, most importantly greater profits.

This review of the literature discussed experiments with a high level of aggregation. In most studies the physiological stage and age of cows are not reported. In addition, chemical composition and digestion rates, by season of the year, are needed, but not generally reported or known, to better predict possible outcomes using a simulation tool such as CNCPS. Simulation tools are good resources for integrating information about cattle, diet and environment in order to predict nutritional requirements and supplemental feed needs for target management groups of animals (e.g., cows throughout calving intervals and forage seasons of the year). With an *ex ante* evaluation in which the dual-purpose systems are systematically examined, possible productivity limitations and potentials might be predicted in order to assess best nutritional options throughout the year.

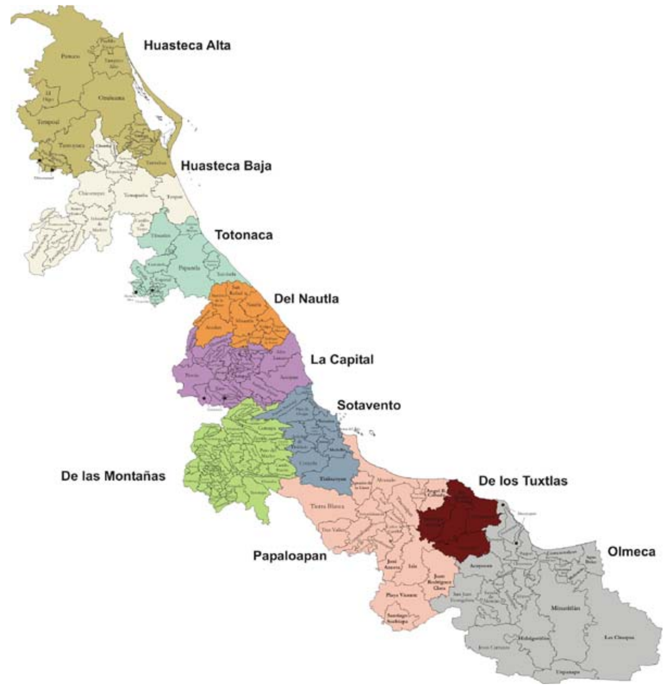
There is a clear need for information about the chemical composition and digestion rates of candidate forages throughout the year in order to screen and evaluate the best options for use. Consequently, dual-purpose cattle systems in Mexico and throughout tropical Latin America are undoubtedly managed less productively than is their potential. Therefore, current situations need to be systematically evaluated to determine alternative management scenarios that are more profitable and environmentally sound.

3.0 Objectives

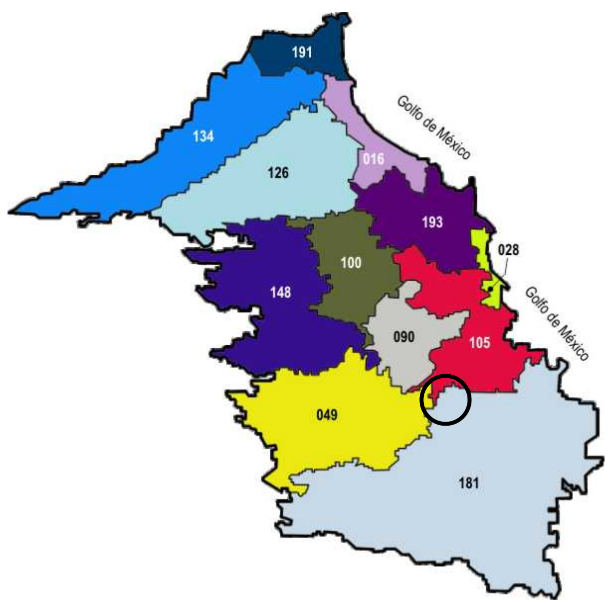
The overall objectives of this study are to determine the probable nutrient requirements and to systematically evaluate the productivity limitations and potentials in dual-purpose cattle herds in the leeward region of the central coastal plain of Veracruz, Mexico (Figure 3).

The first specific objective is to assess the average Genesis herd scenario and a typical scenario for non-Genesis herds. Parameters include predictions of probable nutrient requirements of cows of various parities calving in alternative forage seasons of the year, average milk production and energy balance of cows, and predicted intake of nutrients available from forages and supplements utilized by herd owners to meet requirements. This nutrition management scenario includes a description of the interaction of mobilized and repleted body tissue reserves utilized for milk production and seasonal changes in feed composition throughout calving intervals of cows.

The second specific objective, based on the identified productivity constraints in the current dual-purpose cattle system, is to evaluate strategic priority management options to improve herd performance. Included are identification of nutritional constraints to prompt recovery from the postpartum nadir of energy balance to restore



Panel (a) http://www.sanrafael.gob.mx/secciones.html?seccion=regiones@nregiones



Panel (b) http://www.e-local.gob.mx/work/templates/enciclo/veracruz/regiones.htm

Figure 3 Maps of (a) the 10 counties in the State of Veracruz and (b) the 12 municipalities forming the county of Sotavento. The circle indicates the location of the clientele herds in this study, which are located in the municipality of Medellín de Bravo (105).

ovarian cyclicity, the subsequent achievement of conception for desired calving intervals, and assurance of adequate body tissue reserves during the reproductive cycle for next calving. Greater productivity may be achieved through better management of body tissue energy reserves and better allocation of feedstuffs throughout calving intervals. This objective includes the evaluation of forage quality substitutions, dietary incorporation of legumes and grasses, and needed dietary supplementation with energy-rich feed.

The third objective consists of an economic evaluation of alternative management scenarios to determine the ones with promise for adaptation and use by farmers to improve productivity and herd profits. This objective will be achieved by using the method of partial budgeting to evaluate economic potentials from increased milk production using good nutritional management based on good quality feedstuffs.

4.0 Material and Methods

The target population of dual-purpose cattle herds in this study is located in the Sotavento (leeward) region of Veracruz, primarily in the municipality of Medellín de Bravo where GGAVATT Genesis is located. Most families in this region earn their livings from agriculture, especially livestock production.

Most information about typical animal husbandry, herd management, utilization of feedstuffs, pasture management, cow productivity, technology use, and sales of milk and calves from Genesis herds was obtained from a recent report by Rodriguez-Morales et al. (2005). Information about input use and herd management for non-GGAVATT herds was obtained from a report by INIFAP (2004).

Collectively these reports indicated important nutritional and managerial constraints on calf performance and milk production in these herds. Table 2 contains a

Table 2
Nutritional constraints and management options for dual-purpose cattle herds in the Sotavento region of Veracruz (Adapted from Reynoso-Campos et al., 2004 and Baba, 2007).

Constraints	Actions to resolve the constraints	References
• Producers lack nutritional management information.	• Systematic evaluation of the current nutritional limitations. • Accurate predictions of animal nutrient requirements. • Analysis of forages to obtain their chemical composition and digestion rates of feeds.	Reynoso-Campos et al. (2004) Juarez et al. (1999)
• Low quality nutrient content of the forages. ♦ Intake of energy is the principal limitation; also protein. ♦ Extended calving intervals	• Management of forage and cattle ♦ Forage quality ♦ Grouping cattle ♦ Parity and physiological stage • Overcome negative feed energy balance earlier with appropriate nutrition management. • Tissue reserves. Schedules of target body condition score is a needed management strategy.	Reynoso-Campos et al. (2004) Juarez et al. (1999) Butler (2003) Baba (2007)
• High cost diet supplements ♦ Too little information about local feed resources as a forage alternative to offset the current constraint of low quality forages.	• Systematic evaluation of feedstuffs ♦ Grasses ♦ Legumes (tree)	Juarez et al. (2002) Rueda et al. (2003) Shelton (2004)
• Soil testing and soil fertilization are not currently utilized.	• Soil and forage analyses to monitor the nutrient stocks in the system. • Intensification: higher stoking rate from careful fertilization may improve dual-purpose system productivity.	Rueda et al. (2003)

brief summary of the nutritional constraints for a typical herd in this region based on information in these reports.

4.1. Assumptions of feedstuffs, diets and management groups of cows.

4.1.1. Chemical composition of feeds and diets

Typically, the season of early rains (June 1 to July 31) denotes the time period when vegetatively young forage becomes available with the initiation of rains after a prolonged dry season. The season of late rains (August 1 to September 30) supplies large quantities of more mature forage. The season of scarce rain (October 1 to December 31) marks the beginning of the dry season and further decline in forage quality. The season of little rain (January 1 to May 31) corresponds to poorest availability and quality of grazed forage. Therefore, the seasons of scarce and little rain represent an extended period of low nutrient intake from grazed forage.

However, acknowledging this typical seasonality in the quality and availability of grazed forages, these 18 Genesis farmers, different from most non-GGAVATT farmers in the region, have made investments to provide to their cow herds with grazed forage of a more uniform quality throughout the year from rotational grazing of improved species. The chemical composition of these forages across seasons was estimated based on information from Juarez et al. (2002) and appears in Table 3.

Despite these investments in grazing quality, insufficient pasture supplies during the dry months of the year require Genesis farmers to rely on diets with mostly harvested forages, roughages and other supplements. The sparse grazing opportunity during these seasons contributes relatively little energy to the diet, especially because *ad libitum* dry matter consumption is precluded. Hence, assumptions of *ad libitum* feed intake during the seasons of forage scarcity undoubtedly signify overestimation of feed energy intake.

Table 3
Assumed chemical composition[a] and predicted contents of metabolizable energy and total digestible nutrients of typical grasses and supplemental feedstuffs utilized by Genesis members.

Variable	*Cynodon plectostachyus* (African Star grass)				*Andropogon gayanus* (Llanero grass)			
	Early rains[b]	Late rains[b]	Scarce rain	Little rain	Early rains[b]	Late rains[b]	Scarce rain	Little rain[c]
% DM[i]	20.68	20.95	25.54	34.56	16.70	13.57	20.34	27.30
CP, % of DM	10.41	6.25	6.08	4.33	13.46	12.19	8.32	6.93
Soluble Protein % of CP	94.42	95.25	93.38	92.53	91.45	91.39	91.17	28.21
NPN % of SP	22.56	28.26	25.98	6.06	27.13	5.56	20.39	75.86
ADIP % of CP	2.65	2.73	2.48	2.73	4.06	4.05	6.65	12.50
NDIP % of CP	5.58	4.75	6.63	7.47	8.55	8.61	8.85	46.23
NFC % of DM	3.73	10.57	22.41	6.97	6.11	8.35	9.67	13.42
ADF % of DM	33.08	37.75	36.81	39.75	39.80	28.8	43.95	40.78
NDF % of DM	73.41	68.60	58.62	76.75	67.12	66.14	68.86	70.44
Lignin % of NDF	9.53	11.00	14.70	14.05	6.01	4.89	7.22	7.89
Ash % of DM	9.59	9.83	9.50	8.75	9.45	9.40	9.88	6.08
Ether extract, % of DM	2.86	4.75	3.39	3.20	3.86	3.92	3.27	3.13
ME, Mcal/kg of DM[j]	1.51	1.66	1.69	1.24	2.23	2.32	2.07	2.03
TDN[k]	41.8	45.9	46.7	34.3	61.68	64.17	57.26	56.15

Table 3 (continued)

Variable	Other forage				Dietary supplements		
	Mulato hay[d]	Pangola hay[e]	Maize silage[f]	Cane bagasse[g]	Poultry bedding[g]	Molasses[g]	Commercial concentrate[h]
% DM[i]	89.88	90.03	23.50	15.60	82.00	85.80	92.92
CP, % of DM	4.10	4.04	8.32	2.60	20.40	4.20	17.03
Soluble Protein % of CP	25.08	20.64	43.08	20	46.00	100	26.06
NPN % of SP	61.23	100.00	83.25	95	2.17	100	83.10
ADIP % of CP	37.20	35.45	25.26	65	9.20	0	4.33
NDIP % of CP	70.49	64.55	33.77	75	12.00	0	9.00
NFC % of DM	10.69	14.65	13.25	20.05	23.15	82.00	56.60
ADF % of DM	48.96	43.04	33.20	0	0	0	4.91
NDF % of DM	73.06	69.48	68.57	75.60	39.10	…	9.74
Lignin % of NDF	5.90	7.20	8.10	11.30	9.40	…	3.47
Ash % of DM	8.94	10.23	6.40	1.90	18.50	11.60	9.77
Ether extract, % of DM	3.21	1.60	3.46	1.80	1.30	2.20	6.80
ME, Mcal/kg of DM[j]	1.61	1.51	1.80	1.25	2.01	3.01	2.72
TDN[k]	44.53	41.77	49.79	34.57	…	…	…

[a]From Juarez et al. (2002).
[b]During the seasons of early and late rains GGAVATT herds mostly rotationally graze paddocks of star and Llanero grasses. Mean composition of these grasses would represent the average composition of forages consumed during these seasons. In late rains *Andropogon gayanus* was used as the improved high quality forage.
[c]Chemical composition of Llanero grass at the beginning of little rain at the farm of Jacobo Muñiz.
[d]Chemical composition of a sample of Mulato (*Brachiaria ruziziensis* x *Brachiaria brizantha* cv., Mulato) hay obtained at the farm of Jacobo Muñiz. The age of plant re-growth was 90 days when it was made into hay.
[e]Chemical composition of Pangola hay (*Digitaria decumbens*) obtained from the forage market at El Tejar. The assumed plant age at the time of haymaking was 90 days.
[f]Chemical composition of a sample of maize silage from a farm (Las Maravillas) near to the INIFAP-La Posta station. The chemical analysis was conducted at INIFAP.
[g] CNCPS version 6.1 tropical feed library
[h]The commercial concentrate consist of corn grain ground meal, soybean meal, molasses, urea and minerals and vitamins.
[i]Percentage of dry matter
[j]Metabolizable energy, Mcal per kg of DM
[k]Total digestible nutrients estimated from CNCPS-predicted ME as follows: 1 kg TDN = 4.409 Mcal DE, and DE = ME/.82. % TDN = ((ME/.82)/4.409) x 100.

Harvested forages and other feeds were Mulato hay (*Brachiaria ruziziensis* x *Brachiaria brizantha* cv., Mulato), maize silage, sugar cane bagasse, poultry bedding (comprising rice hulls, manure [feces and urine], feed waste and feathers), and sugar cane molasses. Chemical composition information from the CNCPS tropical feed library was used when local composition information was unavailable (e.g., poultry bedding, molasses and sugar cane bagasse; Table 3). Mulato hay is typically made from mature plants with about 90-d of re-growth. Maize is frequently ensiled after the ears have been removed. The chemical composition of commercial concentrate was obtained from a sample of a local brand that is frequently used by Genesis members (see Table 3).

As described above, the most common grasses utilized by the Genesis farmers are *Cynodon plectostachyus* (African star grass) and *Andropogon gayanus* (Llanero grass). African star grass is grazed mainly during the rainy season while Llanero grass is especially grazed during the dry season. African star grass grows slowly during periods of low rainfall, when it is little grazed. Therefore, two grazed grasses were created for the simulations with the CNCPS; (1) early and late rains, and (2) scarce and little rain. The assumed average chemical composition of grazed grass during the rainy season was the mean composition of African star and Llanero grasses shown in table 4. Dry season grazing on Genesis farms was assumed to consist exclusively of Llanero grass shown in Tables 3 and 4. Information about the composition of Llanero grass at the beginning of the season of little rain was obtained by Dr. Juarez from one Genesis farm. The average value of two legumes (*Gliricidia sepium* and *Leucaena leucocephala;* Table 5) was used for evaluating the benefits of adding legumes to the diets. The chemical composition data used to describe these legumes was obtained from Juarez et al. (2002).

Table 4
Average chemical composition[a] and predicted contents of metabolizable energy and total digestible nutrients of grazed grass used in simulations for early and late rains and for Llanero grass in the seasons of scarce and little rain.

Variable	Early and late rains grazed forage		Scarce and little rain grazed forage	
	Early rains[b]	Late rains[b]	Scarce rain	Little rain[c]
% DM[d]	18.69	17.26	20.34	27.30
CP, % of DM	11.94	9.22	8.32	6.93
Soluble protein, % of CP	92.94	93.32	91.17	28.21
NPN % of SP	24.85	16.91	20.39	75.86
ADIP % of CP	3.36	3.39	6.65	12.50
NDIP % of CP	7.07	6.68	8.85	46.23
NFC % of DM	4.92	9.46	9.67	13.42
ADF % of DM	36.44	33.28	43.95	40.78
NDF % of DM	70.27	67.37	68.86	70.44
Lignin % of NDF	7.77	7.95	7.22	7.89
Ash % of DM	9.52	9.62	9.88	6.08
Ether extract, % of DM	3.36	4.34	3.27	3.13
ME, Mcal/kg of DM[e]	1.87	1.99	2.07	2.03
TDN[f]	51.74	55.04	57.26	56.15

[a]From Juarez et al. (2002).
[b]During the seasons of early and late rains GGAVATT herds are assumed to rotationally graze paddocks of star and Llanero grasses. Therefore the values shown are the mean composition of these grasses which was used in CNCPS simulations to represent the average composition of forages consumed during early and late rain seasons. In evaluating alternatives for scarce rain, *Andropogon gayanus* grown in late rains was used as the improved high quality forage.
[c]Chemical composition of Llanero grass (*Andropogon gayanus*) at the beginning of little rain at the farm of Jacobo Muñiz.
[d]Percentage of dry matter
[e]Metabolizable energy, Mcal per kg of DM
[f]Total digestible nutrients estimated from CNCPS-predicted ME as follows: 1 kg TDN = 4.409 Mcal DE, and DE = ME/.82. % TDN = ((ME/.82)/4.409) x 100.

Table 5
Chemical composition[a] and predicted contents of metabolizable protein, metabolizable energy, and TDN content of *Gliricidia sepium* and *Leucaena leucocephala,* and their corresponding mean values for CNCPS simulations, as potential feeding alternatives for Genesis members[b]

Variable	*Leucaena leucocephala*	*Gliricidia sepium*	Mean
Dry matter yield, kg/ha	2700	1500	2100
% DM[c]	25.0	23.6	24.3
CP, % of DM	22.1	20.9	21.5
Soluble protein, % of CP	21.2	22.1	21.7
NPN % of SP	80.1	54.4	67.3
ADIP % of CP	13.1	12.4	12.8
NDIP % of CP	52.1	61.0	56.6
NFC % of DM	29.4	24.0	26.7
ADF % of DM	13.5	22.5	18.0
NDF % of DM	39.6	38.7	39.2
Lignin % of NDF	7.7	16.0	11.9
Ash % of DM	6.7	10.0	8.4
Ether extract, % of DM	2.2	6.4	4.3
ME, Mcal/kg of DM[d]	2.57	2.55	2.56
MP total supply, g/d[e]	1254	962	1108
TDN[f]	71.1	70.5	70.8

[a]From Juarez et al. (2002).
[b]The age of cut was at 60 days of plant re-growth.
[c]Percentage of dry matter
[d]Metabolizable energy, Mcal per kg of DMI
[e]MP total supply/d (rumen undegradable protein plus protein from bacteria) for multiparous cows with 550 kg of mature weight with *ad libitum* intake of forage
[f]Total digestible nutrients estimated from CNCPS-predicted ME as follows: 1 kg TDN = 4.409 Mcal DE, and DE = ME/.82. % TDN = (ME/.82)/4.409) x 100.

4.1.2. Assumptions about animals and management groups

Energy requirements and feed intakes of animals vary according to body weight, physical activity, physiological status (stage of lactation or pregnancy), and growth stage of development (age or parity) and level of milk production and growth (Fox et al., 2004). Consequently, herd management groups were specified according to physiological status and parity of cows (Table 6). Alternative scenarios were established to describe calving groups of cows at the onset of each of four forage seasons of the year.

The information and assumptions used to specify herd scenarios and animal management groups in this study resulted from field observations and the collective opinion of a panel of experts. Panel members were Dr. Patricia Cervantes-Acosta, Dr. Francisco Juárez-Lagunes, Dr. Eduardo Canudas-Lara, and Dr. Rubén Loeza-Limón (professors at the Universidad Veracruzana (UV)); Dr. Heriberto Román-Ponce, Dr. Bertha Rueda-Maldonado, Dr. Angel Ríos Utrera, M.S. Sergio Román-Ponce and DVM Juvencio Lagunes-Lagunes (researchers at the INIFAP); and Professors Danny Fox and Robert Blake (Cornell University).

Inputs for the CNCPS simulations (Table 7) were based on available information and consensus among the panel members. Using the information about average lactation performance in Genesis herds (Rodriguez-Morales et al., 2005) and INIFAP milk production records, typical average 270-d lactation milk yield guidelines were established by parity and stage of lactation.

Based on Genesis reports, the herd average milk yield per cow (all ages) is about 2000 kg. Partitioning this average into the expected age differences in mean yield by parity resulted in expected average lactation milk yields of about 1850 kg for primiparous cows, 2000 kg for second-parity cows, and 2200 kg for multiparous cows.

These subclass expectations are consistent with the average milk production reported for Genesis herds.

Table 6
Definitions of cow management groups by forage season of calving, parity and physiological stage during the calving interval.

Item	Value
Season of calving	
Early rains	June 1 to July 31
Late rains	August 1 to September 30
Scarce rain	October 1 to December 31
Little rain	January 1 to May 31
Parity of cow	
Primiparous	1
Second-parity	2
Multiparous	>2
Physiological stages during the calving interval (length of period, days)	
Early lactation	90
Mid lactation	90
Late lactation	90
Early dry	128[a]
	67[b]
Late dry	90[c]

[a]Average calving interval for primiparous cows calving in all forage seasons (16 mo).
[b]Average calving interval for second parity and mature cows calving in all forage seasons (14 mo).
[c]90-day period preceding parturition (late gestation).

Additionally, these lactation yields were paired with INIFAP milk production records at the La Posta research station to verify the expected average daily milk production associated with each stage of lactation for parity of cow from the same breed group. Similarly, predicted body weights were obtained from INIFAP body weight records to specify probable body weights and likely body weight losses or gains in alternative stages of lactation. Average daily milk production of pluriparous (parity >1) cows was ≥9.0 kg (peak lactation), which is consistent with INIFAP average daily milk production records and with the reported average milk sales per cow of 1400 kg per lactation for mature cows weighing 550 kg and nursing a calf (with calf milk consumption to weaning assumed to be about 600 kg). Average daily milk yields by parity (1, 2, >2) and stage of lactation [early (0 to 90 d postpartum), mid (next 90 d) and late lactation (90 d)] are specified in Table 7.

Table 7
Descriptions of average cows in three parity groups in Genesis herds[a].

	Parity		
Variable	1	2	>2
Body weight at calving, kg	440	506	550
Average daily gain[b], kg	0.13	0.10	
Calf birth weight, kg	39	41	42
Calving interval, d	488	427	427
Average daily milk yield[c], kg			
Early lactation	8.5	9.0	10.0
Mid lactation	7.0	8.0	8.5
Late lactation	5.0	5.5	6.0

[a]Herd members of a farmer organization named Genesis are part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattleman's Validation and Technology Transfer Group). The primary breed group is ¾ Brown Swiss x ¼ Brahman.
[b]Average growth rate needed to reach target weights at subsequent calving.
[c]Average daily milk yields correspond to the mid-points of each physiological stage of lactation (45 d, 135 d, 225 d post-partum). These yields correspond to 270-d lactation of 1850 kg, 2000 kg and 2200 kg in these parity groups, which is consistent with milk yields reported by GGAVATT Genesis.
[d]Mature weight is 550 kg with a body condition score (dairy-scale) of 3.0 units.
[e]Expected average milk composition: fat = 3.4%, true protein = 3.1%, lactose = 4.7% (Cervantes et al., 2005).

4.2. Equations to estimate energy and protein requirements for immature and mature cow target weights.

The equations in the CNCPS to predict energy and protein requirements for the BW of immature and mature cows were based on the shrunk body weight (SBW) of a typical mature Genesis cow. The SBW was defined as 96% of the full body weight, (FBW), or the average BW expected after an overnight fast without water or feed (Fox et al. 1999; 2004). The SBW is the BW upon which most nutrient requirements are based. An average mature cow in the representative Genesis herd typically weighs about 550 kg (FBW), which is equal to a SBW of 528 kg for a body condition score (BCS) of 3 on a scale of 1.0 to 5.0 units. The target BW for first and second calving was computed as the decimal fraction proportions of mature SBW expected at those ages (parities) with a BCS = 3.0. Thus, the target body weight at first calving was mature SBW times 0.80, which equals 422 kg with a BCS of 3.0. The target SBW at second calving was obtained by multiplying the mature SBW by 0.92, which yielded a BW of 486 kg with BCS 3.0. The target SBW at third calving was obtained by multiplying the mature SBW by 0.96, which yielded a BW of 507 kg with BCS 3.0.

The SBW at each calving was then adjusted for alternative stages of the reproductive cycle. Consensus values for BCS at calving for cows of each parity were combined in an Excel spreadsheet with information from Fox et al. (1999; 2004) to compute BCS changes associated with BW changes by parity and stage of the reproductive cycle. These outputs were then used in the CNCPS to compute the amounts of ME supplied from or required for repletion of body tissue reserves.

4.3 Feed intake

Genesis ranchers usually provide dietary supplementation to lactating cows during the dry season (Table 8). During the dry (non-lactating) period, cows freely

Table 8
Typical diets offered to lactating cows throughout the year by Genesis members[a]

Variable	Little rain Jan-Mar	Little rain Apr-May	Early rains Jun-Jul	Late rains Aug-Sep	Scarce rain Oct-Dec
Grazed forage	x[b]	x[b]	x[b]	x[b]	x[b]
Other forage					
Mulato[d] hay					5.0
Corn silage	15.0				
Sugar cane bagasse		6.0			
Supplement					
Poultry bedding	1.0	2.0	1.0	1.0	1.0
Molasses	1.0	2.0	1.0	1.0	2.0
Commercial concentrate	2.0[c]	2.0[c]	2.0[c]	2.0[c]	2.0[c]

[a]In kilograms on an as-fed basis
[b]Daily intake of grazed forage described in table 4 and 5 was estimated by difference from Cornell Carbohydrate and Protein System (CNCPS)-predicted dry matter intake minus amounts of other fed ingredients.
[c]1.5 kg of commercial concentrate if cows are immature.
[d]*Brachiaria* spp., cv., Mulato
Note: Dry cows do not receive supplementation except during April and May (they are supported with 1.5 kg or 2 kg of commercial concentrate (immature or mature cows, respectively).

roam pasturelands without supplementation except for cows that are dried-off in April-May. Continuous grazing affects maintenance requirements because the distance walked to graze the available forage varies by season of the year.

4.3.1 Genesis herds.

The CNCPS-predicted mean voluntary feed intake, which is determined by body weight, milk production, daily activity, forage quality, and stage of gestation (intake is reduced during late pregnancy due to rumen crowding by the near-term fetus), was used as the probable indicator of a cows' total voluntary feed intake. Because Genesis members feed fixed amounts of supplements and non-grazed forages (Table 8), these quantities were subtracted from the predicted total feed intake. The difference was assumed to be the amount of forage that could be grazed. Correspondingly, cows either mobilized body tissue to offset the feed energy deficit in early lactation to achieve the expected average milk yield, or they gained body weight by repleting body tissues and by growing (if immature) when the diet provided energy in excess of requirements for the expected milk production and maintenance.

The average chemical composition of grazed forage in a given physiological stage of a cow's calving interval was the weighted average contributions from the constituent forage seasons (Table 4). In addition, dietary supplementation varies throughout the year (Table 8). For example, a mature cow that calved during the season of early rains will be in mid-lactation during September (last month of the late rains season), October and November (first two months of the scarce rain season). Therefore, the diet of this cow included one-third of the supplements typically allotted in the late rain season and two-thirds of the supplements allocated during scarce rains. In this example, cows consumed 3.3 kg/day (as fed basis) of Mulato hay, 2 kg/day of molasses, 1 kg/day of poultry bedding and 2 kg/d of commercial concentrate. The same approach was used to determine the amount of grazed forage. In the same example, the total amount of grazed forage (the difference between the total predicted feed intake and the amount of supplemental feeds) is predicted to be 21.4 kg, which comprises 8.1 kg/day (one-third) from grass from the season of late rains and 13.3 kg/day from grass from the season of scarce rain.

Gains in body weight by immature cows were assumed to include tissue repletion and new tissue growth. To avoid double accounting, a separate requirement for growth was not included for cows whose BCS at the end of a physiological stage exceeded the initial one. Calculations were made in other cases to estimate the expected BCS and BW changes to be specified in the CNCPS to accurately account for energy supplied from catabolized tissues and dietary energy required to replenish body tissue losses. Once cows recovered their initial body weight at calving, a BCS of 3 was designated with a separate growth requirement to achieve the target body weight at next calving. If the cows' total nutrient requirements exceeded the available feed energy (i.e., cows were in negative feed energy balance), a growth requirement was not included during this period (i.e. growth did not occur). The final BCS and BW for cows at the end of late gestation corresponded to the expected values at their next calving (parity).

4.3.2. Non-GGAVATT herds.

The farmers who are not members of GGAVATT associations provide dietary supplementation only during April and May. Supplementation in these herds typically consists of about 2 kg/d of purchased Pangola hay (*Digitaria decumbens*) and about 0.5 kg/d each of molasses and poultry bedding. The procedures used for determining the diets during each stage of the reproductive cycle were the same as those described for Genesis cows. For example, a cow calving in the season of scarce rain has 60 of the 90 days of their late lactation stage during April-May. Therefore, their diet in the late lactation stage included about two-thirds of the supplement. Thus, the diets of these cows included 1.3 kg/d of Pangola hay, 0.4 kg/d of poultry manure and 0.3 kg/d of molasses. This amount was subtracted from the predicted total feed intake and the difference (total grazed forage intake) was two-thirds of the little rain season pasture (22.2 kg/d) and one-third of the pasture of early rains (16.2 kg/d). Information about non-GGAVATT cattle inputs was utilized to analyze current management conditions. Except for milk production and mature BW, the animal and environmental inputs were assumed to be the same as those for Genesis herds. INIFAP (2004) reported that typical mature cows in non-GGAVATT herds produce about 1600 kg of milk per lactation, weigh about 500 kg, and have calving intervals that average about 16 mo. Like Genesis herds, most cows are crosses between Brown Swiss and Brahman breeds.

4.4. Determination of maintenance requirements.

Version 6.1 of the CNCPS model (Tylutki et al., 2007) was used to predict ME and MP requirements, feed intakes and feed energy balances for all animal groups described previously. The CNCPS model contains a linked set of sub-models that predict nutrient requirements according to physiological function. These functions are body maintenance, growth, pregnancy, lactation and body tissue reserves (Fox et al., 2004). The maintenance requirement, which is the largest among them under the conditions of this study, is determined by accounting for breed, body weight and composition, physiological status, physical activity, urea excretion and heat stress (Fox et al., 2004). The basal maintenance requirement of net energy in a thermal-neutral environment with minimum activity was specified in the CNCPS for 3/4 *Bos* *taurus* x 1/4 *Bos indicus* cows (Fox et al. 1992), where NEm (Mcal/d) = mean $BW^{0.75}$ x the proportional average of that required for the breeds entered.

Cows frequently mobilize up to 25% of body weight (tissue reserves) to support milk production when BCS at calving ≥3.0 (Nicholson at al., 1994; Baba, 2007). In the present study the maximum BW loss allowed was 20% of calving weight for primiparous cows and for others when BCS <3.0 units. For parities ≥2 with BCS ≥3.0 maximum BW loss allowed was 25% of mature weight. Consequently, maintenance requirements for cows at our study site were adjusted according to expected changes in organ mass and body weight from depressed dietary nutrient supplies, especially in the seasons of scarce and little rain.

Organ mass varies with energy intake in all classes of cattle. An animal's body condition score reflects previous energy intake at all physiological stages (NRC, 2000). The CNCPS model accounts for these relationships in any physiological stage by increasing or decreasing the maintenance requirement by 5% for each BCS unit above or below a score of 3 (Fox et al., 2004). The energy cost of excreting excess N (urea) is calculated by subtracting it from ME intake (Fox and Tylutki, 1998).

The CNCPS model accounts for the energy cost of dissipating excess body heat (Fox et al., 2004) with the current effective temperature index (CETI) as described by Fox and Tylutki (1998). The Centro de Previsión del Golfo de Mexico (1996-2005) reported an average monthly maximum temperature of about 35° C with about 80% humidity. According to the CETI, the daytime climatic effect on animals at our study site is in the extreme caution range (33 to 40° C). However, the mean minimum temperature decreases to 24° C in the seasons of early and late rains, and to about 20° C in the seasons of scarce rain and no rain. The night time temperature at our study site is at the threshold (20° C) that allows for dissipation of body heat accumulated during the day. Panting is seldom observed. Therefore, heat stress was ignored in the simulations in this study.

In addition, the CNCPS model adjusts for differences in physical activity. Energy expenditures from physical activity vary with the amount of time standing, the number of body position changes, and the flat and sloped distances walked daily (Fox et al., 2004). Tedeschi et al. (2004) provided guidelines for these inputs for animals managed in confinement and grazing conditions.

Cows graze intensively during the rainy months, when it was assumed that the cows would be standing for 16 h, change body position 6 times, and would walk 1000 meters of flat distance per day. Terrain slope was inconsequential because Medellín de Bravo is mainly flat land. In addition, during the scarce rain season the cows' activities change as well as their maintenance requirements because most dry matter intake comes from conserved forages and agricultural byproducts. Correspondingly, physical activity to acquire feed probably diminishes in this period of the year. For this reason cows were assumed to have movement similar to animals in a feedlot (3 to 5 m^2/animal) with intensive grazing, which was represented by 14 h standing, 6 position changes and 750 m of a flat distance walked per day. For the little rain season, cows were assumed to walk daily a flat distance of 500 meters with 10 hours standing and 3 body position changes.

4.5. Determination of energy balance, growth and changes in body weights and body tissue reserves.

Changes in body weight were determined first. Lacking databases of typical changes in BCS for cows in this region or in tropical production systems, it was unclear how much body tissue cows actually mobilize in Genesis herds. Therefore, assumptions were based on the consensus BCS at calving (Table 9 and Appendix Table 8.6) and expected changes throughout the calving interval.

The BW and BCS at calving for each forage season and parity of cows are shown in Table 9. The initial BCS were recommendations by the panel of experts (Appendix Table 8.6). The BW and subsequent BCS were calculated based on predicted losses and gains in BW (NRC, 2000; Fox et al., 2004) as previously described.

Table 9
Expected body weights (BW) and body condition scores (BCS) at calving of Brown Swiss x Brahman dual-purpose cows in GGAVATT Genesis herds.

Calving season	(Early rains[a])		(Late rains[b])		(Scarce rain[c])		(Little rain[d])	
Parity	BW[e]	BCS[f]	BW	BCS	BW	BCS	BW	BCS
1	426	2.75	440	3.00	426	2.75	410	2.50
2	506	3.00	506	3.00	469	2.75	470	2.50
> 2	550	3.00	550	3.00	550	3.00	532	2.75

[a]Early rains = June 1 to July 31. [b]Late rains = August 1 to September 30. [c]Scarce rain = October 1 to December 31. [d]Little rain = January 1 to May 31.
[e]Mature BW (kg) is 550 kg with a BCS 3.0. A 440 kg primiparous cow and a 506 kg second parity cow have a BCS 3.0. Maximum BW loss is 20% of calving weight for primiparous cows and for others when BCS<3.0. For parities ≥2 with BCS ≥3.0 maximum BW loss is 25% of mature weight.
[f]The BCS at calving were the consensus judgments of a panel of Mexican professionals. Using these reference scores other BCS were predicted based on expected BW losses and net energy obtained from tissue reserves, and expected BW gains resulting from positive energy balances allowed the recovery of body energy reserves based on NRC (2000) and Fox et al. (2004).

Expected changes in BCS were determined based on its relationships with energy content of BW gain and loss as described by Fox et al. (1999, 2004). The BCS at calving was the consensus of the panel of professionals (Appendix 8.6). Calculations to determine cow energy balance, feed energy balance, energy supplied from BW losses at varying BCS, and total energy associated with unit changes in BCS at varying body weights are given in the following equations and summarized in Table 10 (NRC, 2000; Fox et al., 2004).

Cow energy balance = [MEI (metabolizable energy intake) + ME reserves catabolized - (maintenance + lactation + pregnancy + growth + ME tissue repletion requirements)]

Feed energy balance = (MEI - total ME requirement without contribution from tissue reserves)

NEdlw (Mcal of net energy per kg of daily live weight change) = 0.5381 x BCS + 3.2855

DLW gain, kg/d = ME balance x 0.60/NEdlw (the live weight gain from a positive ME balance)

ME/kg DLW loss = NEdlw/0.60 (the Mcal ME provided by the mobilization of body tissue)

Because ME mobilized from reserves during lactation computed from table 10 were greater than those predicted by the CNCPS version 6.1, the following adjustment was made to CNCPS predicted ME allowable milk: CNCPS version 6.1 ME allowable Milk + (((spreadsheet Mcal reserves mobilized/days in period x .82/.644) – feed energy balance)/1.06), where 1.06 is the average ME required/kg milk based on the milk composition.

The values in Table 10 are expected to be similar to the requirements for new tissue growth in immature cows (Fox et al., 1999; NRC, 2000). New growth was assumed to occur only if energy supply exceeded maintenance plus the requirement for tissue repletion. Thus, in this study, new tissue growth occurs at BW greater than the initial weight at calving.

Table 10
Energy reserves for determining the body condition scores at the beginning and end of each physiological stage of a cow's calving interval.

Calculations for BCS					
	BCS				
Item	1.5	2.0	2.5	3.0	3.5
NEdlw[a]	4.36	4.90	5.44	5.98	6.51
ME required per kg body weight gain or available from 1 kg body weight loss	7.27	8.17	9.06	9.96	10.86
Mcal NE[b]/BCS change					
400 kg	112	126	144	165	193
450 kg	126	141	162	186	217
500 kg	140	157	180	207	242

[a]Net energy for daily live weight change
[b]Net energy = ME x 0.6 (Fox et al., 2004)

As Baba (2007) described, the ME supplied from body weight losses, or required for repletion, were interpolated from the values in Table 10 (Fox et al., 1999, 2004; Tables 3 to 6 in NRC [2000]). Average daily ME allowable milk production for cows initiating lactation in alternative forage seasons of the year was predicted for each parity class of cow. Predicted daily milk yield corresponded to zero cow energy balance (i.e., allowing for tissue energy to support milk synthesis in early lactation).

4.6. Alternative diets to improve herd productivity.

The results from the simulation analysis of typically managed Genesis and non-GGAVATT herds were used to facilitate the identification of nutritional bottlenecks on cow productivity. Based on these findings cow and herd productivity potentials were explored by considering feasible dietary alternatives. Especially relevant for Genesis farmers and others in this region is additional investment in the conservation of harvested forages of good quality. Genesis farmers already have invested in haymaking and ensiling, incorporating these practices into their management protocols. In addition to improved grasses, dietary contributions from legumes were considered because it may improve milk production with more rumen degradable nitrogen and less NDF, which may enhance feed passage rate and DMI. Juarez et al. (2002) provided information on a promising set of forage legumes for use in coastal Veracruz, including legume trees, two of which were considered in this study (Table 5).

4.7. Economic evaluation of alternative diets.

Rueda et al. (2003), following the methods of Boehlje and Eidman (1984) and Mutsaers et al. (1986), applied partial budgeting methods in a sensitivity analysis to screen options for improving cattle system productivity in tropical cattle systems. Although this method is appropriate for a specified range of options and ignores the transition period for technology adoption, partial budgeting analysis helps to identify economically viable alternatives and eliminate those with low potential impact (unprofitable). Farmer adoption of new technology options about which farmers are familiar frequently occurs when net margin increases by at least 50% (CIMMYT, 1988). Net margin (NM) is the difference between total revenue and total variable cost.

The physical information for the partial budgeting analysis in this study consisted of the additional quantities and chemical composition of required feed inputs to obtain the expected increases in milk production compared to typical (baseline) performance for a specified management group of cows. The economic information consisted of the prices of feed inputs and milk sold. This information was combined to calculate the marginal increase in net returns (ΔNM) from the alternative diets compared to typical dietary management. Table 11 contains current market prices of feeds and milk in the Sotavento region that were used for these evaluations (Dr. Juarez, personal communication). The ΔNM for alternative nutritional management compared to typical management was calculated as follows: ΔNM = Δmilk revenues minus Δfeed cost.

Table 11
Market prices for milk and the dietary inputs considered in this study ($/US[a])

Item	$/kg
Poultry bedding	0.04
Molasses	0.14
Commercial concentrate	0.26
Maize silage[b]	0.05
Mulato hay[b]	0.05
Pangola hay[c]	0.15
Improved harvested forage	0.15
Sugar cane bagasse	0.02
Legume[d]	0.15
Sorghum grain	0.24
Milk	0.32

[a] Exchange rate in 2007. $1 USD= $10.97 Mexican pesos. Feed prices are expressed on dry matter basis.
[b]These inputs are produced by Genesis members (Rodriguez-Morales et al., 2005)
[c]This is the price of hay in commercial stores of Medellín de Bravo (El Tejar)
[d]*Gliricidia sepium* or *Leucaena leucocephala*

Supplements like poultry bedding, molasses, commercial concentrate and sugar cane bagasse are typically obtained from local suppliers. Maize silage and Mulato hay are produced by Genesis farmers. The cost for producing good quality improved harvested forage (e.g., Llanero hay, maize silage including ears) was assumed to be equal to the current price of harvested forages in the market place. Milk price varies throughout the year from \$0.26 to \$0.36/kg. The valuation of milk revenues in this study utilized its approximate average price of \$0.32/kg.

5.0 Results and discussion: Baseline analysis to identify principal constraints of typical cow herd management by Genesis herd owners.

This section reports findings from the simulation analysis for cows calving in alternative seasons of the year under baseline nutrition management protocols. The analyses show the predicted feed intakes, body weights, body condition scores, animal energy requirements and dietary ME and MP supplies, energy allowable milk production and feed energy balances throughout the calving intervals of cows in each parity classification.

Section 5.1 illustrates the potential influence from expected fluctuations in environmental factors and physical activity on the predicted energy maintenance requirements for cows in different seasons of the year. Sections 5.2 to 5.4 show the results of systematic evaluation of typical limitations on cow productivity in Genesis herds for different combinations of parity and season of calving. In addition, section 5.5 summarizes milk production, feed intakes, energy balance and growth (for immature cows) with a discussion of the key constraints affecting cows of all ages.

Strategic priority dietary management options to improve herd performance, based on this analysis, are presented in Chapter 6 with a preliminary assessment of their economic potentials utilizing partial budgeting methods. Section 7 contains the summary and conclusions from this study with recommendations for Genesis herd owners and other cattle producers in the Sotavento region of Veracruz.

5.1. Sensitivity of the total energy requirement for maintenance to variations in cow physical activity and environmental factors

Variations in environmental conditions to which animals are exposed often result in changes in behavior and physical activity of animals. Average daily temperature and its diurnal variation, humidity, wind speed, solar radiation and rainfall lead to seasonal variations in thermal stress and forage availability and, consequently, in the amount of maintenance energy expended in physical activity (e.g., grazing) and for thermal regulation (Fox and Tylutki, 1998).

Consequently, an initial sensitivity analysis was conducted to determine changes in the total energy maintenance requirement for the range in environmental conditions expected for herds in this study region. Two contrasting forage seasons of the year were considered: early rains and scarce rain (Appendix Table 8.8). The factors considered and range in their differences between seasons (early rains and scarce rain, respectively) were as follows: temperature (28° C *vs*. 22° C), wind speed (29.7 kph *vs*. 35.5 kph), minimum night temperature (24° C *vs*. 17° C), daily time standing (16 h *vs*. 14 h), daily number of body position changes (6 *vs*. 3) and flat distance walked (1 km *vs*. 0.5 km).

The maximum potential cumulative difference in maintenance requirement associated with the sum of maximum differences for all factors resulted in about 1 Mcal/d additional ME required for body maintenance (Appendix Table 8.9). Most combinations of effects associated with seasonal differences resulted in relatively small influences on the total maintenance requirement. However, in some cases the total maintenance requirement did not correspond perfectly to the cow's body weight. For example, primiparous cows calving in the season of early rains (Table 12) had a smaller predicted maintenance energy requirement in late lactation, which coincided with the season of little rain, despite being heavier than they were in early lactation. This outcome reflected the diminished physical activity expected in that season.

Therefore, variations in predicted average maintenance requirements across seasons are not expected to be perfectly correlated with variations in average body weight across management groups of cows.

Another potential factor affecting the energy maintenance requirement is excess dietary supply of protein, i.e., more than a cow's requirement. Ammonia, which is toxic to the body, is removed as urea primarily by the liver, with the kidneys also playing a minor role in detoxification. Diets that exceed the ammonia threshold incur an energy cost for N excretion as urea, which increases the maintenance requirement. For example, when in their early dry period during the season of little rain, primiparous cows that had calved in the season of early rains consumed about 17% more MP than they required. As a result, this management group of cows incurred additional daily energy expenditure for maintenance of 0.13 Mcal ME to excrete urea.

5.2. Analysis of current management and productivity outcomes for primiparous cows

This section contains results of baseline simulation analysis with constraints identified for cows in first lactation that would calve in each of four alternative forage seasons of the year. Tables report the expected body weights, body growth (if feasible), predicted average daily milk production, energy supplies from diet and body tissue, and feed energy status of cows throughout the first calving interval (and the coinciding annual seasons).

5.2.1. Season of early rains

Primiparous cows calving in the season of early rains (Table 12) typically initiate lactation in thinner body condition (and with lower maintenance requirements) than is desirable. This results from low feed energy intake (from grazing) during the previous season of feed scarcity, when the heifers are typically modestly supplemented daily with about 1.5 kg of commercial concentrate. The average expected body weight at calving was 426 kg with a BCS of 2.75.

The total dietary intake from grazed forage and supplements (molasses, poultry bedding and commercial concentrate) was predicted to be about 18.7 Mcal ME/d. Tissue catabolism was expected to supply another 2.3 Mcal ME/d to support the predicted average daily milk production of 8.4 kg during the 90-d period of early lactation. Therefore, similar to expected outcomes in dairy herds (Reyes et al., 1981), about 11% of total energy for milk synthesis in early lactation was predicted to come from the mobilization of about 41 kg of body tissue reserves. As a result, cows in first lactation were predicted to conclude their early stage of lactation in yet thinner body condition with a BCS ~2.0 and weighing about 385 kg.

In addition to typical dietary supplementation (also with poultry bedding, molasses and commercial concentrate) Genesis cows in mid-lactation are typically fed Mulato hay (3.3 kg/d). This resulted in about 13% greater supply of dietary ME compared to early lactation (21.2 *vs.* 18.7 Mcal ME/d) (Table 12). Corresponding average daily energy allowable milk production during the 90-d period of mid-lactation was predicted to be about 6.8 kg with about 2.1 Mcal ME/day of dietary energy also available for the repletion of previously mobilized body tissues, which also support persistent lactation.

Cows calving during the season of early rains are in late lactation principally during the season of little rain. In this season poor quality grazing is supplemented with poultry bedding, molasses, commercial concentrate, Mulato hay and maize silage. The metabolizable energy supplied by this diet was predicted to be sufficient to support an average daily milk production of 5.0 kg and modest body growth of about 20 kg (or 0.2 kg/d) during this stage of lactation. The predicted average milk

Table 12

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of early rains (June 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Early rains	Late rains	Scarce rain	Little rain	Early rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	5.6	2.7	1.7	8.3	7.5
Other forage[c]	…	2.9	4.6	…	…
Supplement[d]	3.1	3.9	3.1	1.4	1.4
Total DMI, kg/d	8.7	9.5	9.4	9.7	8.9
Total dietary energy, Mcal ME/d	18.7	21.2	20.0	20.5	18.2
Total ME supply, Mcal/d[e]	21.0	21.2	20.0	20.5	20.7
Initial body weight (BW), kg[f]	426	385	420	440	495
Mean BW, kg	406	403	430	468	474
End BW, kg	385	420	440	495	453
Initial body condition score (BCS)[g]	2.75	2.00	2.75	2.75	2.75
End BCS[h]	2.00	2.75	2.75	2.75	2.25
ME allowable growth, kg/d[i]	…	…	0.21	0.42	…
Total energy requirement, Mcal ME/d[j]	21.0	19.1	20.0	20.5	20.7
Maintenance requirement, Mcal ME/d[k]	13.1	11.9	12.2	13.7	15.7
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[l]	8.4	6.8	4.8	…	…
Feed energy balance, Mcal ME/d[m]	-2.3	2.1	0.0	0.0	-2.5

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.

[c]*Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 12 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[i]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 1800 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

production throughout lactation—early, middle and late stages of lactation—corresponded to a total expected 270-day yield of 1800 kg. This milking performance was consistent with typical milk yields observed in primiparous cows at INIFAP's La Posta Experiment Station herd.

Dietary energy during the cow's early dry (non-lactating) period came from forage and about 1.5 kg/d commercial concentrate during the driest months of the year (April and May). Dry cows consuming this diet were expected to grow about 0.42 kg/d during this 128-day period, increasing BW by about 55 kg. However, a 17% excess intake of MP above requirements resulted in an increased energy cost for maintenance of 0.13 Mcal ME/d to excrete the excess N as urea.

Late gestation for these primiparous cows coincides with the subsequent season of early rains when the supply of grazed forage is restored. Nonetheless, cows were predicted to be unable to obtain the target body weight for their second calving of about 500 kg with a BCS of 3.0 units despite daily supplementation with 1.5 kg of commercial concentrate. Predicted intake energy was insufficient to meet the requirements for rapid fetal growth, which forced cows to mobilize 2.5 Mcal ME/d from tissue reserves. This period of negative feed energy balance resulted in cows that were expected to be thinner at their second calving (BW = 453 kg with BCS ~2.25) than they were at first calving. Other things being equal, milk production and postpartum interval to early re-initiation of ovarian cyclicity in second lactation would be jeopardized by reduced body tissue reserves.

5.2.2. Season of late rains

Primiparous cows calving in the season of late rains (Table 13) typically initiate lactation in better body condition (BCS = 3.0) than those calving in the early

Table 13

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of late rains (August 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Late rains	Scarce rain	Little rain	Early rains	Late rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	4.5	2.2	2.7	8.3	9.6
Other forage[c]	1.5	4.5	4.7	…	…
Supplement[d]	3.4	3.7	3.1	1.4	…
Total DMI, kg/d	9.4	10.4	10.5	9.7	9.6
Total dietary energy, Mcal ME/d	20.0	21.9	22.1	19.1	17.4
Total ME supply, Mcal/d[e]	22.6	21.9	22.1	19.1	21.4
Initial body weight (BW), kg[f]	440	398	440	460	483
Mean BW, kg	419	419	450	472	443
End BW, kg	398	440	460	483	402
Initial body condition score (BCS)[g]	3.00	2.25	3.00	3.00	3.00
End BCS[h]	2.25	3.00	3.00	3.00	1.50
ME allowable growth, kg/d[i]	…	…	0.22	0.17	…
Total energy requirement, Mcal ME/d[j]	22.6	19.2	22.1	19.1	21.4
Maintenance requirement, Mcal ME/d[k]	13.6	11.4	13.7	15.7	16.4
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[l]	9.1	7.4	5.2	…	…
Feed energy balance, Mcal ME/d[m]	-2.6	2.7	0.0	0.0	-4.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.

[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 13 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[i]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 1953 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

rains because they benefited from the high quantity of forage available in the preceding season. The average expected body weight of these cows at calving was 440 kg.

The predicted daily dietary energy intake of forage plus supplementation (molasses, poultry bedding, commercial concentrate and Mulato hay) in the season of late rains was about 20.0 Mcal ME. The expected mobilization of body tissue reserves was predicted to also supply 2.6 Mcal ME/d during early lactation for synthesis of about 9.1 kg of milk. About 12% of the energy required for milk synthesis came from 42 kg of body tissue reserves. Correspondingly, these cows were predicted to conclude the period of early lactation in thinner body condition (BCS ~2.25) than at calving and weighing about 398 kg.

Genesis cows in mid-lactation typically receive maize silage (6.6 kg/d as fed) in addition to the other supplementation ingredients. This resulted in about 10% greater supply of dietary ME compared to the period of early lactation (21.9 *vs.* 20.0 Mcal ME/d), principally in the season of scarce rain. As a result average daily energy allowable milk production was predicted to be about 7.4 kg with about 2.7 Mcal ME/d also available for the repletion of previously mobilized body tissues.

This management group of cows is expected to be in their late stage of lactation during the forage season of little rain. The supply of grazed forage is poor at this time and, consequently diets are supplemented with poultry bedding, molasses, commercial concentrate, and maize silage. Cows fed this diet were expected to produce about 5.2 kg/d of milk during this stage of lactation. The expected dietary supply of energy was sufficient to support modest growth of about 0.2 kg/d during this stage of lactation, increasing body weight by about 20 kg. Similar to that of primiparous cows in INIFAP's La Posta Experiment Station herd, the average milk production in the three stages of lactation for cows calving in this forage season corresponded to a 270-day predicted total yield of 1953 kg.

Dietary energy supply during the cow's early dry (non-lactating) period typically comes from grazed forage supplemented with commercial concentrate. Fed this diet cows could increase body mass by about 23 kg during this period from modest predicted daily growth of 0.17 kg, reaching an expected body weight of 483 kg by the end of this stage of the calving interval. This diet provided an excess of protein (about 15%) with a rumen ammonia balance that exceeded requirements by 76%.

Late gestation for this management group coincides with supplies of grazed forage of modest quality in the season of late rains. In these circumstances, farmers typically do not provide supplementation. Thus, the resultant dietary energy supply is insufficient to maintain body weight and to satisfy the increased requirements for fetal growth. Consequently, cows needed to catabolize much more tissue to supply energy to the fetus, about 4.0 Mcal ME/d, than they did to support milk production in early lactation. As a result, cows were predicted to be unacceptably thin with a BCS of ~1.50 units and to weigh about 402 kg at second lactation. Primiparous cows calving in the season of late rains may actually incur longer calving intervals than the assumed average of 16 mo. Cows that are thin and undersized would be expected to have poorer milk performance in the next lactation from less feed intake capacity and a smaller pool of tissue reserves for milk synthesis.

5.2.3. Season of scarce rain

Primiparous cows calving in the season of scarce rain (Table 14) were assumed to initiate lactation with a BCS of 2.75 from modest feed energy intake (unsupplemented grazing) during the seasons of early and late rains. Average expected body weight at calving was 426 kg.

Table 14
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	0.0	2.7	4.3	8.7	8.1
Other forage[c]	4.4	4.7	0.6	…	…
Supplement[d]	3.9	3.1	4.8	…	…
Total DMI, kg/d	8.3	10.5	9.7	8.7	8.1
Total dietary energy, Mcal ME/d	18.5	22.2	21.2	15.7	16.2
Total ME supply, Mcal/d[e]	20.7	22.2	21.2	16.9	17.4
Initial body weight (BW), kg[f]	426	385	430	446	415
Mean BW, kg	406	408	438	431	407
End BW, kg	385	430	446	415	398
Initial body condition score (BCS)[g]	2.75	2.00	2.75	2.75	2.50
End BCS[h]	2.00	2.75	2.75	2.50	1.50
ME allowable growth, kg/d[i]	…	…	0.17	…	…
Total energy requirement, Mcal ME/d[j]	20.8	19.4	21.2	16.9	17.4
Maintenance requirement, Mcal ME/d[k]	11.9	11.5	13.7	16.0	12.4
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[l]	9.3	7.5	5.3	…	…
Feed energy balance, Mcal ME/d[m]	-2.3	2.8	0.0	-1.2	-1.2

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 14 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[i]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 1989 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

In the season of scarce rain the total dietary intake from grazed forage and supplements (molasses, poultry bedding, commercial concentrate and Mulato hay) was predicted to supply about 18.5 Mcal ME/d. Tissue catabolism was expected to supply another 2.3 Mcal ME/d to support the predicted average daily milk production of 9.3 kg during the 90-day period of early lactation. Therefore, about 11% of total energy for milk synthesis in early lactation was predicted to come from the mobilization of about 41 kg of body tissue reserves. As a result, cows were predicted to conclude early lactation in thinner body condition (BCS ~2.00) weighing about 385 kg.

In addition to typical dietary supplementation (also with poultry bedding, molasses and commercial concentrate) Genesis cows in mid-lactation are typically fed maize silage (20 kg/d). This resulted in about 20% greater supply of dietary ME compared to early lactation (22.2 *vs.* 18.5 Mcal ME/d). Corresponding average daily energy allowable milk production during the 90-d mid-lactation period was predicted to be about 7.5 kg with about 2.8 Mcal ME of dietary energy also available for repletion of previously mobilized body tissues.

Cows in this management group are in late lactation principally during the season of early rains. At this time grazed forage is supplemented with poultry bedding, molasses, commercial concentrate and sugar cane bagasse. The dietary supply of metabolizable energy was predicted to be sufficient to support an average daily milk yield of 5.3 kg. In addition, modest daily growth of about 0.17 kg was expected during this stage of lactation, increasing body weight by 16 kg. The predicted average milk production throughout a 270-day lactation was 1989 kg.

Dietary energy during the cows' 128-d early dry period came from forages grown in the seasons of early and late rains. This diet was insufficient to meet the total energy requirements. Consequently, 31 kg of body weight loss was predicted from an average daily feed energy deficit of 1.2 Mcal ME, which resulted in a predicted ending body weight of 415 kg. Also associated with this diet were 372% more peptides and 119% more rumen ammonia than required, which resulted in a daily urea excretion expenditure of 0.29 Mcal ME.

Late gestation for cows in this management group coincides with the subsequent season of scarce rain when the supply of grazed forage is limited. Consequently, cows were predicted to be unable to obtain the target body weight of 500 kg with a BCS of 3.0 units for their second calving. Predicted intake was insufficient to support the expected rapid fetal growth of late gestation, which forced cows in this stage of the calving interval to mobilize about 1.2 Mcal ME/d from tissue reserves. This period of negative feed energy balance resulted in cows predicted to be thinner at their second calving (BW = 398 kg with BCS ~1.50) than they were at first calving. Other things being equal, milk production and postpartum interval to the re-initiation of ovarian cyclicity in second lactation would be jeopardized by a smaller pool of body tissue reserves.

5.2.4. Season of little rain

Primiparous cows calving in the season of little rain (Table 15) typically initiate lactation in thinnest body condition (BCS = 2.50) because of their lower feed energy intake (from grazing) during the preceding season. The average expected body weight at calving was 410 kg.

This season provides least forage compared to grazing in other seasons of the year. For this reason, intake energy from grazing is expected to be least in this season of the year. The predicted daily dietary energy intake from forage plus typical supplementation was about 18.4 Mcal ME. The expected mobilization of body tissue reserves during early lactation was predicted to also supply 1.5 Mcal ME/d for the synthesis of about 8.3 kg of milk. About 8% of the energy required for milk synthesis

Table 15
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of little rain (January 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Little rain	Early rains	Late rains	Scarce rain	Little rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	1.8	3.8	6.2	9.4	9.5
Other forage[c]	3.5	0.9	…	…	…
Supplement[d]	3.1	4.8	3.1	…	…
Total DMI, kg/d	8.4	9.5	9.3	9.4	9.5
Total dietary energy, Mcal ME/d	18.4	20.9	19.7	19.4	19.7
Total ME supply, Mcal/d[e]	19.9	20.9	19.7	19.4	19.7
Initial body weight (BW), kg[f]	410	384	416	428	473
Mean BW, kg	397	400	422	451	481
End BW, kg	384	416	428	473	488
Initial body condition score (BCS)[g]	2.50	2.00	2.50	2.50	2.50
End BCS[h]	2.00	2.50	2.50	2.50	2.75
ME allowable growth, kg/d[i]	…	…	0.13	0.34	0.16
Total energy requirement, Mcal ME/d[j]	29.9	18.9	19.7	19.4	19.7
Maintenance requirement, Mcal ME/d[k]	11.5	11.8	13.1	13.8	12.6
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[l]	8.3	6.7	4.7	…	…
Feed energy balance, Mcal ME/d[m]	-1.5	2.0	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 15 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[i]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 1773 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

came from the catabolism of 26 kg of body tissue reserves. Correspondingly, these cows were predicted to conclude the period of early lactation in poorer body condition (BCS = ~2.00) than at calving, weighing about 384 kg.

Genesis cows in mid-lactation typically receive sugar cane bagasse in addition to the other supplements. This resulted in about 14% greater supply of dietary ME compared to early lactation (20.9 *vs*. 18.4 Mcal ME/d) from the relatively higher nutritional quality of the diet (more grazed forage plus more molasses supplementation than previous stage). As a result, average daily energy allowable milk production was predicted to be about 6.7 kg with about 2.0 Mcal ME/day of dietary energy also available for the repletion of previously mobilized body tissues.

This management group of cows is expected to be in late lactation in the season of late rains. Forage supply and quality are good at this time of year when diets are typically supplemented with molasses, poultry bedding and commercial concentrate. Cows fed this diet were expected to produce about 4.7 kg/d milk. The expected dietary supply of energy was sufficient to support slow growth of about 0.1 kg/d during this stage of lactation, slightly increasing body weight by about 12 kg. The average 270-d lactation milk production for this management group was 1773 kg.

Dietary energy during the early dry period typically comes from mature forage of low quality (scarce rain season) without supplementation. However, cows consuming this diet were able to increase body mass about 45 kg during this stage of the calving interval by growing about 0.3 kg/d and reaching an expected average body weight of 473 kg by the end of this stage.

Late gestation for these primiparous cows coincides with the subsequent season of little rain when feeding quality of grazed forage is depressed and diets are unsupplemented. However, predicted intake energy was sufficient to satisfy the requirements for rapid fetal growth and maintenance (17.6 Mcal ME/d) plus some growth, 0.16 kg/d. However, these pregnant cows did not achieve their target BW and BCS for the next calving, which may signify calving intervals longer than 16 mo or diminished milking performance in their next lactation with a BCS of 2.75 units and body weight of 488 kg.

Results from this simulation analysis clearly showed that primiparous cows are vulnerable especially to slow growth rates and poor feed energy status during the dry period and late gestation. Both conditions represent major direct and indirect constraints (e.g., physiological transition) on subsequent lactation and reproductive performance.

5.3. Analysis of current management and productivity outcomes for second-parity cows

This section contains results of baseline simulations and identification of constraints for cows in second lactation calving in each of four alternative forage seasons of the year. As for primiparous cows, the tables show the expected body weights, body growth, predicted average daily milk production, average metabolizable energy supplies from dietary intakes and body tissue reserves, and feed energy status of cows throughout the calving interval (and the coinciding annual seasons).

5.3.1. Season of early rains

Cows calving for the second time in the season of early rains (Table 16) were assumed to initiate lactation in good body condition (BCS = 3.0) and weighing 506 kg. These parturition targets are achieved by supplementing grazed forage with commercial concentrate.

The diet of grazed forage and typical supplementation (molasses, poultry bedding and commercial concentrate) in early lactation was predicted to supply about 20.7 Mcal ME/d. Tissue catabolism was expected to supply another 2.9 Mcal ME/d to

Table 16

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for second parity cows in Genesis[a] herds calving in the season of early rains (June 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Early rains	Late rains	Scarce rain	Little rain	Early rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	6.3	3.2	3.4	8.4	8.2
Other forage[c]	…	3.0	4.6	…	…
Supplement[d]	3.3	4.2	3.3	1.6	1.6
Total DMI, kg/d	9.6	10.4	11.3	9.9	9.8
Total dietary energy, Mcal ME/d	20.7	23.0	24.0	21.2	20.0
Total ME supply, Mcal/d[e]	23.6	23.0	24.0	21.2	22.8
Initial body weight (BW), kg[f]	506	457	483	552	568
Mean BW, kg	482	470	518	560	549
End BW, kg	457	483	552	568	530
Initial body condition score (BCS)[g]	3.00	2.25	2.75	3.50	3.50
End BCS[h]	2.25	2.75	3.50	3.50	2.50
ME allowable growth, kg/d[i]	…	…	0.51	0.22	…
Total energy requirement, Mcal ME/d[j]	23.6	21.3	19.7	21.2	22.8
Maintenance requirement, Mcal ME/d[k]	15.4	13.7	14.1	16.9	17.5
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.30
ME allowable milk production, kg/d[l]	8.9	7.2	5.1	…	…
Feed energy balance, Mcal ME/d[m]	-2.9	1.7	4.3	0.0	-2.8

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.

[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 16 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a second calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (third) calving.
[i]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 1908 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

support the predicted average daily milk production of 8.9 kg during this 90-d period. Therefore, about 12% of total energy in early lactation was predicted to come from the mobilization of about 49 kg of body tissue reserves. As a result, cows in second lactation were predicted to conclude early lactation weighing about 457 kg with a BCS ~2.25.

Genesis cows in mid-lactation consume about 11% more dietary ME than in early lactation (23.0 *vs.* 20.7 Mcal ME/d) due to the nutritional contribution by Mulato hay. As a result, the average daily energy allowable milk production in mid-lactation was predicted to be about 7.2 kg with about 1.7 Mcal ME of dietary energy also available for body tissue repletion.

This management group of second-calf cows is in late lactation principally during the season of little rain, when scarce grazing is supplemented with typical ingredients plus Mulato hay and maize silage. The metabolizable energy from this diet was predicted to be sufficient to support an average daily milk production of 5.1 kg and daily body growth of 0.5 kg (total gain of 46 kg) during this stage of lactation.
The predicted total milk production was 1908 kg in a 270-d lactation. This milking performance was consistent with the observed milk yields of second parity cows in INIFAP's La Posta Experiment Station herd.

Dietary energy during the early dry period came from grazed forage supplemented by about 1.75 kg/d commercial concentrate during the driest months of April and May. Dry cows consuming this diet were expected to increase body mass by growing about 0.2 kg/d during this 67-day period, slightly increasing BW by 16 kg. Growth potential was reduced by a 30% excess MP intake above requirements that resulted in a daily energy cost of about 0.22 Mcal ME to excrete excess N as urea.

Late gestation for this second-parity management group coincides with the subsequent season of early rains when the supply of grazed forage is highest.

Nonetheless, cows were predicted to be unable to obtain the target body weight for their third calving of 550 kg with a BCS of 3.0 units despite daily supplementation with 1.75 kg of commercial concentrate. Requirements for rapid fetal growth forced cows to mobilize daily 2.8 Mcal ME from tissue reserves. This undesirable negative feed energy balance resulted in cows that were expected to be thinner at their third calving (BW = 530 kg with BCS ~2.50) than they were at second calving. Other things being equal, milk production and postpartum interval to the re-initiation of ovarian cyclicity in third lactation would be jeopardized by a smaller pool of body tissue reserves. In addition, this diet provided excesses of peptides (84%) and ammonia (38%), which precipitated a daily urea excretion cost of 0.21 Mcal ME.

5.3.2. Season of late rains

Second parity cows calving in the season of late rains (Table 17) are assumed to initiate lactation in good body condition (BCS = 3.0) and weighing 506 kg. These parturition targets are achieved by supplementing the grazing diet with commercial concentrate.

In the season of late rains the predicted daily dietary energy intake in early lactation from forage plus supplementation (molasses, poultry bedding, and commercial concentrate and Mulato hay) was about 20.8 Mcal ME/d. The average daily mobilization of body tissue reserves was predicted to also supply 2.8 Mcal ME/d during early lactation for synthesis of about 9.6 kg of milk. About 12% of the total energy required came from 53 kg of body tissue reserves. Correspondingly, these cows were predicted to conclude the period of early lactation in thinner body condition (BCS = 2.25) weighing about 453 kg.

Table 17
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for second parity cows in Genesis[a] herds calving in the season of late rains (August 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Late rains	Scarce rain	Little rain	Early rains	Late rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	4.5	2.9	3.5	7.6	9.2
Other forage[c]	1.5	4.5	4.7	…	…
Supplement[d]	3.6	3.9	3.3	1.6	…
Total DMI, kg/d	9.6	11.3	11.5	9.2	9.2
Total dietary energy, Mcal ME/d	20.8	24.1	24.3	18.2	16.8
Total ME supply, Mcal/d[e]	23.6	24.1	24.3	18.2	22.1
Initial body weight (BW), kg[f]	506	453	506	527	530
Mean BW, kg	480	480	517	529	479
End BW, kg	453	506	527	530	427
Initial body condition score (BCS)[g]	3.00	2.25	3.00	3.00	3.00
End BCS[h]	2.25	3.00	3.00	3.00	1.25
ME allowable growth, kg/d[i]	…	…	0.22	0.02	…
Total energy requirement, Mcal ME/d[j]	23.6	20.9	24.3	18.2	22.1
Maintenance requirement, Mcal ME/d[k]	15.1	12.7	15.2	17.0	16.8
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.30
ME allowable milk production, kg/d[l]	9.6	7.8	5.5	…	…
Feed energy balance, Mcal ME/d[m]	-2.8	3.2	0.0	0.0	-5.3

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 17 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a second calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (third) calving.
[i]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 2061 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

Genesis cows in mid-lactation typically consume maize silage (6.6 kg/d as fed) in addition to the previously mentioned supplements. As a result, this diet delivered about 24.1 Mcal ME/day to these cows. Corresponding average daily energy allowable milk production was predicted to be about 7.8 kg with about 3.2 Mcal ME also available for the repletion of previously mobilized body tissues.

This management group of cows is expected to be in their late stage of lactation during the forage season of little rain. The supply of grazed forage is poor at this time and diets are supplemented with poultry bedding, molasses, commercial concentrate and maize silage. Cows fed this diet were expected to produce about 5.5 kg/d of milk during this stage of lactation. The expected dietary supply of energy was sufficient to support modest growth of about 0.2 kg/d during this stage of lactation, increasing body weight by about 21 kg. Similar to second parity cows in INIFAP's La Posta Experiment Station herd, the average 270-day lactation milk production for cows calving in this forage season was 2061 kg.

Dietary energy during the cows' early dry period typically comes from grazed forage and commercial concentrate. With this diet cows could maintain BW despite energy wastage from excesses of protein (about 31%) and rumen ammonia (77%).

Late gestation for this management group coincides with supplies of grazed forage of modest quality. In these circumstances farmers typically do not provide supplementation. Thus, the resultant dietary energy supply is insufficient to maintain body weight and to meet the increased requirements for accelerating fetal growth. Consequently, cows would be expected to catabolize 90% more tissue reserves to supply energy to the fetus, about 5.3 Mcal ME/d, than they did to support milk production in early lactation. As a result, they were predicted to be quite thin with a BCS of ~1.25 units and to weigh about 427 kg. In addition, rumen nitrogen balance indicated NH_3 supply exceeded requirements by 115%. Consequently, second parity cows calving in the season of late rains may actually incur average calving intervals longer than the assumed mean of 14 mo. Cows that are thin and undersized would be expected to have poorer milk performance in the next lactation from less feed intake capacity and a smaller pool of tissue reserves for milk synthesis.

5.3.3. Season of scarce rain

Second parity cows calving in the season of scarce rain (Table 18) were assumed to initiate lactation with a BCS of 2.75 from modest feed energy intake (also from unsupplemented grazing) during the preceding forage season. Average body weight at calving was 489 kg.

In the season of scarce rain the total dietary intake from grazed forage and supplements (poultry bedding, molasses, commercial concentrate and Mulato hay) was predicted to supply 20.2 Mcal ME/d. Tissue catabolism was expected to supply another 2.5 Mcal ME/d to support the predicted average daily milk production of 9.9 kg during the 90-d period of early lactation. About 11% of total energy in early lactation was predicted to come from the mobilization of about 44 kg of body tissue reserves. Consequently, cows in second lactation were predicted to conclude early lactation with a BCS ~2.0 weighing 445 kg.

In addition to typical dietary supplementation (also with poultry bedding, molasses and commercial concentrate) Genesis cows in mid- lactation are typically fed maize silage. This diet provided 24.6 Mcal ME/day to support lactation and growth. Corresponding average daily energy allowable milk production during the 90-d mid-lactation period was predicted to be about 8.0 kg with about 3.3 Mcal ME of dietary energy also available for repletion of body tissues.

Table 18
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for second parity cows in Genesis[a] herds calving in the season of scarce rain (October 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	0.5	3.5	5.1	10.2	9.2
Other forage[c]	4.4	4.7	0.6	…	…
Supplement[d]	4.2	3.3	5.0	…	…
Total DMI, kg/d	9.1	11.5	10.7	10.2	9.2
Total dietary energy, Mcal ME/d	20.2	24.6	23.3	18.3	18.4
Total ME supply, Mcal/d[e]	22.7	24.6	23.3	19.0	20.0
Initial body weight (BW), kg[f]	489	445	495	508	497
Mean BW, kg	467	470	502	503	487
End BW, kg	445	495	508	497	476
Initial body condition score (BCS)[g]	2.75	2.00	2.75	2.75	2.75
End BCS[h]	2.00	2.75	2.75	2.75	2.00
ME allowable growth, kg/d[i]	…	…	0.15	…	…
Total energy requirement, Mcal ME/d[j]	22.7	21.3	23.3	19.0	20.0
Maintenance requirement, Mcal ME/d[k]	13.2	12.9	15.3	18.1	14.7
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.30
ME allowable milk production, kg/d[l]	9.9	8.0	5.6	…	…
Feed energy balance, Mcal ME/d[m]	-2.5	3.3	0.0	-0.7	-1.6

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 18 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a second calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (third) calving.
[i]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 2115 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

Cows in this management group are in late lactation during the forage season of early rains. At this time grazed forage is supplemented with poultry bedding, molasses, commercial concentrate and sugar cane bagasse (4 kg/d). The dietary supply of metabolizable energy was predicted to be sufficient to support an average daily milk yield of 5.6 kg. In addition, modest daily growth of about 0.15 kg was expected during this stage of lactation, slightly increasing body weight by 13 kg. The predicted average milk production for a 270-day lactation was 2115 kg.

Dietary energy during the cow's 67-d early dry period came from unsupplemented grazed forages grown in the seasons of early and late rains. This diet was insufficient in meeting the energy requirements, requiring mobilization of about 11 kg of body tissues because of an average daily feed energy deficit of 0.7 Mcal ME. Consequently, the predicted body weight at the end of this period was 497 kg. Associated with this diet were 371% more peptides and 121% more rumen ammonia than required, which resulted in a daily urea excretion expenditure of 0.34 Mcal ME.

Late gestation for cows in this management group coincides with the subsequent season of scarce rain. Cows in this stage of the calving interval and forage season were predicted to be unable to obtain the target body weight of 550 kg with a BCS of 3.0 units for their third calving. Predicted intake was insufficient to achieve the expected rapid fetal growth in this physiological stage, which forced cows to mobilize 1.6 Mcal ME/d from tissue reserves. This period of negative feed energy balance resulted in cows predicted to be thinner at their third calving (BW = 476 kg with BCS ~2.00) than they were at second calving. Other things being equal, milk production and postpartum interval to the re-initiation of ovarian cyclicity in third lactation would be jeopardized by a smaller pool of body tissue reserves.

5.3.4. Season of little rain

Second parity cows calving in the season of little rain (Table 19) were assumed to initiate lactation in thinner-than-desired body condition (BCS = 2.50). The average expected body weight at calving was 470 kg.

The predicted daily dietary energy intake of forage plus typical supplementation in this season was about 19.7 Mcal ME/d. The expected mobilization of body tissue reserves during early lactation was predicted to also supply 1.7 Mcal ME/d to support synthesis of about 8.8 kg/d of milk. About 8.0% of the energy required came from 31 kg of body tissue reserves. Correspondingly, these cows were predicted to conclude the period of early lactation with a BCS = 2.00 and weighing about 439 kg.

Genesis cows in mid-lactation typically receive sugar cane bagasse in addition to other supplements, which resulted in a diet providing 22.5 Mcal ME/day. Consequently, average daily energy allowable milk production was predicted to be about 7 kg with about 1.9 Mcal ME of dietary energy also available for tissue repletion.

This management group of cows is expected to be in late lactation in the season of late rains. The grazing supply of forage is low at this time of the year when diets are typically supplemented with molasses, poultry bedding and commercial concentrate. Cows fed this diet were expected to produce about 5.0 kg/d milk. The expected dietary supply of energy was sufficient to support slow growth of about 0.15 kg/d during this stage of lactation, increasing body weight by about 14 kg. The average 270-d lactation milk production for this management group was 1881 kg.

Table 19
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for second parity cows in Genesis[a] herds calving in the season of little rain (January 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Little rain	Early rains	Late rains	Scarce rain	Little rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	2.0	4.4	7.0	8.6	10.4
Other forage[c]	3.5	0.9	…	…	…
Supplement[d]	3.3	5.0	3.3	…	…
Total DMI, kg/d	8.8	10.3	10.3	8.6	10.4
Total dietary energy, Mcal ME/d	19.7	22.5	21.8	17.7	21.5
Total ME supply, Mcal/d[e]	21.4	22.5	21.8	17.7	21.5
Initial body weight (BW), kg[f]	470	439	470	484	495
Mean BW, kg	455	455	477	455	505
End BW, kg	439	470	484	495	515
Initial body condition score (BCS)[g]	2.50	2.00	2.50	2.50	2.50
End BCS[h]	2.00	2.50	2.50	2.50	2.50
ME allowable growth, kg/d[i]	…	…	0.15	0.15	0.21
Total energy requirement, Mcal ME/d[j]	21.4	20.6	21.8	17.7	21.5
Maintenance requirement, Mcal ME/d[k]	12.8	13.1	14.4	14.8	13.1
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.30
ME allowable milk production, kg/d[l]	8.8	7.1	5.0	…	…
Feed energy balance, Mcal ME/d[m]	-1.7	1.9	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 19 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a second calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (third) calving.
[i]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 1881 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

Dietary energy during the early dry period typically comes from forage without supplementation. Cows consuming this diet were able to increase body mass slightly, about 11 kg, during this period by growing about 0.15 kg/d to reach an expected average body weight of 495 kg by the end of this period.

Late gestation for these cows coincides with the subsequent little rain season. Despite the positive feed energy balance in this stage of the calving interval, second parity cows could not reach the target BCS and BW for their next reproductive cycle. Cows calving during the little rain season ended gestation with a BCS of 2.50 units at 515 kg.

Like primiparous cows calving in alternative seasons, second parity cows are vulnerable especially to slow growth rates and poor feed energy status during the dry period, especially late gestation. In addition, most second parity cows ended the late gestation stage in thinner condition than they were at the same stage when they were primiparous cows. The latter is the carryover effect of inadequate energy for cows during the dry period. Consequently, subsequent lactation and reproduction are likely to be of poorest performance.

5.4. Analysis of current management and productivity outcomes for multiparous cows

This section contains results of baseline simulations and identification of constraint for cows in third lactation that calve in each of four alternative forage seasons of the year. Tables contain expected body weights, body tissue repletion, predicted average daily milk production, energy supplies from dietary intakes and from body tissue reserves and feed energy status of cows throughout the calving interval (and the coinciding annual seasons).

5.4.1. Season of early rains

Mature cows calving in the season of early rains (Table 20) were assumed to initiate lactation in good body condition (BCS = 3.0) and weighing 550 kg. These parturition targets are achieved by supplementing the grazed forage with commercial concentrate.

The diet of grazed forage and supplements (molasses, poultry bedding and commercial concentrate) in early lactation was predicted to supply about 23.0 Mcal of ME/d. Tissue catabolism was expected to supply another 2.3 Mcal ME/d to support the predicted average daily milk production of 9.1 kg during this 90-d period. Therefore, about 9% of total energy supply in early lactation was predicted to come from the mobilization of about 40 kg of body tissue reserves. As a result, multiparous cows were predicted to conclude early lactation weighing about 510 kg with a BCS ~2.50.

Genesis cows in mid-lactation consume about 11% more dietary ME than in early lactation (25.5 *vs*. 23.0 Mcal ME/d) due to the nutritional contribution from Mulato hay. As a result, the average daily energy allowable milk production in mid-lactation was predicted to be about 7.3 kg with about 2.4 Mcal ME of dietary energy also available for body tissue repletion.

This management group of mature cows is in late lactation principally during the season of scarce rain when grazing is supplemented with typical ingredients plus Mulato hay and maize silage. The metabolizable energy from this diet was predicted to be sufficient to support an average daily milk production of 5.7 kg and with energy also available to replete about 50 kg BW in this stage of lactation. The predicted 270-d total milk production was 1989 kg. This milking performance was consistent with the observed milk yields of mature cows in INIFAP's La Posta Experiment Station herd.

Table 20
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of early rains (June 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Early rains	Late rains	Scarce rain	Little rain	Early rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	7.2	4.1	3.2	8.9	8.1
Other forage[c]	…	2.9	4.6	…	…
Supplement[d]	3.5	4.4	3.8	1.9	1.9
Total DMI, kg/d	10.7	11.4	11.6	10.8	10.0
Total dietary energy, Mcal ME/d	23.0	25.5	25.1	22.9	20.7
Total ME supply, Mcal/d[e]	25.3	25.5	25.1	22.9	24.8
Initial body weight (BW), kg[f]	550	510	546	596	636
Mean BW, kg	530	528	571	616	609
End BW, kg	510	546	596	636	581
Initial body condition score (BCS)[g]	3.00	2.50	3.00	3.50	4.00
End BCS[h]	2.50	3.00	3.50	4.00	3.50
Total energy requirement, Mcal ME/d[i]	25.3	23.1	21.7	19.3	24.8
Maintenance requirement, Mcal ME/d[j]	16.6	15.4	15.5	18.4	19.4
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[k]	9.1	7.3	5.7	…	…
Feed energy balance, Mcal ME/d[l]	-2.3	2.4	3.4	3.6	-4.1

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 20 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[i]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[j] Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[k]Predicted 270-d lactation milk production was 1989 kg.
[l]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

Dietary energy during the early dry period came from grazed forage supplemented daily by about 2 kg commercial concentrate. Dry cows consuming this diet were expected to replete about 40 kg during this 67-d period. Therefore, this diet was sufficient to meet all the nutritional requirements and for cows to replenish tissue reserves.

Late gestation for this management group of mature cows coincides with the season of early rains grazed forage supplemented with commercial concentrate (2.0 kg/d). Nonetheless, cows were predicted unable to maintain a desired body weight of 550 kg with a BCS of 3.0 units for the next lactation despite daily supplementation with concentrate. Requirements for accelerating fetal growth in this stage of the calving interval forced cows to mobilize 4.1 Mcal ME/d from tissue reserves. This undesirable negative feed energy balance resulted in cows that were expected to still be in good body condition at their fourth calving (BW = 581 kg with BCS ~3.50). Nevertheless, the substantial BW loss of 55 kg that occurred in this stage reduced overall energetic efficiency and may also predispose cows to subsequent metabolic disorders (i.e., ketosis).

5.4.2. Season of late rains

Multiparous cows calving in the season of late rains (Table 21) were assumed to initiate lactation in good body condition (BCS = 3.0). The average expected body weight of these cows at calving was 550 kg.

In early lactation the predicted daily dietary energy intake from grazed forage plus supplements (molasses, poultry bedding, commercial concentrate and Mulato hay) was about 24 Mcal ME. The expected mobilization of body tissue reserves was predicted to also supply 2.6 Mcal ME/d during early lactation for synthesis of about

Table 21
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of late rains (August 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Late rains	Scarce rain	Little rain	Early rains	Late rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	5.9	4.3	4.2	7.7	10.0
Other forage[c]	1.5	4.5	4.7	…	…
Supplement[d]	3.8	4.1	3.5	1.9	…
Total DMI, kg/d	11.2	12.9	12.4	9.6	10.0
Total dietary energy, Mcal ME/d	24.0	27.6	26.6	19.3	18.2
Total ME supply, Mcal/d[e]	26.6	27.6	26.6	20.8	24.2
Initial body weight (BW), kg[f]	550	505	571	608	594
Mean BW, kg	528	538	590	601	537
End BW, kg	505	571	608	594	479
Initial body condition score (BCS)[g]	3.00	2.50	3.25	3.50	3.50
End BCS[h]	2.50	3.25	3.50	3.50	2.00
Total energy requirement, Mcal ME/d[i]	26.6	23.3	23.9	20.8	24.2
Maintenance requirement, Mcal ME/d[j]	16.4	14.1	17.3	19.9	18.8
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[k]	10.7	8.7	6.1	…	…
Feed energy balance, Mcal ME/d[l]	-2.6	4.3	2.7	-1.5	-6.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 21 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[i]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[j] Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[k]Predicted 270-d lactation milk production was 2295 kg.
[l]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

10.7 kg of milk. About 10% of the energy required for milk synthesis came from catabolism of about 45 kg of body tissue reserves. Correspondingly, these cows were predicted to conclude the period of early lactation in thinner body condition (BCS = 2.50) and weighing about 505 kg.

Genesis cows in mid-lactation typically receive maize silage in addition to other supplements. This diet supplied sufficient ME to produce about 8.7 kg/d of milk with about 4.3 Mcal ME/d for the repletion of previously catabolized tissues. This management group of cows is expected to be in their late stage of lactation during the forage season of little rain. The diminished supply of grazed forage is typically managed by supplementing diets with poultry bedding, molasses, commercial concentrate and maize silage. Cows fed this diet were expected to produce about 6.1 kg/d of milk during this stage of lactation. The expected dietary supply of energy was sufficient to support about 37 kg of BW gain. Similar to multiparous cows in INIFAP's La Posta Experiment Station herd, the average 270-d milk production for cows calving in this forage season was about 2295 kg.

The dietary energy supply during the cows' early dry period typically comes from grazed forage supplemented with commercial concentrate. The predicted daily negative energy balance of 1.5 Mcal ME/d resulted in about 14 kg of body tissues that were mobilized to support fetal energy requirements. This diet provided an excess of protein (about 44%) with a rumen ammonia balance that exceeded desired levels by 76%, thus causing an expected daily urea excretion cost of 0.35 Mcal ME.

The period of late gestation for this management group coincides with large supplies of grazed forage in the seasons of early and late rains. In these circumstances, farmers typically do not provide supplementation. Thus, the resultant dietary energy supply is insufficient to maintain body weight and to satisfy the increased requirements for fetal growth. As a result, cows are forced to catabolize 130% more tissue energy to support the rapidly-growing fetus, about 6.0 Mcal ME/d, than they did to support milk synthesis in early lactation. As a result, overall energy balance was further depressed with cows becoming undesirably thin by the end of gestation (BCS of ~2.00 units) and weighing about 479 kg. Consequently, mature cows calving in the season of late rains may actually incur longer calving intervals than the assume average of 14 mo. Mature cows that are thin also would be expected to have poorer milk performance in the next lactation from a smaller pool of tissue reserves for milk synthesis. In addition, the predicted daily urea excretion expenditure was 0.29 Mcal ME.

5.4.3. Season of scarce rain

Multiparous cows calving in the season of scarce rain (Table 22) were assumed to initiate lactation with a BCS of 3.0 from modest feed energy intake (from unsupplemented grazing). Average body weight at calving was 550 kg.

In the season of scarce rain the total dietary intake from grazed forage and supplements (poultry bedding, molasses, commercial concentrate and Mulato hay) was predicted to supply about 23.0 Mcal ME/d. Tissue catabolism was expected to supply another 2.1 Mcal ME/d to support the predicted average daily milk production of 10.9 kg during the 90-d period of early lactation. Therefore, about 8% of total energy supply in early lactation was predicted to come from about 35 kg of body tissue reserves. As a result, cows in third lactation and greater were predicted to conclude early lactation with a BCS ~2.50 and weighing about 515 kg.

In addition to typical dietary supplementation (also with poultry bedding, molasses and commercial concentrate) Genesis cows in mid-lactation are typically fed maize silage. This resulted in about 15% greater supply of dietary ME compared

Table 22

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	1.6	4.1	5.8	10.9	9.6
Other forage[c]	4.4	4.7	0.6	…	…
Supplement[d]	4.4	3.5	5.2	…	…
Total DMI, kg/d	10.4	12.3	11.6	10.9	9.6
Total dietary energy, Mcal ME/d	23.0	26.5	25.3	19.5	19.2
Total ME supply, Mcal/d[e]	25.1	26.5	25.3	21.1	21.3
Initial body weight (BW), kg[f]	550	515	550	572	549
Mean BW, kg	533	533	561	561	533
End BW, kg	515	550	572	549	516
Initial body condition score (BCS)[g]	3.00	2.50	3.00	3.25	3.00
End BCS[h]	2.50	3.00	3.25	3.00	2.50
Total energy requirement, Mcal ME/d[i]	25.1	24.1	23.8	21.1	21.3
Maintenance requirement, Mcal ME/d[j]	14.5	14.8	17.1	20.2	15.9
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[k]	10.9	8.8	6.2	…	…
Feed energy balance, Mcal ME/d[l]	-2.1	2.4	1.5	-1.6	-2.1

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.

[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 22 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[i]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[j] Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[k]Predicted 270-d lactation milk production was 2331 kg.
[l]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

to early lactation (26.5 *vs.* 23.0 Mcal ME/d). Corresponding average daily energy allowable milk production during the 90-d mid-lactation period was predicted to be about 8.8 kg with about 2.4 Mcal ME/day of dietary energy also available for repletion of body tissues, which also helps assure persistent lactation.

Cows in this management group are in late lactation during the forage season of early rains. Plentiful grazing is supplemented mainly with poultry bedding, molasses, and commercial concentrate. The dietary supply of metabolizable energy was predicted to be sufficient to support an average daily milk yield of about 6.2 kg. The dietary energy supply was sufficient to support a modest body weight gain of about 22 kg. The predicted average 270-d lactation milk production was 2331 kg.

Dietary energy during the cows' 67-d early dry period came from unsupplemented grazed forages grown in the seasons of early and late rains. This diet was insufficient to meet the energy requirements. Consequently, 23 kg of body weight loss was predicted from an average daily feed energy deficit of 1.6 Mcal ME, which resulted in a predicted ending body weight of 549 kg. Associated with this diet was a daily urea excretion expenditure of 0.36 Mcal ME.

Late gestation for cows in this management group coincides with the seasons of late and scarce rain when cows were predicted unable to obtain the target body weight of 550 kg with a BCS of 3.0 units for their fourth calving. Predicted intake was insufficient to sustain the expected rapid fetal growth of late gestation, which would force cows to mobilize about 2.1 Mcal ME/d from tissue reserves. This period of negative feed energy balance resulted in cows predicted to be thinner at their fourth calving (BW = 516 kg with BCS ~2.50) than they were at third calving. Other things being equal, milk production and postpartum interval to the re-initiation of ovarian cyclicity in fourth lactation would be jeopardized by a smaller pool of body tissue reserves.

5.3.4. Season of little rain

Multiparous cows calving in the season of little rain (Table 23) initiate lactation in thin body condition (BCS = 2.75). The average expected body weight at calving was 532 kg.

The predicted daily dietary energy intake of forage plus typical supplementation in this season of calving was about 22.2 Mcal ME. The expected mobilization of body tissue reserves during early lactation was predicted to also supply 2.0 Mcal ME/d for the synthesis of about 9.8 kg of milk. About 8% of the energy supply came from 34 kg of body tissue reserves. Correspondingly, these cows were predicted to conclude their early lactation with a BCS = 2.25) and weighing about 498 kg.

Genesis cows in mid-lactation typically receive sugar cane bagasse in addition to other supplements. This resulted in about 12% greater supply of dietary ME compared to the period of early lactation (24.9 *vs.* 22.2 Mcal ME/d) from the higher ME intake from the diet (grazed forage plus more molasses supplementation than the previous stage). As a result, average daily energy allowable milk production was predicted to be about 7.9 kg with about 1.8 Mcal ME/d of dietary energy also available for the repletion of body tissues.

This management group of cows is expected to be in late lactation in the season of late rains when grazed forage is typically supplemented with molasses, poultry bedding and commercial concentrate. Cows fed this diet were expected to produce about 5.6 kg/d milk. The expected dietary supply of energy was sufficient to support 23 kg of tissue repletion during this stage of lactation. The average 270-d lactation milk production for this management group was 2097 kg.

Table 23
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of little rains (January 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Little rain	Early rains	Late rains	Scarce rains	Little rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	2.9	5.4	7.6	9.2	11.1
Other forage[c]	3.5	0.9	…	…	…
Supplement[d]	3.5	5.2	3.5	…	…
Total DMI, kg/d	9.9	11.5	11.1	9.2	11.1
Total dietary energy, Mcal ME/d	22.2	24.9	23.6	19.0	23.0
Total ME supply, Mcal/d[e]	24.2	24.9	23.6	19.0	23.0
Initial body weight (BW), kg[f]	532	498	525	548	563
Mean BW, kg	515	512	537	556	581
End BW, kg	498	525	548	563	599
Initial body condition score (BCS)[g]	2.75	2.25	2.75	3.00	3.00
End BCS[h]	2.25	2.75	3.00	3.00	3.50
Total energy requirement, Mcal ME/d[i]	24.2	23.1	22.2	17.8	20.8
Maintenance requirement, Mcal ME/d[j]	14.5	14.8	16.1	16.9	15.4
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[k]	9.8	7.9	5.6	…	…
Feed energy balance, Mcal ME/d[l]	-2.0	1.8	1.4	1.2	2.2

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).

Table 23 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[i]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[j] Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[k]Predicted 270-d lactation milk production was 2097 kg.
[l]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if allowed). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetus.

Dietary energy during the early dry period typically comes from grazed forage without supplementation. However, cows consuming this diet repleted 15 kg and reached an expected average body weight of 563 kg by the end of this stage of the calving interval.

Late gestation for these cows coincides with depressed supply of grazed forage in the subsequent little rain season. However, predicted intake energy under the assumption of *ad libitum* feed intake would be sufficient to satisfy the requirements for rapid fetal growth and maintenance (20.8 Mcal ME/d) and to replenish some body weight. Cows calving during the little rain season were predicted to end the late gestation stage with a BCS of 3.50 units and weighing 599 kg. However, the *ad libitum* feed intake assumption (from the grazing component) probably results in an overestimation of energy intake (and BCS and body weight) for cows of all ages during this season of the year.

In most cases (except cows calving in little rains) mature cows encountered the same bottleneck as immature ones. Energy deficits occurred during the dry period, especially in late gestation. Consequently, cows were forced to mobilize tissue energy reserves to support increased energy demands by the fetus, which resulted in thin body condition scores at next lactation. In turn, depressed tissue reserves predispose cows to longer calving intervals and diminished milk production.

5.5. Conclusions from the baseline simulations and the identification of key management constraints on cow productivity

Table 24 shows CNCPS-predicted milking performance for all management groups of cows consistent with an overall herd average 270-d lactation milk yield of 2000 kg. These findings agree with the overall Genesis herd performance (Rodriguez-Morales et al., 2005) and with milk production records from INIFAP's La Posta herd for crossbred cows from the same genetic group consuming forages grown in the same agroecozone. Information required to use the CNCPS principally involves three general groups of inputs: dietary ingredients description and their chemical composition, animal characteristics, and environmental characteristics. Therefore, using this information the CNCPS model proved effective in accurately describing typical milking performance for this herd population with modest reliance on tissue reserves for milk synthesis in early lactation. Since predicted milk production agreed with actual production, nutritional constraints to production can be identified and feeding management alternatives that reduce those constraints can be developed with confidence that they will be acceptably accurate.

Table 24
Simple and weighted average 270-day milk production for cows of different parities and calving in alternative forage seasons of the year.

Calving season	Parity			Herd
	1[a]	2[a]	>2[a]	
Early rains	1800	1910	1990	
Late rains	1950	2060	2290	
Scarce rain	1990	2110	2330	
Little rain	1770	1880	2100	
Simple average	1880	1990	2180	2020
Weighted average	1857	1970	2177	2000

[a]Values were rounded to the nearest kilogram.
[b]Approximate calving frequencies by season of the year are: early rains (10%), late rains (10%), scarce rain (30%) and little rain (50%).

Under the assumptions of this study, the preponderance of energy deficits during the dry period indicated that dry cows of all ages constitute a particularly vulnerable herd management group. Another interpretation of this finding could be that calving intervals frequently may be longer than the assumed mean values of 14 and 16 mo in this study. For animals with these lengths of calving interval, there is a strong suggestion that acute dietary energy deficits may occur in late gestation, resulting in smaller pools of tissue reserves at the next calving than at the preceding one.

Dietary supplies of ME, especially from forages, were chronically insufficient for desired growth in immature cows. Constraints on growth result in smaller cows with less DMI capacity, curtailed milk production and delayed postpartum return to ovarian cyclicity (time period to the nadir of negative energy balance; Butler, 2003). Therefore, results from this study suggest that energetic limitation is the main constraint on cattle productivity in the Sotavento region. In some cases excess dietary protein probably aggravates energy status.

First parity cows calving in the four forage seasons ended their calving intervals with average feed energy balances of -2.5, -4.0, -1.2, and 2.1 Mcal ME/d in late gestation. The negative energy balances occurring in most cows throughout the year were equal to or exceeded the negative energy balance in support of milk synthesis that is typical of early lactation. Energy balance for calvings in the season of little rain when grazing is scarce were probably overestimated under the assumption of *ad libitum* feed intake. Results suggest that first-calf cows may incur calving intervals longer than the average of 16 mo that was assumed in this study.

This same pattern of response occurs in other cow age classes: predicted feed energy balance in late gestation was mostly negative. Second parity cows calving in these alternative forage seasons ended their calving interval with mostly negative average feed energy balances of -2.8, -5.3, -1.6, and 3.1 Mcal ME/d during late gestation. Mature cows ended their calving intervals with average feed energy balances of -4.1, -6.0, -2.1 and 2.2 Mcal ME/d, respectively. Therefore, these results suggest that most cows are vulnerable and may incur calving intervals longer than the averages assumed in this study. Furthermore, energy deficits during this period may predispose cows to health problems (i.e., metabolic) in subsequent lactations.

To put this analysis in context, however, it is important to acknowledge that typical dietary management by Genesis producers is actually above average for this region. Genesis farmers have made investments in grazing management and to conserve forage of higher quality than that which is normally done on other farms. The CNCPS-predicted herd productivity for these farms reflects returns from investments already made by these farmers. Investments in harvested forage and dietary supplementation are primary reasons why Genesis herd average milk production exceeds the non-GGAVATT average yield of 1600 kg in the Sotavento region (Appendix section 8.11).

5.5.1. Summary of the systematic analysis of typical Genesis management

Tables 25, 26, and 27 summarize for parity (age) groups of cows the expected daily milk production, dry matter intake, feed energy balance and growth rates (of immature cows) throughout calving intervals initiated in alternative forage seasons of calving. Columns correspond to physiological stages of cows. For each season of calving, the expected nutritional status of cows in each season of the year and physiological stage of the calving interval is read from the table horizontally in the same sequence: early lactation (emboldened values on the block diagonal corresponding to parturition in each calving season), late lactation, early and late dry periods. (Note: some physiological stages appear out of sequence when reading values in a row from left to right because the calving interval is longer than one year.) For example, cows calving in the season of early rains will be in late lactation in the season of scarce rain, in the early dry period during the little rain season, and in late gestation in the next early rains season.

Table 25

Expected daily milk yield, dry matter intake (DMI) and feed energy (FE) balances throughout calving intervals[a] of primiparous cows calving in alternative forage seasons[b,c] under typical management in Genesis ranches.

	Early rains				Late rains				Scarce rain				Little rain			
	Lactation		Dry		Lactation		Dry		Lactation		Dry		Lactation		Dry	
Calving season	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Early rains (June 1)																
Milk yield, kg/d	**8.4**	…	…	…	…	…	…	…	…	4.8	…	…	…	…	…	…
DMI predicted, kg/d	**8.7**	…	…	8.9	…	…	…	…	…	9.4	…	…	…	…	9.7	…
FE balance, Mcal ME/d	**-2.3**	…	…	-2.5	…	…	…	…	…	2.6	…	…	…	…	5.9	…
Growth, kg/d	**…**	…	…	…	…	…	…	…	…	0.2	…	…	…	…	0.4	…
Late rains (August 1)																
Milk yield, kg/d	…	…	…	…	**9.1**	…	…	…	…	5.2	…	…	…	…	…	…
DMI predicted, kg/d	…	…	9.7	…	**9.4**	…	…	9.6	…	10.5	…	…	…	…	…	…
FE balance, Mcal ME/d	…	…	2.5	…	**-2.6**	…	…	-4.0	…	5.5	…	…	…	…	…	…
Growth, kg/d	…	…	0.2	…	**…**	…	…	…	…	0.2	…	…	…	…	…	…
Scarce rain (October 1)																
Milk yield, kg/d	…	…	…	…	…	…	…	…	**9.3**	…	…	…	…	5.3	…	…
DMI predicted, kg/d	…	…	…	…	…	…	8.7	…	**8.3**	…	…	8.1	…	9.7	…	…
FE balance, Mcal ME/d	…	…	…	…	…	…	-1.2	…	**-2.3**	…	…	-1.2	…	1.9	…	…
Growth, kg/d	…	…	…	…	…	…	…	…	**…**	…	…	…	…	0.2	…	…
No rain (February 1)																
Milk yield, kg/d	…	4.7	…	…	…	…	…	…	…	…	…	…	**8.3**	…	…	...
DMI predicted, kg/d	…	9.3	…	…	…	…	…	…	…	…	9.4	…	**8.4**	…	…	9.5
FE balance, Mcal ME/d	…	4.7	…	…	…	…	…	…	…	…	4.7	…	**-1.5**	…	…	2.1
Growth, kg/d	…	0.1	…	…	…	…	…	…	…	…	0.3	…	**…**	…	…	0.2

[a]Early lactation period = days 1 to 90 postpartum. Late lactation = days 181 to 270. Early dry = variable length period commencing on day 270. Late dry = final 90 d of calving interval (late gestation).

[b]Early rains = June 1 to July 31. Late rains = August 1 to September 30. Scarce rain = October 1 to December 31. Little rain = January 1 to May 31.

[c]Chemical composition and kinetic digestion parameters of Genesis forages were based on the collective opinion of a panel of local professionals and available laboratory analyses.

Table 26

Expected daily milk yield, dry matter intake (DMI) and feed energy (FE) balances throughout calving intervals[a] of second parity cows calving in alternative forage seasons[b,c] under typical management in Genesis ranches.

	Early rains				Late rains				Scarce rain				Little rain			
	Lactation		Dry		Lactation		Dry		Lactation		Dry		Lactation		Dry	
Calving season	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Early rains (June 1)																
Milk yield, kg/d	**8.9**	…	…	…	…	…	…	…	…	5.1	…	…	…	…	…	…
DMI predicted, kg/d	**9.6**	…	…	9.8	…	…	…	…	…	11.3	…	…	…	…	9.9	…
FE balance, Mcal ME/d	**-2.9**	…	…	-2.8	…	…	…	…	…	4.3	…	…	…	…	3.4	…
Growth, kg/d	**…**	…	…	…	…	…	…	…	…	0.5	…	…	…	…	0.2	…
Late rains (August 1)																
Milk yield, kg/d	…	…	…	…	**9.6**	…	…	…	…	5.5	…	…	…	…	…	…
DMI predicted, kg/d	…	…	…	…	**9.6**	…	…	9.2	…	11.5	…	…	…	9.2	…	…
FE balance, Mcal ME/d	…	…	…	…	**-2.8**	…	…	-5.3	…	3.1	…	…	…	0.3	…	…
Growth, kg/d	…	…	…	…	**…**	…	…	…	…	0.2	…	…	…	…	…	…
Scarce rain (October 1)																
Milk yield, kg/d	…	…	10.2	…	…	…	…	…	**9.9**	…	…	…	…	5.6	…	…
DMI predicted, kg/d	…	…	-0.7	…	…	…	…	…	**9.1**	…	…	9.2	…	10.7	…	…
FE balance, Mcal ME/d	…	…	…	…	…	…	…	…	**-2.5**	…	…	-1.6	…	1.9	…	…
Growth, kg/d	…	…	…	…	…	…	…	…	**…**	…	…	…	…	0.2	…	…
No rain (February 1)																
Milk yield, kg/d	…	5.0	…	…	…	…	…	…	…	…	…	…	**8.8**	…	…	…
DMI predicted, kg/d	…	10.3	…	…	…	…	…	…	…	…	8.6	…	**8.8**	…	…	10.4
FE balance, Mcal ME/d	…	1.9	…	…	…	…	…	…	…	…	2.0	…	**-1.7**	…	…	3.1
Growth, kg/d	…	0.2	…	…	…	…	…	…	…	…	0.2	…	**…**	…	…	0.2

[a]Early lactation period = days 1 to 90 postpartum. Late lactation = days 181 to 270. Early dry = variable length period commencing on day 270. Late dry = final 90 d of calving interval (late gestation).

[b]Early rains = June 1 to July 31. Late rains = August 1 to September 30. Scarce rain = October 1 to December 31. Little rain = January 1 to May 31.

[c]Chemical composition and kinetic digestion parameters of Genesis forages were based on the collective opinion of a panel of local professionals and available laboratory analyses.

Table 27

Expected daily milk yield, dry matter intake (DMI) and feed energy (FE) balances throughout calving intervals[a] of multiparous cows calving in alternative forage seasons[b,c] under typical management in Genesis ranches.

	Early rains				Late rains				Scarce rain				Little rain			
	Lactation		Dry		Lactation		Dry		Lactation		Dry		Lactation		Dry	
Calving season	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Early rains (June 1)																
Milk yield, kg/d	**9.1**	…	…	…	…	…	…	…	…	5.7	…	…	…	…	…	…
DMI predicted, kg/d	**10.7**	…	…	10.0	…	…	…	…	…	11.6	…	…	…	…	10.8	…
FE balance, Mcal ME/d	**-2.3**	…	…	-4.1	…	…	…	…	…	3.4	…	…	…	…	3.6	…
Late rains (August 1)																
Milk yield, kg/d	…	…	…	…	**10.7**	…	…	…	…	6.1	…	…	…	…	…	…
DMI predicted, kg/d	…	…	…	…	**11.2**	…	…	10.0	…	12.4	…	…	…	…	9.6	…
FE balance, Mcal ME/d	…	…	…	…	**-2.6**	…	…	-6.0	…	2.7	…	…	…	…	-1.5	…
Scarce rain (October 1)																
Milk yield, kg/d	…	…	10.9	…	…	…	…	…	**10.9**	…	…	…	…	6.2	…	…
DMI predicted, kg/d	…	…	-1.6	…	…	…	…	…	**10.4**	…	…	9.6	…	11.6	…	…
FE balance, Mcal ME/d	…	…	…	…	…	…	…	…	**-2.1**	…	…	-2.1	…	1.5	…	…
No rain (February 1)																
Milk yield, kg/d	…	5.6	…	…	…	…	…	…	…	…	…	…	**9.8**	…	…	...
DMI predicted, kg/d	…	11.1	…	…	…	…	…	…	…	…	9.2	…	**9.9**	…	…	11.1
FE balance, Mcal ME/d	…	1.4	…	…	…	…	…	…	…	…	1.2	…	**-2.0**	…	…	2.2

[a]Early lactation period = days 1 to 90 postpartum. Late lactation = days 181 to 270. Early dry = variable length period commencing on day 270. Late dry = final 90 d of calving interval (late gestation).

[b]Early rains = June 1 to July 31. Late rains = August 1 to September 30. Scarce rain = October 1 to December 31. Little rain = January 1 to May 31.

[c]Chemical composition and kinetic digestion parameters of Genesis forages were based on the collective opinion of a panel of local professionals and available laboratory analyses.

These tables indicate diets are consistently deficient in metabolizable energy during late gestation, which would certainly constrain the overall lifetime productivity of a cow. As a result, there is a reduction in the pool of energy reserves needed for the next lactation, i.e., less milk production potential. This deficiency would also be expected to result in delays in the postpartum return to ovarian cyclicity would result in fewer calves per cow from extended calving intervals. For these reasons Genesis farmers would likely benefit from investments to properly manage the dry period. Special attention is needed during the transition period when homeorhesis requires greater, complementary energy support (Overton and Waldron, 2004).

Tables 25-27 indicate undesirable energy deficiencies during the dry period of cows of all parities (ages) need to be addressed. Sorghum grain, which is less expensive than commercial concentrate, may provide needed amounts of energy. Although sorghum supplementation during critical stages of the calving interval may achieve this goal, it may be prohibitively expensive. Greater use of higher quality harvested forage is likely to achieve objectives at lower cost. The use of harvested forage of good quality during lactation may also enhance milking and growth performance by increasing dietary energy supply. In addition to greater use of better quality grass forages, the use of legume forage, especially in early lactation when cows exploit body tissue reserves for peak milk production, might improve voluntary dry matter intake by improving the overall digestibility of the diet and, consequently, feed passage rate. In addition, less energy supplementation may be required to achieve desired body condition scores and body weights during the calving interval.

Additionally, greater energy intakes during early lactation also might be beneficial by reducing reliance on body tissue energy reserves for milk to quickly overcome negative energy balances. Consequently, immature cows could improve their growth performance and attain heavier body weights at next lactation. Mature cows could also reach heavier body weights by repleting and maintaining tissue reserves more efficiently.

6.0 Results and discussion: Management options for Genesis herd owners to improve dietary support of the cow herd.

The first subsection of this chapter consists of an estimation of the amount of energy from sorghum grain required for dry cows to achieve desired body weights and tissue reserve status at the next lactation for the average lengths of calving interval assumed in this study. The ensuing subsections provide evaluations of potential alternative diets for cows of all ages (parities 1, 2, >2) that would calve in the season of scarce rain. Section 6.2 focuses on cows fed harvested forage of good quality (e.g., hay or silage). In these evaluations, harvested forage of good quality corresponded to that with chemical composition equal to that of Genesis-grown *Andropogon gayanus* harvested in the season of late rains (Table 3).

Section 6.3 shows the results of adding legume forage (*Leucaena* or *Gliricidia*) to these improved diets. Section 6.4 reports important findings about the cumulative effects on cows' lifetime productivity from incorporating improved quality harvested forage starting at first parturition. Further, section 6.5 shows the cumulative effects on cow productivity from substituting legume for poultry bedding in early lactation. Finally, section 6.6 provides an assessment of the potential economic benefits expected to accrue in the first three lactations of a cow's lifetime from these management options for the case of cows calving in the season of scarce rain.

6.1. Dry cow vulnerability

Based on the chronic constraints affecting Genesis cows during the dry period, especially in late gestation, that were identified in chapter 5, the quantities of sorghum grain and good quality forage needed to alleviate these energy deficits were estimated.

These amounts of feed (energy) are those that would be required to achieve the target body weights and body condition scores at next calving for the specified calving intervals. Instead of sorghum only, the lower-cost practice of substituting grazing with harvested forage of good quality, similar to that of *Andropogon gayanus* (Llanero grass) grown in the season of late rains (Table 3), and supplemented by sorghum grain was also considered. Two cow management groups were considered, primiparous and mature cows, for calvings in each forage season of the year.

The tables in section 8.11 of the Appendix contain simulation findings for primiparous and mature cows. Appendix Table 8.12 contains a summary of the quantities of sorghum grain (as the only feed) and harvested forage supplemented with sorghum grain that would be needed to maintain body weights of these cows during their dry period. About one-third less sorghum grain is needed if good quality forage is provided, which is similar to the finding by Morales and co-workers (2003) who found that 30% less concentrate is needed when harvested forage is of good quality. Assuring good forage quality has important sparing effects on required quantities of supplements to achieve management objectives.

The relatively high cost of grain to achieve this management objective, about \$180 for primiparous cows and \$45 for multiparous cows, would likely preclude its use by most farmers. This investment would be the equivalent in value to about 550 kg of milk sales from primiparous cows and about 150 kg of milk sales from mature cows.

A management approach is needed using affordable feeds to reduce the risks of cow vulnerability by assuring growth of immature cows and desirable body tissue reserves throughout lactation. Cows with larger body size consuming more forage also are enabled to produce more milk. Early postpartum return to feed energy balance underwrites potentials for earlier conception and more calves per cow lifetime. Larger pools of body tissue reserves by achieving desirable target BCS ≥3.0 at calving contribute to greater lactation milk yields and earlier return to ovarian cyclicity. Thus the following management options with harvested forage were examined to meet these objectives.

6.2. Diets with harvested forage of good quality for cows calving in the season of scarce rain

The following sections report the expected animal performance responses from alternative diets for cows calving in the season of scarce rain. This was the season consistently associated with greatest energy deficits during the dry period. Alternative diets consisted of either hay or maize silage equivalent in feeding quality to the Llanero hay already produced by Genesis farm owners (*Andropogon gayanus* harvested in late rains, Table 3).

6.2.1. Primiparous cows

Predicted intakes of diets containing good quality harvested forage (Table 28) supplied primiparous cows in early lactation with about 16% more ME than those typically consumed by this management group of cows (21.5 *vs*. 18.5 Mcal ME/d). As a result, average daily milk production in early lactation increased by about one-third to about 12.2 kg. Furthermore, this average milk yield would be obtained with less reliance on body tissue reserves to support milk synthesis, mobilizing about 0.50 units of BCS, than in the baseline scenario with typical management.

Cows in mid-lactation were predicted to consume about 25.4 Mcal ME/d, or about 14% more ME, than under typical management. Corresponding average daily energy allowable milk production was predicted to be 9.9 kg with about 25% more ME (3.5 Mcal) available to replete previously catabolized tissues compared to the baseline scenario.

Table 28
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) fed good quality harvested forage during lactation and harvested forage supplemented by sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	0.0	2.7	4.3	…	…
High quality harvested forage[c]	4.4	4.7	0.6	8.5	5.7
Supplement[d]	3.9	3.1	4.8	…	…
Sorghum[e]	…	…	…	…	2.2
Total DMI, kg/d	8.3	10.5	9.7	8.5	7.9
Total dietary energy, Mcal ME/d	21.5	25.4	24.2	19.4	19.6
Total ME supply, Mcal/d[f]	23.2	25.4	24.2	19.4	19.6
Initial body weight (BW), kg[g]	426	398	449	474	510
Mean BW, kg	412	424	462	492	510
End BW, kg	398	449	474	510	510
Initial body condition score (BCS)[h]	2.75	2.25	3.00	3.00	3.00
End BCS[i]	2.25	3.00	3.00	3.00	3.00
ME allowable growth, kg/d[j]	…	…	0.27	0.27	…
Total energy requirement, Mcal ME/d[k]	23.2	21.9	24.2	19.4	19.6
Maintenance requirement, Mcal ME/d[l]	10.9	11.5	13.9	15.0	14.6
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[m]	12.2	9.9	7.0	…	…
Feed energy balance, Mcal ME/d[n]	-1.7	3.5	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 28 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent the grazed forage diet for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for scarce and little rain seasons.
[c]Harvested forage was assumed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 2614 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

In late lactation these cows were predicted to produce an average of 7.0 kg/d from a dietary energy supply that was also sufficient to support about 25 kg of growth, or 25% more than under typical management. About one-third more total milk was expected during a 270-day lactation compared to typical management, increasing from 1989 kg to 2614 kg, similar to the responses in milk production observed by Fujisaka and co-workers (2005) from good quality silage.

The expected daily dietary energy supply during the early dry period of primiparous cows was about 19.4 Mcal ME, or about 24% more than from typical management, which supported about 36 kg of body growth for this management group. Furthermore, primiparous cows receiving this management did not require supplementation with grain.

Cows in late gestation were predicted to consume about 19.6 Mcal ME/d, which was sufficient to maintain body weight and to satisfy fetal growth requirements. Expected body weight and BCS at second calving were 506 kg and 3.0 units. In this case about one-half as much sorghum supplementation, 2.2 kg/d *vs*. 5.0 kg/d, was required to achieve this goal compared to cows under baseline management during lactation and receiving sorghum grain and improved quality harvested forage during the dry period (Appendix Table 8.11.11).

6.2.2. Second-parity cows

Like primiparous cows, the predicted dietary intakes (Table 29) were expected to supply about 16% more ME than the baseline diet (23.4 *vs*. 20.2 Mcal ME/d). As a result, second parity cows were expected to improve average daily milk production in early lactation by about one-third, yielding about 13.0 kg. In addition, they relied less on the mobilization of body tissue reserves (0.50 units of BCS) to support lactation

Table 29
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for second parity cows in Genesis[a] herds calving in the season of scarce rain (October 1) fed good quality harvested forage during lactation and harvested forage supplemented by sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	0.5	5.1	6.7	…	…
High quality harvested forage[c]	4.4	4.7	0.6	7.7	7.8
Supplement[d]	4.2	3.3	5.0	…	…
Sorghum[e]	…	…	…	0.4	1.5
Total DMI, kg/d	9.1	13.1	12.3	8.1	9.3
Total dietary energy, Mcal ME/d	23.4	30.8	30.1	18.7	22.0
Total ME supply, Mcal/d[f]	25.2	30.8	30.1	18.7	22.0
Initial body weight (BW), kg[g]	489	457	559	593	593
Mean BW, kg	473	508	576	593	593
End BW, kg	457	559	593	593	593
Initial body condition score (BCS)[h]	2.75	2.25	3.50	3.50	3.50
End BCS[i]	2.25	3.50	3.50	3.50	3.50
ME allowable growth, kg/d[j]	…	0.78	0.36	…	…
Total energy requirement, Mcal ME/d[k]	25.2	24.5	30.1	18.7	22.0
Maintenance requirement, Mcal ME/d[l]	12.1	13.4	17.3	17.8	16.7
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.30
ME allowable milk production, kg/d[m]	13.0	10.5	7.4	…	…
Feed energy balance, Mcal ME/d[n]	-1.8	6.3	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 29 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent grazed forage for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for the scarce and little rain seasons.
[c]Harvested forage was assumed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a second parity cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (third) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 2768 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

than second-parity cows calving in this season with baseline management (0.75 units of BCS).

Cows in mid-lactation were predicted to consume about 30.8 Mcal ME/d, or one-fourth more energy than counterparts receiving baseline nutritional support. The corresponding average daily energy allowable milk production was 10.5 kg with about 6.3 Mcal ME available to replenish tissue reserves and for body growth (0.78 kg/d).

The increased supply of dietary energy in late lactation was sufficient to support an average daily milk production of 7.4 kg and about 34 kg of body growth (0.36 kg/d) during this stage, 60% more than with typical management. The predicted average 270-d lactation milk yield was 2768 kg, about one-third more than for the baseline case with typical management.

The predicted dietary energy supply in the early dry period (18.7 Mcal ME/d) was sufficient to maintain the already-achieved target body weight for next calving. A small average daily amount (0.4 kg) of sorghum grain was required to obtain this goal.

The target body weight and body condition were maintained during late gestation with the predicted daily intake of 22.0 Mcal ME. About 1.5 kg/d of sorghum grain was required during this stage of the calving interval to achieve this goal.

6.2.3. Multiparous cows

Predicted intakes of diets containing good quality harvested forage (Table 30) supplied multiparous cows in early lactation with about 16% more ME than typical diets for this management group of cows (26.6 *vs*. 23.0 Mcal ME/d). As a result average daily milk production in early lactation increased about two-fifths to about 15.1 kg. In addition, this performance utilized the same amount of body tissue reserves (0.50 units of BCS) as for mature cows calving in this season with typical management to support early lactation.

Table 30
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) fed good quality harvested forage during lactation and harvested forage supplemented by sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	1.6	4.0	5.2	…	…
High quality harvested forage[c]	4.4	4.7	0.6	7.9	8.8
Supplement[d]	4.4	3.5	5.2	…	…
Sorghum[e]	…	…	…	…	0.5
Total DMI, kg/d	10.4	12.2	11.0	7.9	9.3
Total dietary energy, Mcal ME/d	26.6	29.4	27.5	18.0	21.4
Total ME supply, Mcal/d[f]	28.8	29.4	27.5	18.0	21.4
Initial body weight (BW), kg[g]	550	515	550	573	573
Mean BW, kg	533	533	562	573	573
End BW, kg	515	550	573	573	573
Initial body condition score (BCS)[h]	3.00	2.50	3.00	3.25	3.25
End BCS[i]	2.50	3.00	3.25	3.25	3.25
Total energy requirement, Mcal ME/d[j]	28.8	27.1	26.0	18.0	21.4
Maintenance requirement, Mcal ME/d[k]	13.6	14.0	16.1	17.1	16.0
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	15.1	12.4	9.2	…	…
Feed energy balance, Mcal ME/d[m]	-2.2	2.3	1.5	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent grazed forage for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for the scarce and little rain seasons.

Table 30 (Continued)

[c] Harvested forage was assumed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 3303 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Cows in mid-lactation were predicted to consume about 29.4 Mcal ME/d, or about 11% more ME than with typical management. Corresponding average daily energy allowable milk production was predicted to be 12.4 kg with about 2.3 Mcal ME to replenish tissue reserves.

In late lactation these cows were predicted to produce an average 9.2 kg/d of milk. In addition, there was sufficient energy available to replete 23 kg of tissue reserves. About 40% more total milk was expected for a 270-day lactation compared to cows receiving typical management, increasing from 2331 kg to 3303 kg.

The expected daily dietary energy supply during the early dry period of multiparous cows was about 18.0 Mcal ME. This energy intake was sufficient to maintain the body weight acquired in the previous stage of calving interval.

Cows in late gestation were predicted to consume about of 21.4 Mcal ME/d to maintain body weight and to satisfy fetal growth requirements. In this case about 70% less daily supplementation with sorghum grain, 0.5 *vs.* 1.8 kg, was required to achieve this goal compared to cows receiving baseline nutrition support from sorghum grain and good quality harvested forage during the dry period (Appendix Table 8.11.15).

6.3. Effect of adding forage legume to diets with harvested grass forage of good quality.

The following sections illustrate the potential substitution value of good quality legume forage in place of poultry bedding for lactating cows calving in the season of scarce rain (October 1). Alternative diets consisted of grazing, harvested grass and legume forages, and other typical supplements during lactation, and harvested grass forage, sorghum grain and other typical supplements during the dry period. Dietary addition of legume was expected to enhance protein content and digestibility (Ramirez-Restrepo and Barry, 2005), which would be expected to result, other things being equal, in greater total feed intake and milk production.

6.3.1. Primiparous cows

As hypothesized, the substitution of legume for poultry bedding was predicted to result in about one-fifth more milk than was expected from diets enriched only with good quality harvested grass (plus sorghum grain). Compared to typical management the combination of good quality grass and legume forages resulted in about 60% more milk production (Table 31). As a result, predicted 270-d milk production for this management group was 3129 kg, 515 kg more milk than from diets including good-quality harvested grass forage only.

6.3.2. Second-parity cows

The substitution of legume for poultry bedding had a similar effect on milk yield in second lactation compared to typical management (Table 32). About one-fifth more milk was predicted from diets with harvested grass and legume of good quality. As a result, predicted lactation milk production for this management group was 3313 kg, an increase of 545 kg over diets supported by harvested grass only.

6.3.3. Multiparous cows

Legume substitution in lieu of poultry bedding also resulted in similar milk yield increases (Table 33) for mature cows. The predicted 270-d lactation milk production for this management group was 3699 kg, an increase of 396 kg over diets supported by harvested grass only.

6.4. Cumulative, multi-lactation effects from systematic incorporation of good quality harvested grass forage for improved diets

The following sections report the expected responses in milk production for cows in their second and third lactations calving in the season of scarce rain (October 1) and receiving diets with good quality harvested grass forage and judicious supplementation with sorghum grain from first parturition. As previously shown, these cows would become less vulnerable from energy deficiencies throughout their productive lifetimes. As a result, cows receiving alternative management would be permitted to grow more, would consume more forage, and would achieve heavier body weights with desirable pools of body tissue reserves to initiate lactation than their counterparts with baseline management. Greater feed intake capacity by larger cows of all ages, especially from good quality harvested forage, is expected to underwrite higher lifetime milk production and better reproductive efficiency (Urbina, 1999), i.e., more calves per cow lifetime (Vera et al., 1993).

6.4.1. Second-parity cows

Greater intake of dietary energy from better quality harvested grass forage consumed by cows that achieved larger body size at this age and desirable BCS at calving (Table 34) resulted in higher predicted milk production than for cows of typical body weight and BCS. As a result, predicted 270-d milk production in second lactation increased by two-thirds compared to the baseline scenario, or 1421 kg, to 3536 kg for this management group.

6.4.2. Third-parity cows

Greater intake of dietary energy from better quality harvested grass forage consumed by mature cows that had grown more rapidly to achieve larger body size at this age and desirable BCS at calving (Table 35) also resulted in about two-thirds

Table 31
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) with supplemental higher quality forage and legume instead of poultry bedding during lactation with amounts of sorghum and high quality harvested forage needed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	0.0	3.5	5.9	…	…
High quality harvested forage[c]	4.4	4.7	0.6	8.2	5.7
Supplement[d]	3.1	2.3	3.2	…	…
Legume[e]	1.6	0.8	0.8	…	…
Sorghum[e]	…	…	…	…	2.2
Total DMI, kg/d	9.1	11.3	10.5	8.2	7.9
Total dietary energy, Mcal ME/d	24.0	27.4	26.3	18.6	19.6
Total ME supply, Mcal/d[f]	25.7	27.4	26.3	18.6	19.6
Initial body weight (BW), kg[g]	426	398	451	482	510
Mean BW, kg	412	425	467	496	510
End BW, kg	398	451	482	510	510
Initial body condition score (BCS)[h]	2.75	2.25	3.00	3.00	3.00
End BCS[i]	2.25	3.00	3.00	3.00	3.00
ME allowable growth, kg/d[j]	…	…	0.33	0.21	…
Total energy requirement, Mcal ME/d[k]	25.7	23.8	26.3	18.6	19.6
Maintenance requirement, Mcal ME/d[l]	10.8	11.4	13.9	15.1	14.6
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.0
ME allowable milk production, kg/d[m]	14.6	11.8	8.3	…	…
Feed energy balance, Mcal ME/d[n]	-1.7	3.6	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 31 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent grazed forage for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for scarce and little rain seasons.
[c] Harvested forage was assumed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Average value of *Gliricidia sepium* and *Leucaena leucocephala*. This legume substituted the poultry bedding supplementation. Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 3129 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Table 32
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for second parity cows in Genesis[a] herds calving in the season of scarce rain (October 1) with supplemental higher quality forage and legume instead of poultry bedding during lactation with amounts of sorghum and high quality harvested forage needed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	0.5	5.9	7.7	…	…
High quality harvested forage[c]	4.4	4.7	0.6	7.7	7.8
Supplement[d]	3.4	2.5	3.4	…	…
Legume[e]	1.6	0.8	0.8	…	…
Sorghum[e]	…	…	…	0.4	1.4
Total DMI, kg/d	9.9	13.9	12.5	8.1	9.2
Total dietary energy, Mcal ME/d	25.9	32.9	31.0	18.7	21.9
Total ME supply, Mcal/d[f]	27.7	32.9	31.0	18.7	21.9
Initial body weight (BW), kg[g]	489	457	559	592	592
Mean BW, kg	473	508	576	592	592
End BW, kg	457	559	592	592	592
Initial body condition score (BCS)[h]	2.75	2.25	3.50	3.50	3.50
End BCS[i]	2.25	3.50	3.50	3.50	3.50
ME allowable growth, kg/d[j]	…	0.78	0.33	…	…
Total energy requirement, Mcal ME/d[k]	27.7	26.5	31.0	18.7	21.9
Maintenance requirement, Mcal ME/d[l]	12.0	13.3	17.1	17.8	16.6
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.30
ME allowable milk production, kg/d[m]	15.5	12.5	8.8	…	…
Feed energy balance, Mcal ME/d[n]	-1.8	6.4	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 32 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent grazed forage for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for scarce and little rain seasons.
[c] Harvested forage was assumed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Average value of *Gliricidia sepium* and *Leucaena leucocephala*. This legume substituted the poultry bedding supplementation. Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a second calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (third) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 3313 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Table 33
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) with supplemental higher quality forage and legume instead of poultry bedding during lactation with amounts of sorghum and high quality harvested forage needed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	1.5	4.7	6.2	…	…
High quality harvested forage[c]	4.4	4.7	0.6	8.1	8.2
Supplement[d]	3.6	2.7	3.6	…	…
Legume[e]	1.6	0.8	0.8	…	…
Sorghum[e]	…	…	…	…	1.0
Total DMI, kg/d	11.1	12.9	11.2	8.1	9.2
Total dietary energy, Mcal ME/d	28.9	31.1	28.4	18.3	21.6
Total ME supply, Mcal/d[f]	31.0	31.1	28.4	18.3	21.6
Initial body weight (BW), kg[g]	550	515	552	579	579
Mean BW, kg	533	534	566	579	579
End BW, kg	515	552	579	579	579
Initial body condition score (BCS)[h]	3.00	2.50	3.00	3.25	3.25
End BCS[i]	2.50	3.00	3.25	3.25	3.25
Total energy requirement, Mcal ME/d[j]	31.0	28.6	26.6	18.3	21.6
Maintenance requirement, Mcal ME/d[k]	13.5	14.0	16.1	17.4	16.2
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	17.4	13.9	9.8	…	…
Feed energy balance, Mcal ME/d[m]	-2.1	2.5	1.8	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent grazed forage for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for the scarce and little rain seasons.

Table 33 (Continued)

[c] Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Average value of *Gliricidia sepium* and *Leucaena leucocephala*. This legume substituted the poultry bedding supplementation. Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 3699 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Table 34
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for second parity cows calving in the season of scarce rain (October 1) and receiving supplemental higher quality harvested forage and sorghum grain since their first calving interval in Genesis[a] herds.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	2.5	5.0	6.0	…	…
High quality harvested forage[c]	4.4	4.7	0.6	7.1	7.3
Supplement[d]	4.2	3.3	5.0	…	…
Sorghum[e]	…	…	…	0.3	1.7
Total DMI, kg/d	11.1	13.0	11.6	7.4	9.0
Total dietary energy, Mcal ME/d	28.1	30.7	28.5	17.0	21.4
Total ME supply, Mcal/d[f]	30.1	30.7	28.5	17.0	21.4
Initial body weight (BW), kg[g]	510	482	521	542	542
Mean BW, kg	496	502	532	542	546
End BW, kg	482	521	542	542	550
Initial body condition score (BCS)[h]	3.00	2.50	3.25	3.25	3.25
End BCS[i]	2.50	3.25	3.25	3.25	3.00
ME allowable growth, kg/d[j]	…	0.12	0.22	…	0.09
Total energy requirement, Mcal ME/d[k]	30.1	27.6	28.5	27.0	21.4
Maintenance requirement, Mcal ME/d[l]	13.0	13.5	15.7	16.1	15.1
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.30
ME allowable milk production, kg/d[m]	16.5	13.4	9.4	…	…
Feed energy balance, Mcal ME/d[n]	-2.0	3.1	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 34 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent grazed forage for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for the scarce and little rain seasons.
[c]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a second parity cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (third) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 3536 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Table 35

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for third parity cows calving in the season of scarce rain (October 1) and receiving supplemental higher quality harvested forage and sorghum grain since their first calving interval in Genesis[a] herds.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	3.8	4.7	5.2	…	…
High quality harvested forage[c]	4.4	4.7	0.6	7.6	8.5
Supplement[d]	4.4	3.5	5.2	…	…
Sorghum[e]	…	…	…	…	0.5
Total DMI, kg/d	12.6	12.9	11.0	7.6	9.0
Total dietary energy, Mcal ME/d	31.8	30.8	27.7	17.4	20.8
Total ME supply, Mcal/d[f]	33.7	30.8	27.7	17.4	20.8
Initial body weight (BW), kg[g]	584	553	553	558	558
Mean BW, kg	569	553	556	558	558
End BW, kg	553	553	558	558	558
Initial body condition score (BCS)[h]	3.50	3.00	3.00	3.00	3.00
End BCS[i]	3.00	3.00	3.00	3.00	3.00
Total energy requirement, Mcal ME/d[j]	33.7	30.8	27.3	17.4	20.8
Maintenance requirement, Mcal ME/d[k]	15.0	15.2	16.0	16.5	15.4
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	18.3	14.8	10.5	…	…
Feed energy balance, Mcal ME/d[m]	-1.9	0.0	0.4	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent grazed forage for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for scarce and little rain seasons.

Table 35 (Continued)

[c] Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 3929 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

greater lactation milk yield compared to counterparts receiving typical inputs. As a result, predicted milk production in third lactation for this management group was 3929 kg, an increase of 1598 kg.

6.5. Cumulative, multi-lactation effects from systematic inclusion of good quality legume forage in addition to harvested grass forage to improve diets

The following sections report the expected responses in milk production by cows in their second and third lactation calving in the season of scarce rain (October 1). These cows received from their first parturition forage legume instead of poultry bedding in diets with good quality harvested grass forage supplemented with sorghum grain.

6.5.1. Second-parity cows

Like previous analyses of management alternatives based on improved forage quality, these cows were predicted to consume more dietary energy (Table 36) than counterparts not fed legume forage. Consequently, milk production was predicted to increase 298 kg, to 3834 kg, which represents about 8% more milk compared to the cumulative case with harvested grass. In addition, predicted milk production in this management group increased by 1719 kg to 3834 kg, which constitutes 80% more milk than from counterparts receiving typical inputs in the baseline scenario.

6.5.2. Third-parity cows

Greater intake of dietary energy from the legume substitution (Table 37) among mature cows resulted in about 8% greater lactation milk yield compared to larger body size counterparts consuming good quality harvested grass forage. As a result, predicted milk production in third lactation for this management group was

Table 36

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for second parity cows calving in the season of scarce rain (October 1) and receiving supplemental higher quality harvested forage plus legume and sorghum grain starting at first parturition in Genesis[a] herds.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	2.0	6.2	8.5	…	…
High quality harvested forage[c]	4.4	4.7	0.6	7.7	7.8
Supplement[d]	3.4	2.5	3.4	…	…
Legume[e]	1.6	0.8	0.8	…	…
Sorghum[e]	…	…	…	0.4	1.4
Total DMI, kg/d	11.4	14.2	13.3	8.1	9.2
Total dietary energy, Mcal ME/d	29.4	33.5	32.7	18.7	21.9
Total ME supply, Mcal/d[f]	31.4	33.5	32.7	18.7	21.9
Initial body weight (BW), kg[g]	506	473	559	592	592
Mean BW, kg	490	516	576	592	592
End BW, kg	473	559	592	592	592
Initial body condition score (BCS)[h]	3.00	2.50	3.50	3.50	3.50
End BCS[i]	2.50	3.50	3.50	3.50	3.50
ME allowable growth, kg/d[j]	…	0.78	0.33	…	…
Total energy requirement, Mcal ME/d[k]	31.4	28.1	32.7	18.7	21.9
Maintenance requirement, Mcal ME/d[l]	12.7	13.7	17.1	17.8	16.6
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.30
ME allowable milk production, kg/d[m]	18.5	13.7	10.4	…	…
Feed energy balance, Mcal ME/d[n]	-2.0	5.4	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 36 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent grazed forage for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for scarce and little rain seasons.
[c]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Average value of *Gliricidia sepium* and *Leucaena leucocephala*. This legume substituted the poultry bedding supplementation. Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a second calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (third) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 3834 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Table 37
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for third parity cows calving in the season of scarce rain (October 1) and receiving supplemental higher quality harvested forage plus legume and sorghum grain starting at first parturition in Genesis[a] herds.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	2.7	5.9	7.0	…	…
High quality harvested forage[c]	4.4	4.7	0.6	8.1	8.2
Supplement[d]	3.6	2.7	3.6	…	…
Legume[e]	1.6	0.8	0.8	…	…
Sorghum[e]	…	…	…	…	1.0
Total DMI, kg/d	12.3	14.1	12.0	8.1	9.2
Total dietary energy, Mcal ME/d	31.5	33.5	30.1	18.3	21.6
Total ME supply, Mcal/d[f]	33.6	33.5	30.1	18.3	21.6
Initial body weight (BW), kg[g]	550	515	552	579	579
Mean BW, kg	533	534	566	579	579
End BW, kg	515	552	579	579	579
Initial body condition score (BCS)[h]	3.00	2.50	3.00	3.25	3.25
End BCS[i]	2.50	3.00	3.25	3.25	3.25
Total energy requirement, Mcal ME/d[j]	33.6	31.1	28.3	18.3	21.6
Maintenance requirement, Mcal ME/d[k]	13.6	14.1	16.1	17.4	16.2
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	19.9	16.1	11.4	…	…
Feed energy balance, Mcal ME/d[m]	-2.1	2.4	1.8	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses was used to represent grazed forage for the seasons of early and late rains, and *Andropogon gayanus* was used for grazed forage for the scarce and little rain seasons.

Table 37 (Continued)

[c] Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silage.
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Average value of *Gliricidia sepium* and *Leucaena leucocephala*. This legume substituted the poultry bedding supplementation. Sorghum chemical information is from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.50 units of BCS.
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 4260 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

4260 kg, an increase of 1929 kg, or 80% more lactation milk yield than from typical inputs in the baseline case.

Table 38 summarizes CNCPS-predicted lactation yields for cows with typical (frequently underweight) and desirable body weights and BCS at calving that consume typical (baseline) diets or alternative diets containing harvested grass and legume forage of good quality. The substitution of harvested grass forage of good quality for grazing is expected to potentially increase milk yields by about one-third (625 kg in first, 653 in second and 972 kg more milk in third lactation) over typical scenarios for underweight cows (Figure 4). However, if cows grow to achieve desirable body weights, receiving this dietary support from their first calving, milk production in second and third lactations would be substantially improved, about 60%, with predicted increases of 1421 kg and 1598 kg, respectively. Judiciously supplemented diets based on good quality grass that also incorporated legume forages starting at first calving were predicted to further increase productivity. About 80% more milk would be expected (Table 38) compared to the baseline nutritional regime (i.e., from group management with CNCPS monitoring and properly supplemented diets with good forage quality).

6.6. Economic assessment

A simple partial budgeting analysis of marginal costs and returns provided an approximation of the potential economic incentive to implement alternative dietary management in Genesis herds. The principal strategy involves greater investment by farmers to produce good quality harvested grass forage, relying on it during times of grazing scarcity and to replace forages of lower quality throughout a cow's lifetime. Therefore, the economic assessment was focused on a strategy where cows would receive the above mentioned dietary management beginning at their first calving.

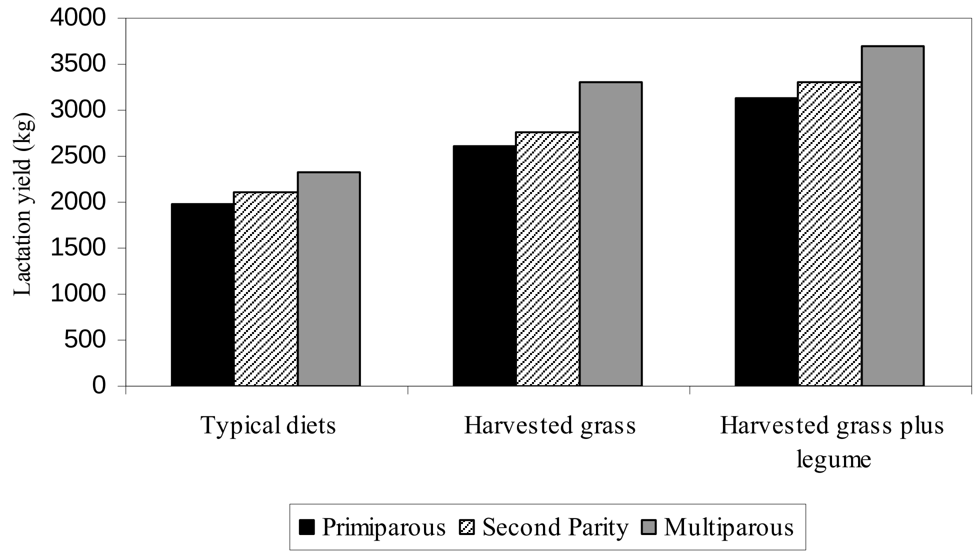


Figure 4 Predicted 270-d lactation milk yields for cows calving in the season of scarce rain (October 1) with typical body weights and condition scores and underweight cows with low condition scores consuming diets with harvested grass and harvested grass plus legume.

Table 38

Predicted 270-d lactation milk yields[a] and expected yield increases (kg) for cows with typical (underweight) or desirable body weights and condition scores at calving in the season of scarce rain (October 1) and fed typical (baseline) or alternative diets containing harvested grass forage and legume of good quality.

Parity	Typical diet	Harvested grass[b]		Yield increase (grass minus typical)		Harvested grass plus legume[c]		Yield increase (grass plus legume minus grass)	
		Under weight	Desired weight	Under weight	Desired weight	Under weight	Desired weight	Under weight	Desired weight
1	1989	2614	2614	625	625	3129	3129	515	515
2	2115	2768	3536	653	1421[d]	3313	3834	545	298[e]
3	2331	3303	3929	972	1598[d]	3699	4260	396	331[e]

[a]These milk yields correspond to single lactation yields and their corresponding cumulative effects across 1 lactation for cows consuming harvested grass diets and harvested grass plus legume over a 3-lactation lifetime.

[b]About 30% increment in milk production occurred compared to baseline case.

[c]About 15% more milk production was predicted compared to harvested grass of good quality.

[d]Additional milk from providing good quality harvested forage to cows calving during the season of scarce rain throughout a 3-lactation lifetime.

[e]Additional milk from providing good quality harvested forage plus legume to cows calving during the season of scarce rain throughout a 3-lactation lifetime compared to cows receiving harvested grass of good quality with desirable BW and BCS.

An additional component of this strategy involved the substitution of good quality legume forage for poultry bedding in early lactation. Protein is especially needed at this time to complement energy supplies from the mobilization of body tissues for milk synthesis. The corresponding marginal changes in income over feed cost were obtained from estimated increases (decreases) in harvested forages and sorghum grain (poultry bedding) to obtain predicted increases in lactation milk production and body growth of immature cows. Increases in net margin in this study indicate the value of improved milking performance but do not account for the potential increased revenues from sales of heavier culled cows and more calves from better dietary energy support of reproduction.

Table 39 shows the changes in net margin (ΔNM) from incorporating either good quality harvested grass or grass combined with forage legume (in lieu of poultry bedding) into diets that are appropriately supplemented with sorghum grain across the first three lactations of a cow's lifetime. The corresponding large increases in net margin across a (truncated) 3-lactation cow lifetime, \$670 from diets relying on harvested grass and \$935 from diets relying on grass plus legume, correspond to milk sales equivalent to total yield from at least one additional lactation per cow. If net margin from the first three lactations is approximately 50% of milk sales (i.e., NM = 0.50 [6435 kg milk × \$0.32/kg]) then this strategy may be expected to increase NM by about 65% (grass) or 90% (grass + legume) compared to typical management (Table 39). For the adoption of new technologies with which they are familiar, farmers have been found to require at least a 50% increase in expected net margins (CIMMYT, 1988). Therefore, this expected outcome clearly represents a substantial economic incentive for farmers to greatly reduce cow management group vulnerability and improve herd productivity by investing in the production of better quality harvested forage.

Genesis members are expected to obtain additional economic benefits that were not estimated in this study. These include increases in the expected average productive lifetime resulting in more calf sales and more total milk production, and in greater salvage values from heavier cows at culling. In conclusion, Genesis farmers, and probably many other dual purpose herd owners in coastal Veracruz, apparently have large economic incentives to increase milk and calf sales and net incomes by implementing nutritional management strategies like those considered in this study.

Fundamentally important to this strategy is quality control of good quality forages (i.e., analysis and monitoring of chemical composition), thrifty production of harvested forages, and their separate storage for feeding to management groups of cows that differ in their nutritional requirements. Furthermore, sensitive herd management depends on the effective use of a nutrition tool like the CNCPS model. The outcomes predicted in this study correspond to a monitoring protocol throughout calving intervals of cow management groups that are defined by forage season of calving, age of cow, and physiological stages of the calving interval.

Table 39
Changes in net margin and feed cost from improved dietary quality to obtain greater milk production in a 3-lactation lifetime of cows calving in the forage season of scarce rain in Genesis herds ($US).

Variable	Harvested grass	Harvested grass plus legume
Milk production		
Δ milk, kg/3-lactation lifetime	3644	4788
Revenues and variable costs		
Δ Milk sales, $/3-lactations[a]	1166	1532
Feed costs, $/3-lactations [a]		
Poultry bedding[b]	…	-35
Sorghum[c]	100	106
Good quality grass forage[d]	396	396
Legume[e]	…	130
Δ Total variable costs	496	597
Δ Net margin, $/3-lactations	670	935

[a]Negative values indicate reduced usage. Positive values indicate additional input use. Milk price = $0.32/kg
[b]Cost per kg of dry matter (DM) = $0.04
[c]Cost per kg of DM = $0.24
[d, e]Cost per kg of DM = $0.15

7.0 Conclusions

This case study clearly identified key biological (energetic) and management limitations affecting dual-purpose cattle herds in the central coastal region of Veracruz. It is believed to be the first published study for a tropical environment to systematically evaluate the interactions of energy balance, milk production, expected growth in immature cows and, indirectly, probable effects on calving interval for specified cow management groups. Cow management groups, defined by three age classifications (parities 1, 2 and >2), four forage seasons of calving (early rains, late rains, scarce rain, and little rain), and five sequential physiological stages of lactation (3 stages of lactation and 2 stages during the dry period), were evaluated across the production cycles. In addition to a constraints analysis of productivity and profitability bottlenecks, a strategic set of nutrition management alternatives were considered in an evaluation consisting of 162 simulations to describe productivity status of cows and potentials for improved milk production and profit.

Results showed accurate representation of typical lactation productivity scenarios for Genesis herds by the CNCPSv6 model. Findings also revealed important cow and herd vulnerabilities constraining milk production and, probably, reproductive performance (i.e., calf production) by the cow. Average CNCPS-predicted milk production outcomes based on chemical composition of feeds and typical feeding policy agreed with the overall Genesis herd performance (Rodriguez-Morales et al., 2005), and with milking performance by INIFAP's La Posta herd for crossbred cows from the same genetic group consuming forages grown in the same agroecozone. This study clearly showed the CNCPS is a valuable tool in identifying nutritional constraints and monitoring productivity cycles (calving intervals) of cows. This outcome underwrites the accuracy of predicting sensible differential outcomes from alternative management strategies aimed at improving productivity and herd profit.

Findings from the analysis of baseline scenarios suggested two key vulnerabilities constraining cow productivity: chronic energy deficits among dry cows of all ages and impeded growth among immature cows. Regardless of the forage season of calving, most, if not all, cows incur energy deficits in their dry period, especially the last trimester of gestation. Negative feed energy balance prior to parturition reduces the pool of tissue energy that is available for milk synthesis, thus constraining milk production in the next lactation. Alternatively these energy deficits signify calving intervals that are longer than the averages considered in this study. Correspondingly, fewer calves would be born (and less total milk produced) per cow productive lifetime. Energy supplies often resulted in thin body condition scores and slow or arrested growth in young (immature) cows. Consequently, cows under typical management conditions are frequently smaller and underweight for their age, which limits their feed intake capacity, milk production and the probability of early postpartum return to ovarian cyclicity.

Consequently, a management approach was developed using affordable feeds, especially good quality harvested grass forage (e.g., grass hay, maize silage) to reduce the risks of cow vulnerability by assuring growth of immature cows and desirable body tissue reserves throughout lactation. The substitution of harvested grass forage of good quality for grazing increased milk yields by about one-third (625 kg in first, 653 in second and 972 kg more milk in third lactation) over typical scenarios for underweight cows. When diets from first parturition properly supported cow growth and tissue repletion to obtain desirable body weights, milk production in second and third lactations was substantially improved, about 60%, with predicted increases of 1421 kg and 1598 kg, respectively. Judiciously supplemented diets based on good quality grass that also incorporated legume forages starting at first calving were predicted to further increase productivity. About 80% more milk would be expected compared to the baseline nutritional regime (i.e., from group management with CNCPS monitoring and properly supplemented diets with good forage quality). Contributions from larger pools of body tissue reserves resulted in greater lactation milk yields and earlier return to ovarian cyclicity.

The changes in net margin (ΔNM) from incorporating either good quality harvested grass or grass combined with forage legume (in lieu of poultry bedding) into properly supplemented diets resulted in large increases in net margin across a (truncated) 3-lactation cow lifetime ($670 from diets relying on harvested grass and $935 from diets relying on grass plus legume). These values corresponded to at least one additional lactation per cow. This strategy may result in about 65% (grass) or 90% (grass + legume) greater NM compared to typical management. This expected outcome clearly represents a substantial economic incentive for farmers to improve herd productivity by investing in the production of better quality harvested forage to minimize production vulnerabilities of cow groups managed with tools like the CNCPS model. Additional expected economic benefits were not accounted in this study. These included increases in the expected average productive lifetime of cows, which means more calf sales, more total milk production, and heavier cows at culling.

In conclusion, Genesis farmers, and probably many other dual purpose herd owners in coastal Veracruz, apparently have large economic incentives to increase milk and calf sales and net incomes by implementing nutritional management strategies like those considered in this study. Fundamental to this achievement is quality control of good quality forages (i.e., analysis and monitoring of chemical composition), thrifty production of harvested forages, and their separate storage for feeding to management groups of cows that differ in their nutritional requirements. In addition, sensitive herd management depends on the effective use of a nutrition tool like the CNCPS model.

APPENDICES

8.1. Total Mexican exports of live calves to the U.S. for the period 1990 to 2005.

8.2. Summary of recommended management practices for use of farmers of GGAVATT Génesis members.

8.3. Land area distribution in the coastal plain of Veracruz.

8.4. List of the ranches belonging to the GGAVATT Genesis membership; the list includes the size of each ranch and cattle owned by each member.

8.5. Crossbred distribution within the GGAVATT Genesis herds.

8.6. Body condition scores throughout the calving interval of cows in a typical Sotavento, Veracruz dual-purpose herd as recommended by a panel of professionals.

8.7. Rivers, slopes, locations, rainfall distribution, altitudes and land use.

8.8. Contrasting activity environmental conditions to evaluate the sensitivity of Cornell Net Carbohydrate and Protein System predictions of animal energy requirements for maintenance.

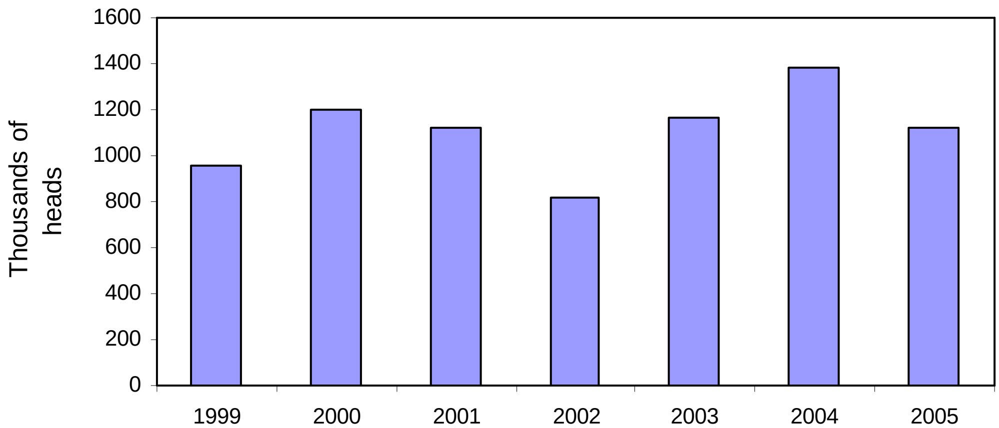
8.9. Impact of environmental factors affecting energy requirements for maintenance and milk.

8.10. Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in non-GGAVATT herds calving in alternative seasons of the year under baseline nutrition management.

8.11. Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous and multiparous cows in Genesis[a] herds calving in alternative seasons under baseline nutrition management during lactation with sorghum only supplementation and good quality harvested forage supplemented with sorghum grain during the dry period.

8.12. Quantities of sorghum grain and supplemental forage of good quality required during the dry period to obtain target body condition scores at next calving for primiparous and multiparous cows calving in different forage seasons of the year.

Appendix 8.1
Total Mexican exports of live calves to the U.S. for the period 1990 to 2005.

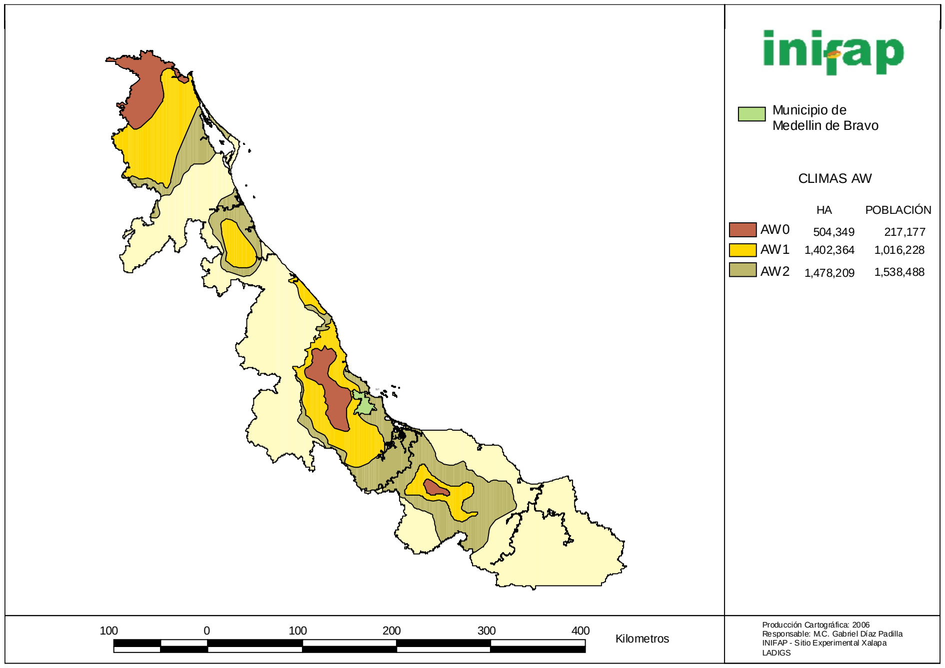


Since 1990, Mexico has been exporting important number of calves to the U.S. Exports are closely related to the U.S. demand. If price is low, compared to what U.S. is used to pay, calves are raised and finished in Mexico for domestic consumption. This information includes males and females calves and heifers (Gallardo-Nieto et al., 2006).

Appendix 8.2
Summary of recommended management practices for use of farmers of GGAVATT Génesis members

Management practices	Percentage used (%)
Pasture	
Weed control	100
Pasture re-establishment	100
Forage conservation (hay, silage)	100
Rotational grazing	100
Fertilization	0
Dietary supplementation	
Minerals	100
Concentrates	100
Animal health	
Vaccination (e.g., rabdovirus, clostridia) and drenching	60
Tuberculosis test	100
Brucellosis test	100
Tick control	50
California mastitis test	64
Reproduction	
Reproductive health check of the bull (semen motility)	71
Pregnancy diagnosis	50
Anoestrus treatment	0
Record keeping (animal identification, performance, costs)	100

Appendix 8.3
Land area distribution in the coastal plain of Veracruz



This digital map shows the distribution of the Aw climates, total number of hectares that falls in each climate zone type.

Aw_0 is a warm and moist climate with average annual temperature higher than 22° C and coldest monthly mean temperature higher than 18° C. The rainfall during the driest month is between 0 and 60 mm; during summer less than 43.2 % of the total rainfall occurs and during winter from 5 to 10.2% of the total rainfall occurs.

Aw_1 is a warm and moist climate with average annual temperature higher than 22° C and coldest monthly mean temperature higher than 18° C. The rainfall during the driest month is less than 60 mm; during summer between 43.2 and 55.3 % of the total rainfall occurs and during winter from 5 to 10.2% of the total rainfall occurs.

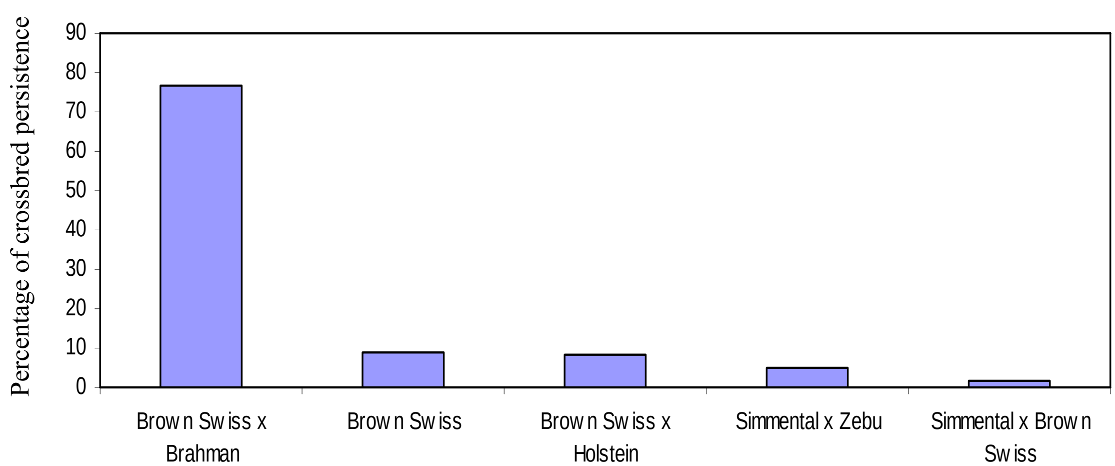
Aw_2 is a warm and moist climate with average annual temperature higher than 22° C and coldest monthly mean temperature higher than 18° C. The rainfall during the driest month is between 0 and 60 mm; during summer more than 55.3 % of the total rainfall occurs and during winter from 5 to 10.2% of the total rainfall occurs (Diaz-Padilla and Cortina-Cardea, 2006).

Note: The differences among the Aw subtypes are based on the rainfall distribution during summer and winter. They are not based on the total rainfall of each subtype since there are variations in total rainfall from one municipality to another.

Appendix 8.4
List of the ranches belonging to the GGAVATT Genesis membership; the list includes the size of each ranch and cattle owned by each member.

Name	Farm name	Farm size (ha)	Cattle owned
José A. Muñiz Montiel	Los Capulines	24	98
José A. Morales García	El Potrillo	28	47
Vicente Muñiz Morales	Santa Inés	34	110
Fermín Morales Aguilar	El Picadero	38	52
Nazario Rivera Hernández	Los Rivera	44	80
Andrés Muñiz Susunaga	Los Capulines	45	69
José A. Espinoza Morales	Mata Espino	52	32
José Ma. Rodríguez Morales	El Crecido	67	91
Abel Morales Aguilar	La Breña	73	155
Agustín Álvarez Lagunas	Buena Vista	73	278
Pedro Vargas Fernández	Paso Flores	81	63
Daniel Pérez Valdez	El Jícaro	98	157
Tomás Muñiz Morales	La Breña	98	100
José A. Lagunes Meza	El Ancla	100	97
Saúl Muñiz Rivera	Soyolapan	142	60
Juan A. Lagunes Morales	El Jícaro	147	253
David Muñiz Rivera	Soyolapan	148	58
José J. Muñiz Renteral	San Ramón	283	214
Total	18	1575	2014

Appendix 8.5
Crossbred distribution within the GGAVATT Genesis herds



Three-fourths of the animals owned by this GGAVATT are mostly crosses Brown Swiss x Brahman (Rodriguez-Morales et al., 2005).

Appendix Table 8.6

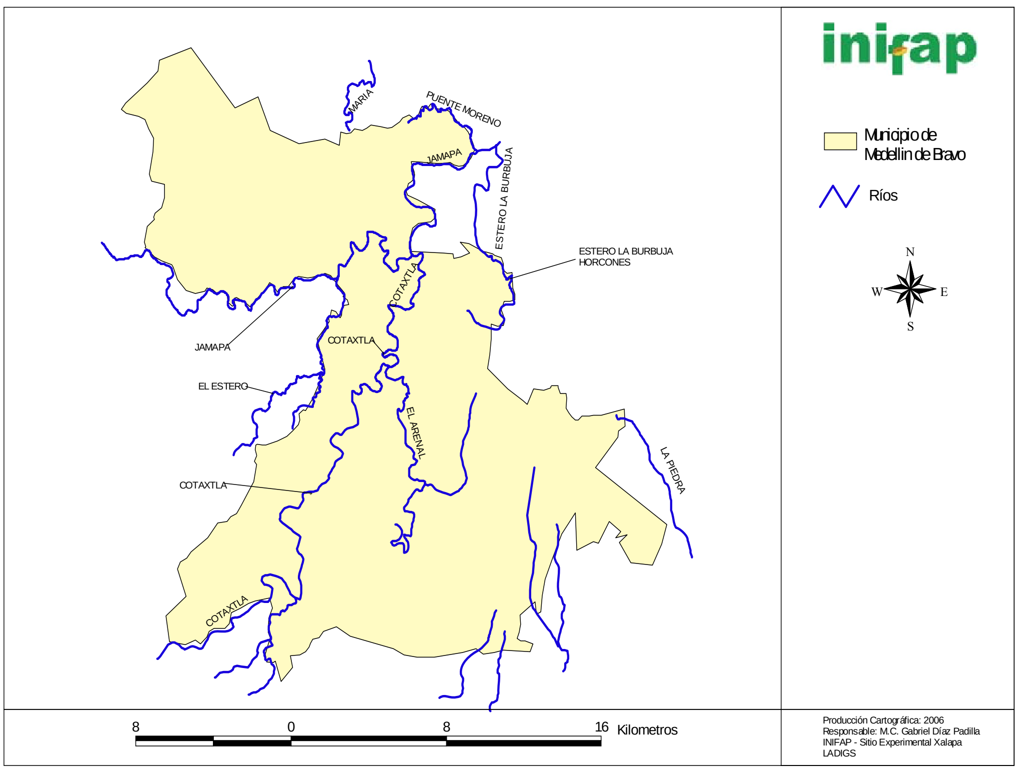
Body condition scores throughout the calving interval of cows in a typical Sotavento, Veracruz dual-purpose herd as recommended by a panel of professionals[a]

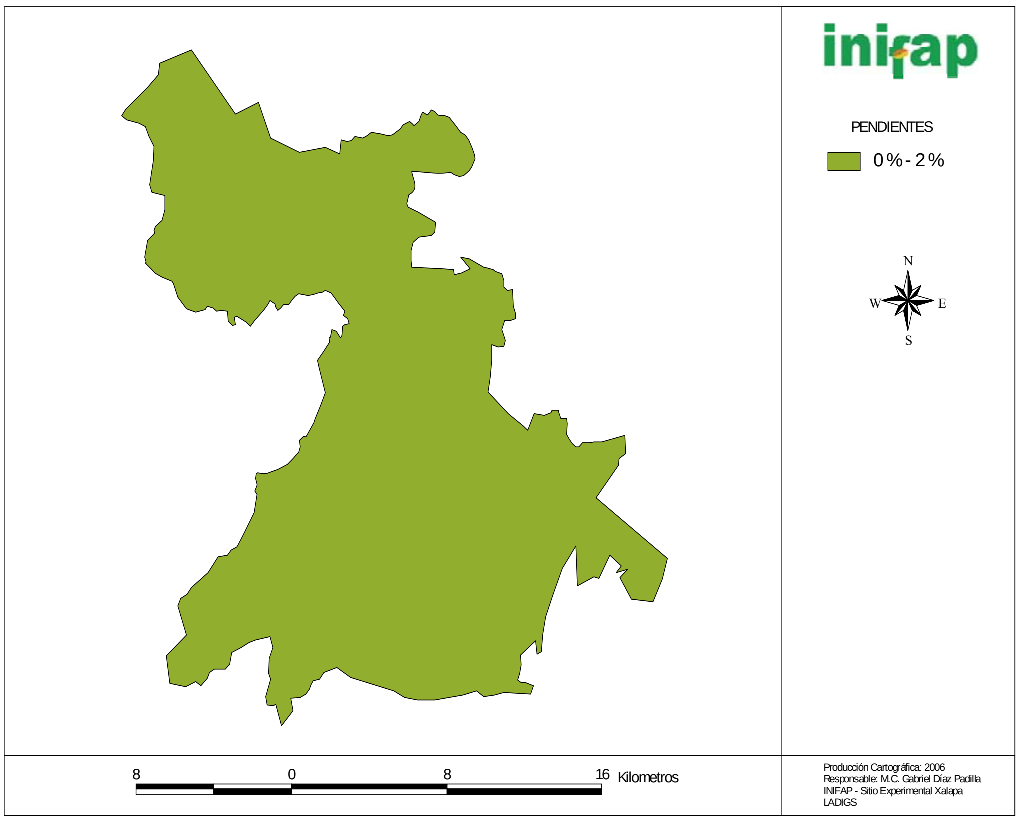
Early rains[b]							Late rains[c]						
	Lactation				Dry period			Lactation				Dry period	
Parity	Calving[f]	Early[g]	Mid[h]	Late[i]	Early[j]	Late[k]	Parity	Calving	Early	Mid	Late	Early	Late
1	2.75	2.00	2.25	2.00	2.25	3.00	1	3.0	2.25	2.00	2.25	2.75	3.25
2	3.00	2.50	2.25	2.50	2.75	3.00	2	3.0	2.50	2.25	2.50	3.00	3.50
>2	3.00	2.50	2.25	2.50	2.75	3.00	>2	3.0	2.75	2.50	2.75	3.00	3.50

Scarce rain[d]							Little rain[e]						
	Lactation				Dry period			Lactation				Dry period	
Parity	Calving	Early	Mid	Late	Early	Late	Parity	Calving	Early	Mid	Late	Early	Late
1	2.75	2.25	2.00	2.25	2.75	3.00	1	2.50	2.25	2.00	2.25	2.75	3.00
2	2.75	2.50	2.25	2.50	3.00	3.00	2	2.50	2.25	2.25	2.50	2.75	3.00
>2	3.00	2.75	2.50	2.75	3.00	3.25	>2	2.75	2.50	2.75	3.00	3.00	3.25

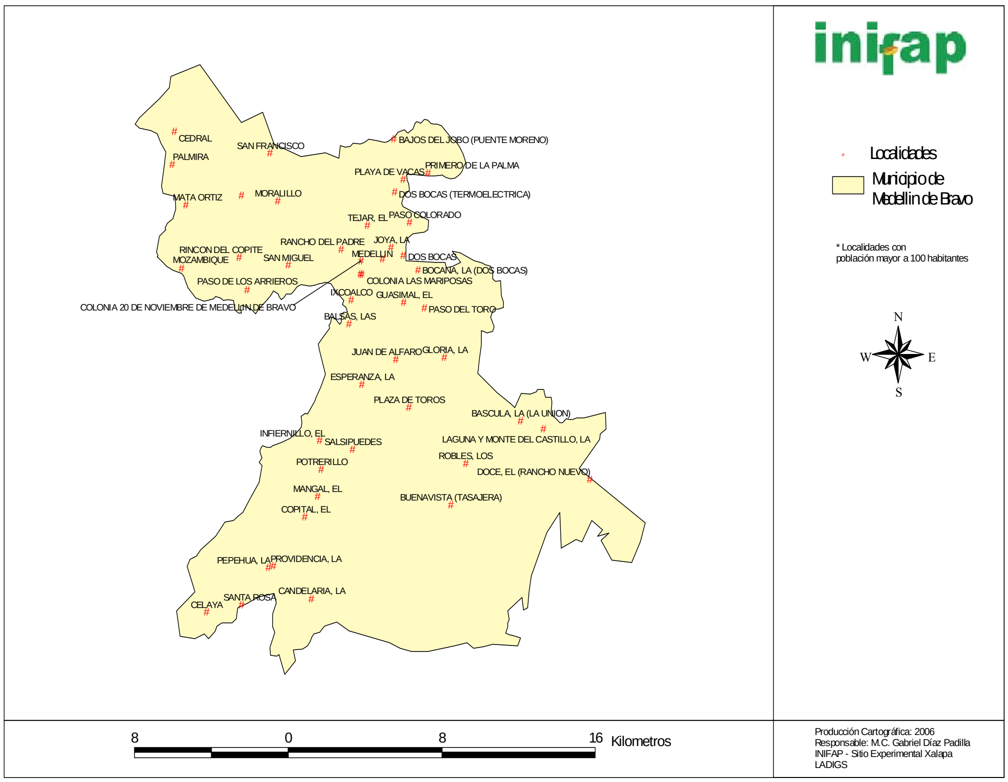
[a]Panel members are F. Juárez, E. Canudas (professors at the Universidad Veracruzana); B. Rueda, (researcher at the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias)]
[b]Early rains = June 1 to July 31.
[c]Late rains = August 1 to September 30.
[d]Scarce rain = October 1 to December 31.
[e]Little rain = January 1 to May 31.
[f]BCS at calving was utilized in the CNCPS simulations; others were based on assumed BW changes. [g]Early lactation period = days 1 to 90 postpartum. [h]Mid lactation = days 91 to 180. [i]Late lactation = 181 to 270 days postpartum.
[j]Early dry has a variable length of period (table 6). [k]Late dry period = 90 days prior to calving (late gestation).

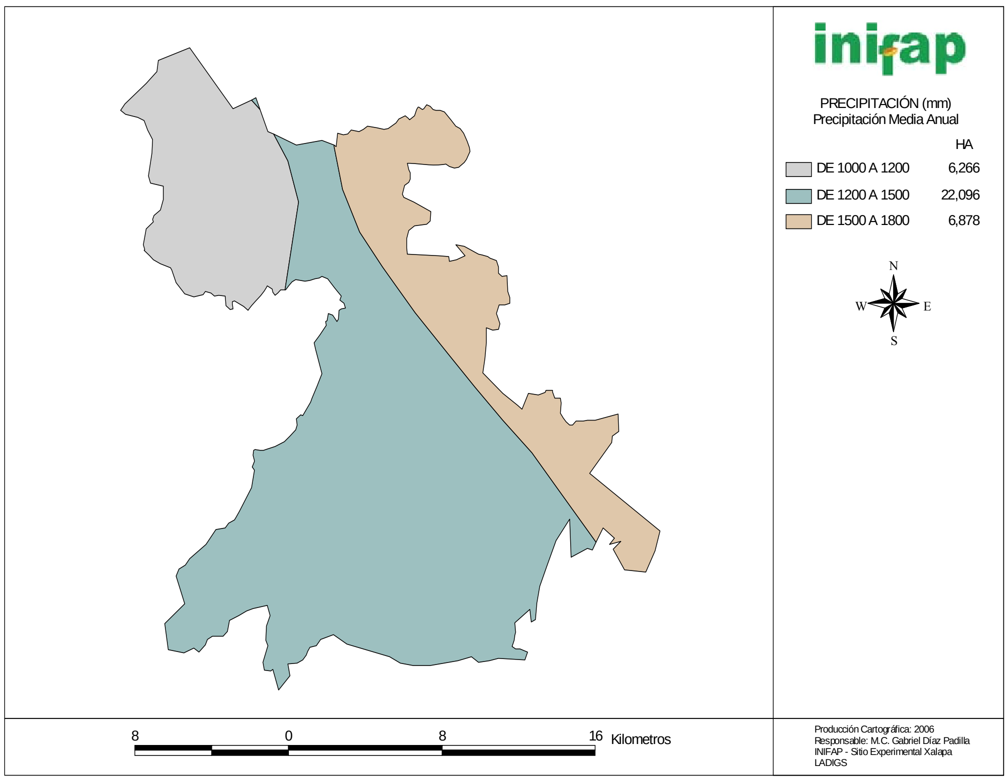
Appendix 8.7
These maps include: rivers, slopes, locations, rainfall distribution, altitudes and land use

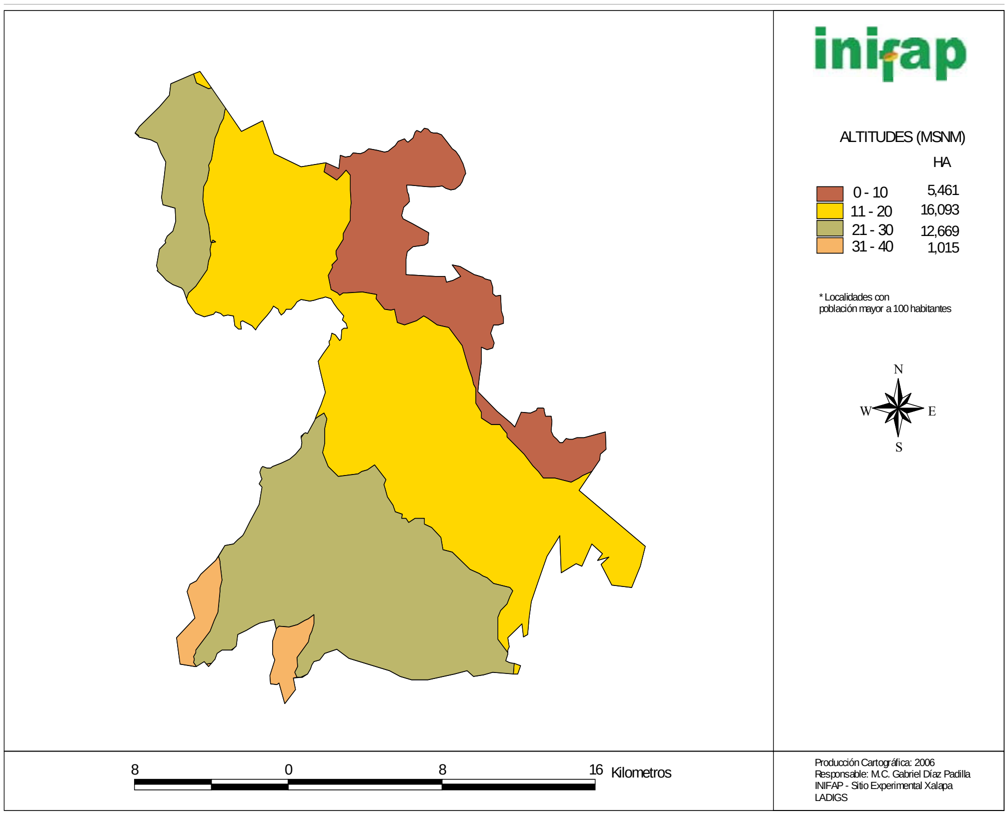


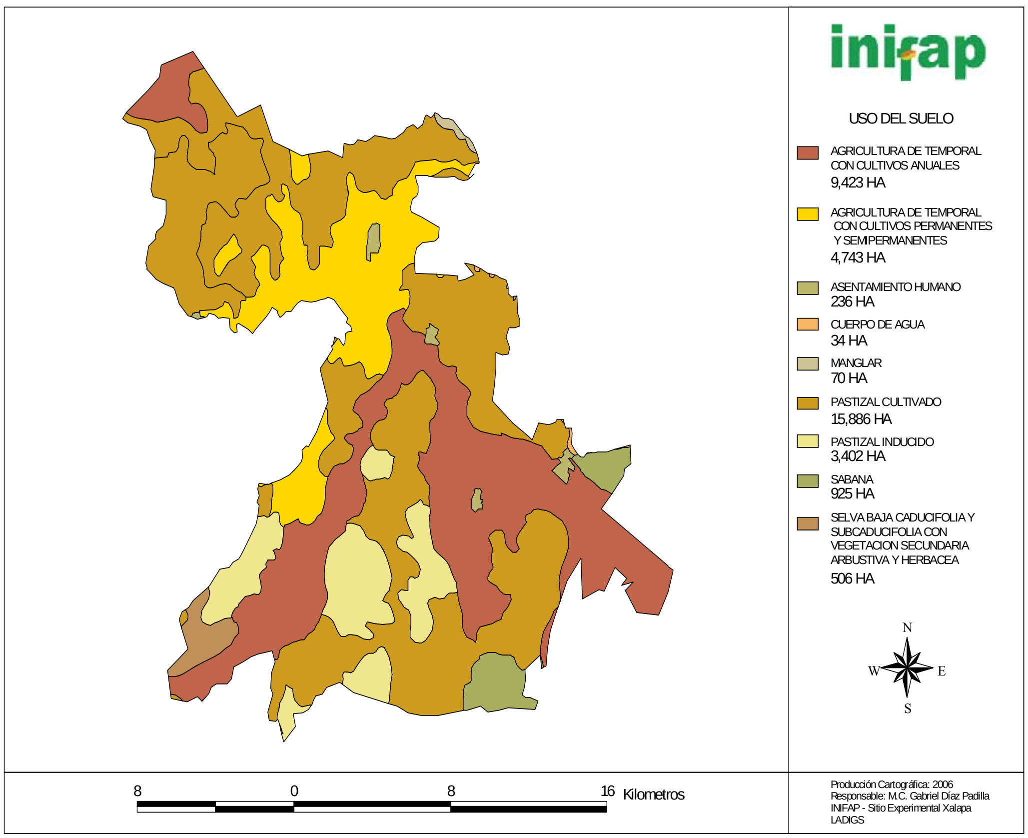


Terrain slope is flat in Medellín. This information was useful for our CNCPS simulations in accounting for the daily distance walk for cows.


CEDRAL
SAN FRANCISCO
BAJOS DEL JOBO (PUENTE MORENO)
PALMIRA
PLAYA DE VACAS
PRIMERO DE LA PALMA
MATA ORTIZ
MORALILLO
DOS BOCAS (TERMOELECTRICA)
TEJAR, EL
PASO COLORADO
RANCHO DEL PADRE
JOYA, LA
RINCON DEL COPITE
MOZAMBIQUE
SAN MIGUEL
MEDELLIN
DOS BOCAS
BOCANA, LA (DOS BOCAS)
PASO DE LOS ARRIEROS
COLONIA LAS MARIPOSAS
IXCOALCO
GUASIMAL, EL
COLONIA 20 DE NOVIEMBRE DE MEDELLIN DE BRAVO
PASO DEL TORO
BALSAS, LAS
JUAN DE ALFARO
GLORIA, LA
ESPERANZA, LA
PLAZA DE TOROS
BASCULA, LA (LA UNION)
INFIERNILLO, EL
SALSIPUEDES
LAGUNA Y MONTE DEL CASTILLO, LA
ROBLES, LOS
POTRERILLO
DOCE, EL (RANCHO NUEVO)
MANGAL, EL
BUENAVISTA (TASAJERA)
COPITAL, EL
PEPEHUA, LA
PROVIDENCIA, LA
CANDELARIA, LA
SANTA ROSA
CELAYA
inifap
Localidades
Municipio de Medellin de Bravo
* Localidades con población mayor a 100 habitantes
N
W
E
S
8
0
8
16
Kilometros
Producción Cartográfica: 2006
Responsable: M.C. Gabriel Díaz Padilla
INIFAP - Sitio Experimental Xalapa
LADIGS


inifap
PRECIPITACIÓN (mm)
Precipitación Media Anual
HA
DE 1000 A 1200 6,266
DE 1200 A 1500 22,096
DE 1500 A 1800 6,878
N
W
E
S
8 0 8 16 Kilometros
Producción Cartográfica: 2006
Responsable: M.C. Gabriel Díaz Padilla
INIFAP - Sitio Experimental Xalapa
LADIGS


inifap
ALTITUDES (MSNM)
HA
0 - 10 5,461
11 - 20 16,093
21 - 30 12,669
31 - 40 1,015
* Localidades con
población mayor a 100 habitantes
N
W
E
S
8 0 8 16 Kilometros
Producción Cartográfica: 2006
Responsable: M.C. Gabriel Díaz Padilla
INIFAP - Sitio Experimental Xalapa
LADIGS


inifap
USO DEL SUELO
AGRICULTURA DE TEMPORAL CON CULTIVOS ANUALES
9,423 HA
AGRICULTURA DE TEMPORAL CON CULTIVOS PERMANENTES Y SEMIPERMANENTES
4,743 HA
ASENTAMIENTO HUMANO
236 HA
CUERPO DE AGUA
34 HA
MANGLAR
70 HA
PASTIZAL CULTIVADO
15,886 HA
PASTIZAL INDUCIDO
3,402 HA
SABANA
925 HA
SELVA BAJA CADUCIFOLIA Y SUBCADUCIFOLIA CON VEGETACION SECUNDARIA ARBUSTIVA Y HERBACEA
506 HA
N
W
E
S
8
0
8
16
Kilometros
Producción Cartográfica: 2006
Responsable: M.C. Gabriel Díaz Padilla
INIFAP - Sitio Experimental Xalapa
LADIGS

Appendix Table 8.8
Contrasting activity environmental conditions to evaluate the sensitivity of Cornell Net Carbohydrate and Protein System predictions of animal energy requirements for maintenance

Variable	Early rains	Scarce rain
Temperature, °C	28.0	22.0
Wind speed, kph	29.7	35.5
Minimum night temperature, °C	24.0	17.0
Time standing, h/d	16.0	14.0
Number of body position changes	6.0	3.0
Flat distance walked, km	1.0	0.5[a]

[a]This input did not correspond to this particular case because this table intended to represent the rage of all the values existing for the Genesis scenario; the actual value was 0.8 km.

Appendix Table 8.9
Impact of environmental factors affecting energy requirements for maintenance and milk.

Variable	Early rains		Scarce rain		Difference	
	ME maint	ME milk	ME maint	ME milk	Maint	Milk
Temperature, °C	1.2	1.4	0.9	0.8	0.3	0.6
Wind speed, kph	0.7	0.9	0.4	0.3	0.3	0.6
Minimum night temperature, °C	0.0	0.0	0.0	0.0	…	…
Time standing, h/d	0.1	0.2	0.2	0.1	0.1	0.1
Number position changes	0.1	0.2	0.2	0.2	0.1	0.0
Flat distance walked, km	0.3	0.4	0.3	0.3	0.0	0.1
1 unit change in BCS	0.1	1.8	0	2	0.1	0.2
50 kg decrease in BW	1.2	0.9	1.1	1.4	0.1	0.5

Appendix section 8.10

Appendix Table 8.10.1
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in non-GGAVATT[a] herds calving in the season of early rains (June 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Early rains	Late rains	Scarce rain	Little rain	Early rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	9.7	9.5	8.9	5.4	7.1
Other forage[c]	…	…	…	1.8	1.8
Supplement[d]	…	…	…	0.8	0.8
Total DMI, kg/d	9.7	9.5	8.9	8.0	9.7
Total dietary energy, Mcal ME/d	17.5	19.1	18.8	16.0	18.5
Total ME supply, Mcal/d[e]	20.2	19.1	18.8	16.0	19.4
Initial body weight (BW), kg[f]	500	447	461	500	518
Mean BW, kg	474	454	481	509	509
End BW, kg	447	461	500	518	500
Initial body condition score (BCS)[g]	3.00	2.25	2.50	3.00	3.25
End BCS[h]	2.25	2.50	3.00	3.25	3.00
Total energy requirement, Mcal ME/d[i]	20.2	18.2	16.5	15.2	19.4
Maintenance requirement, Mcal ME/d[j]	15.2	12.8	12.7	14.3	14.5
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	4.90
ME allowable milk production, kg/d[k]	6.3	5.1	3.6	…	…
Feed energy balance, Mcal ME/d[l]	-2.7	0.9	2.3	0.8	-0.9

[a]Dual-purpose cattle herds that do not belong to any farmer's organization in the leeward region of Veracruz.
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c]*Digitaria decumbens* (Pangola) hay. Some non-GGAVATT farmers purchase this input for the driest months of the little rain season (Table 3).

Table 8.10.1 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses (0.5 kg/d, each).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 500 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS during early and late rains, 0.50 units during scarce rain and 0.25 units of BCS during little rain season.
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[i]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[j] Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[k]Predicted 270-d lactation milk production was 1350 kg.
[l]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.10.2

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in non-GGAVATT[a] herds calving in the season of late rains (August 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Late rains	Scarce rain	Little rain	Early rain	Late rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	10.0	10.2	9.5	7.8	9.0
Other forage[c]	…	…	0.6	0.9	…
Supplement[d]	…	…	0.3	0.4	…
Total DMI, kg/d	10.0	10.2	10.4	9.1	9.0
Total dietary energy, Mcal ME/d	19.1	21.4	21.1	17.4	16.6
Total ME supply, Mcal/d[e]	22.0	21.4	21.1	17.4	20.4
Initial body weight (BW), kg[f]	500	447	478	515	535
Mean BW, kg	474	463	497	525	504
End BW, kg	447	478	515	535	473
Initial body condition score (BCS)[g]	3.00	2.25	2.75	3.25	3.50
End BCS[h]	2.25	2.75	3.25	3.50	2.50
Total energy requirement, Mcal ME/d[i]	22.0	19.5	18.9	16.4	20.4
Maintenance requirement, Mcal ME/d[j]	14.3	12.1	13.6	15.5	15.5
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	4.90
ME allowable milk production, kg/d[k]	8.7	7.0	5.0	…	…
Feed energy balance, Mcal ME/d[l]	-2.9	1.9	2.2	1.0	-3.8

[a]Dual-purpose cattle herds that do not belong to any farmer's organization in the leeward region of Veracruz.
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c]*Digitaria decumbens* (Pangola) hay. Some non-GGAVATT farmers purchase this input for the driest months of the little rain season (Table 3).

Table 8.10.2 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses (0.5 kg/d, each).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 500 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS during early and late rains, 0.50 units during scarce rain and 0.25 units of BCS during little rain season.
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[i]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[j] Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[k]Predicted 270-d lactation milk production was 1864 kg.
[l]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.10.3

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in non-GGAVATT[a] herds calving in the season of scarce rain (October 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rain	Late rains	Scarce rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	9.1	9.4	8.3	9.2	9.1
Other forage[c]	…	…	1.2	…	…
Supplement[d]	…	…	0.6	…	…
Total DMI, kg/d	9.1	9.4	10.1	9.2	9.1
Total dietary energy, Mcal ME/d	19.1	19.5	20.1	16.5	18.3
Total ME supply, Mcal/d[e]	21.0	19.5	20.1	16.5	18.3
Initial body weight (BW), kg[f]	500	465	465	500	500
Mean BW, kg	483	465	483	500	500
End BW, kg	465	465	500	500	500
Initial body condition score (BCS)[g]	3.00	2.50	2.50	3.00	3.00
End BCS[h]	2.50	2.50	3.00	3.00	3.00
Total energy requirement, Mcal ME/d[i]	21.0	19.5	18.1	16.5	18.3
Maintenance requirement, Mcal ME/d[j]	13.4	12.5	13.1	15.6	13.4
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	4.90
ME allowable milk production, kg/d[k]	8.1	6.6	4.7	…	…
Feed energy balance, Mcal ME/d[l]	-1.9	0.0	2.0	0.0	0.0

[a]Dual-purpose cattle herds that do not belong to any farmer's organization in the leeward region of Veracruz.
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c]*Digitaria decumbens* (Pangola) hay. Some non-GGAVATT farmers purchase this input for the driest months of the little rain season (Table 3).

Table 8.10.3 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses (0.5 kg/d, each).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 500 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS during early and late rains, 0.50 units during scarce rain and 0.25 units of BCS during little rain season.
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[i]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[j] Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[k]Predicted 270-d lactation milk production was 1750 kg.
[l]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.10.4
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in non-GGAVATT[a] herds calving in the season of little rain (January 1) under baseline nutrition management.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Little rain	Early rain	Late rains	Scarce rains	Little rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	9.0	8.7	9.8	8.1	9.5
Other forage[c]	…	1.2	…	…	…
Supplement[d]	…	0.6	…	…	…
Total DMI, kg/d	9.0	10.5	9.8	8.1	9.5
Total dietary energy, Mcal ME/d	18.6	21.0	17.6	16.8	19.6
Total ME supply, Mcal/d[e]	19.6	21.0	18.8	16.8	19.6
Initial body weight (BW), kg[f]	482	465	500	479	542
Mean BW, kg	474	483	490	511	542
End BW, kg	465	500	479	542	542
Initial body condition score (BCS)[g]	2.75	2.50	3.00	2.75	3.50
End BCS[h]	2.50	3.00	2.75	3.50	3.50
Total energy requirement, Mcal ME/d[i]	19.6	18.8	18.8	14.5	19.6
Maintenance requirement, Mcal ME/d[j]	13.0	13.1	15.3	13.6	14.7
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	4.90
ME allowable milk production, kg/d[k]	6.7	5.4	3.8	…	…
Feed energy balance, Mcal ME/d[l]	-1.0	2.2	-1.2	2.3	0.0

[a]Dual-purpose cattle herds that do not belong to any farmer's organization in the leeward region of Veracruz.
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c]*Digitaria decumbens* (Pangola) hay. Some non-GGAVATT farmers purchase this input for the driest months of the little rain season (Table 3).

Table 8.10.4 (Continued)

[d]Forage-based diets supplemented with poultry manure, molasses (0.5 kg/d, each).
[e]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[f]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 500 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS during early and late rains, 0.50 units during scarce rain and 0.25 units of BCS during little rain season.
[g]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[h]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[i]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[j] Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[k]Predicted 270-d lactation milk production was 1435 kg.
[l]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.10.5

Expected daily milk yield, dry matter intake (DMI) and feed energy (FE) balances throughout calving intervals[a] of multiparous ½ Brown Swiss x ½ Brahman cows calving in alternative forage seasons[b,c] under baseline management in non-GGAVATT ranches.

	Early rains				Late rains				Scarce rain				Little rain			
	Lactation		Dry		Lactation		Dry		Lactation		Dry		Lactation		Dry	
Calving season	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Early rains (June 1)																
Milk yield, kg/d	**6.3**	…	…	…	…	…	…	…	…	3.6	…	…	…	…	…	…
DMI predicted, kg/d	**9.7**	…	…	9.7	…	…	…	…	…	8.9	…	…	…	…	8.0	…
FE balance, Mcal ME/d	**-2.7**	…	…	-0.9	…	…	…	…	…	2.3	…	…	…	…	0.8	…
Late rains (August 1)																
Milk yield, kg/d	…	…	…	…	**8.7**	…	…	…	…	5.0	…	…	…	…	…	…
DMI predicted, kg/d	…	…	9.1	…	**10.0**	…	…	9.0	…	10.4	…	…	…	…	…	…
FE balance, Mcal ME/d	…	…	1.0	…	**-2.9**	…	…	-3.8	…	2.2	…	…	…	…	…	…
Scarce rain (October 1)																
Milk yield, kg/d	…	…	…	…	…	…	…	…	**8.1**	…	…	…	…	4.7	…	…
DMI predicted, kg/d	…	…	…	…	…	…	9.2	…	**9.1**	…	…	9.1	…	10.1	…	…
FE balance, Mcal ME/d	…	…	…	…	…	…	0.0	…	**-1.9**	…	…	0.0	…	2.0	…	…
No rain (February 1)																
Milk yield, kg/d	…	3.8	…	…	…	…	…	…	…	…	…	…	**6.7**	…	…	...
DMI predicted, kg/d	…	9.8	…	…	…	…	…	…	…	…	8.1	…	**9.0**	…	…	9.5
FE balance, Mcal ME/d	…	-1.2	…	…	…	…	…	…	…	…	2.3	… …	**-1.0**	…	…	0.0

[a]Early lactation period = days 1 to 90 postpartum. Late lactation = days 181 to 270. Early dry = 128 d commencing on day 270. Late dry = final 90 d of calving interval (late gestation).

[b]Early rains = June 1 to July 31. Late rains = August 1 to September 30. Scarce rain = October 1 to December 31. Little rain = January 1 to May 31.

[c]Chemical composition and kinetic digestion parameters of Sotavento forages were based on the collective opinion of a panel of local professionals and available laboratory analyses.

Appendix section 8.11

Appendix Table 8.11.1

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of early rains (June 1) under baseline nutrition management during lactation and supplementation with sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Early rains	Late rains	Scarce rain	Little rain	Early rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	5.6	2.7	1.7	8.3	5.3
Other forage[c]	…	2.9	4.6	…	…
Supplement[d]	3.1	3.9	3.1	1.4	1.4
Sorghum[e]	…	…	…	…	2.3
Total DMI, kg/d	8.7	9.5	9.4	9.7	8.9
Total dietary energy, Mcal ME/d	18.7	21.2	20.0	20.5	20.5
Total ME supply, Mcal/d[f]	21.0	21.2	20.0	20.5	20.5
Initial body weight (BW), kg[g]	426	385	420	440	495
Mean BW, kg	406	403	430	468	501
End BW, kg	385	420	440	495	506
Initial body condition score (BCS)[h]	2.75	2.00	2.75	2.75	2.75
End BCS[i]	2.00	2.75	2.75	2.75	3.00
ME allowable growth, kg/d[j]	…	…	0.21	0.42	…
Total energy requirement, Mcal ME/d[k]	21.0	19.1	20.0	20.5	20.5
Maintenance requirement, Mcal ME/d[l]	13.1	11.9	12.2	13.7	14.1
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[m]	8.4	6.8	4.8	…	…
Feed energy balance, Mcal ME/d[n]	-2.3	2.1	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 8.11.1 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorgum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 1800 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.2
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of late rains (August 1) under baseline nutrition management during lactation and supplementation with sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Late rains	Scarce rain	Little rain	Early rains	Late rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	4.5	2.2	2.7	8.3	5.1
Other forage[c]	1.5	4.5	4.7	…	…
Supplement[d]	3.4	3.7	3.1	1.4	…
Sorghum[e]	…	…	…	…	4.5
Total DMI, kg/d	9.4	10.4	10.5	9.7	9.6
Total dietary energy, Mcal ME/d	20.0	21.9	22.1	19.1	22.1
Total ME supply, Mcal/d[f]	22.6	21.9	22.1	19.1	22.1
Initial body weight (BW), kg[g]	440	398	440	460	483
Mean BW, kg	419	419	450	472	495
End BW, kg	398	440	460	483	506
Initial body condition score (BCS)[h]	3.00	2.25	3.00	3.00	3.00
End BCS[i]	2.25	3.00	3.00	3.00	3.00
ME allowable growth, kg/d[j]	…	…	0.22	0.17	0.24
Total energy requirement, Mcal ME/d[k]	22.6	19.2	22.1	19.1	22.1
Maintenance requirement, Mcal ME/d[l]	13.6	11.4	13.7	15.7	14.1
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[m]	9.1	7.4	5.2	…	…
Feed energy balance, Mcal ME/d[n]	-2.6	2.7	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 8.11.2 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorgum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 1953 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.3
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) under baseline nutrition management during lactation and supplementation with sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	0.0	2.7	4.3	5.7	2.8
Other forage[c]	4.4	4.7	0.6	…	…
Supplement[d]	3.9	3.1	4.8	…	…
Sorghum[e]	…	…	…	3.0	5.3
Total DMI, kg/d	8.3	10.5	9.7	8.7	8.1
Total dietary energy, Mcal ME/d	18.5	22.2	21.2	18.9	20.7
Total ME supply, Mcal/d[f]	20.7	22.2	21.2	18.9	20.7
Initial body weight (BW), kg[g]	426	385	430	446	484
Mean BW, kg	406	408	438	465	495
End BW, kg	385	430	446	484	506
Initial body condition score (BCS)[h]	2.75	2.00	2.75	2.75	2.75
End BCS[i]	2.00	2.75	2.75	2.75	3.00
ME allowable growth, kg/d[j]	…	…	0.17	0.29	0.23
Total energy requirement, Mcal ME/d[k]	20.8	19.4	21.2	18.9	20.7
Maintenance requirement, Mcal ME/d[l]	11.9	11.5	13.7	14.2	13.1
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[m]	9.3	7.5	5.3	…	…
Feed energy balance, Mcal ME/d[n]	-2.3	2.8	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 8.11.3 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorgum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 1989 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.4
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of little rain (January 1) under baseline nutrition management during lactation and supplementation with sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Little rain	Early rains	Late rains	Scarce rain	Little rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	1.8	3.8	6.2	9.4	6.3
Other forage[c]	3.5	0.9	…	…	…
Supplement[d]	3.1	4.8	3.1	…	…
Sorghum[e]	…	…	…	…	3.2
Total DMI, kg/d	8.4	9.5	9.3	9.4	9.5
Total dietary energy, Mcal ME/d	18.4	20.9	19.7	19.4	21.7
Total ME supply, Mcal/d[f]	19.9	20.9	19.7	19.4	21.7
Initial body weight (BW), kg[g]	410	384	416	428	473
Mean BW, kg	397	400	422	451	490
End BW, kg	384	416	428	473	506
Initial body condition score (BCS)[h]	2.50	2.00	2.50	2.50	2.50
End BCS[i]	2.00	2.50	2.50	2.50	3.00
ME allowable growth, kg/d[j]	…	…	0.13	0.34	0.36
Total energy requirement, Mcal ME/d[k]	29.9	18.9	19.7	19.4	21.7
Maintenance requirement, Mcal ME/d[l]	11.5	11.8	13.1	13.8	12.1
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[m]	8.3	6.7	4.7	…	…
Feed energy balance, Mcal ME/d[n]	-1.5	2.0	0.0	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen’s Validation and Technology Transfer Group).

Table 8.11.4 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorgum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 1773 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.5

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of early rains (June 1) under baseline nutrition management during lactation and supplementation with sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Early rains	Late rains	Scarce rain	Little rain	Early rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	7.2	4.1	3.2	8.9	6.9
Other forage[c]	…	2.9	4.6	…	…
Supplement[d]	3.5	4.4	3.8	1.9	1.9
Sorghum[e]	…	…	…	…	1.2
Total DMI, kg/d	10.7	11.4	11.6	10.8	10.0
Total dietary energy, Mcal ME/d	23.0	25.5	25.1	22.9	22.0
Total ME supply, Mcal/d[f]	25.3	25.5	25.1	22.9	24.5
Initial body weight (BW), kg[g]	550	510	546	596	636
Mean BW, kg	530	528	571	616	623
End BW, kg	510	546	596	636	609
Initial body condition score (BCS)[h]	3.00	2.50	3.00	3.50	4.00
End BCS[i]	2.50	3.00	3.50	4.00	3.75
Total energy requirement, Mcal ME/d[j]	25.3	23.1	21.7	19.3	24.5
Maintenance requirement, Mcal ME/d[k]	16.6	15.4	15.5	18.4	19.1
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	9.1	7.3	5.7	…	…
Feed energy balance, Mcal ME/d[m]	-2.3	2.4	3.4	3.6	-2.5

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.

Table 8.11.5 (Continued)

[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorgum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 1989 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.6

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of late rains (August 1) under baseline nutrition management during lactation and supplementation with sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Late rains	Scarce rain	Little rain	Early rains	Late rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	5.9	4.3	4.2	7.7	5.9
Other forage[c]	1.5	4.5	4.7	…	…
Supplement[d]	3.8	4.1	3.5	1.9	…
Sorghum[e]	…	…	…	…	4.1
Total DMI, kg/d	11.2	12.9	12.4	9.6	10.0
Total dietary energy, Mcal ME/d	24.0	27.6	26.6	19.3	22.6
Total ME supply, Mcal/d[f]	26.6	27.6	26.6	20.8	22.6
Initial body weight (BW), kg[g]	550	505	571	608	594
Mean BW, kg	528	538	590	601	594
End BW, kg	505	571	608	594	594
Initial body condition score (BCS)[h]	3.00	2.50	3.25	3.50	3.50
End BCS[i]	2.50	3.25	3.50	3.50	3.50
Total energy requirement, Mcal ME/d[j]	26.6	23.3	23.9	20.8	22.6
Maintenance requirement, Mcal ME/d[k]	16.4	14.1	17.3	19.9	17.2
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	10.7	8.7	6.1	…	…
Feed energy balance, Mcal ME/d[m]	-2.6	4.3	2.7	-1.5	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.

Table 8.11.6 (Continued)

[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorgum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 2295 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.7
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) under baseline nutrition management during lactation and supplementation with sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	1.6	4.1	5.8	10.1	6.9
Other forage[c]	4.4	4.7	0.6	…	…
Supplement[d]	4.4	3.5	5.2	…	…
Sorghum[e]	…	…	…	0.8	2.7
Total DMI, kg/d	10.4	12.3	11.6	10.9	9.6
Total dietary energy, Mcal ME/d	23.0	26.5	25.3	20.4	21.6
Total ME supply, Mcal/d[f]	25.1	26.5	25.3	20.4	21.6
Initial body weight (BW), kg[g]	550	515	550	572	572
Mean BW, kg	533	533	561	572	572
End BW, kg	515	550	572	572	572
Initial body condition score (BCS)[h]	3.00	2.50	3.00	3.25	3.25
End BCS[i]	2.50	3.00	3.25	3.25	3.25
Total energy requirement, Mcal ME/d[j]	25.1	24.1	23.8	20.4	21.6
Maintenance requirement, Mcal ME/d[k]	14.5	14.8	17.1	19.5	16.2
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	10.9	8.8	6.2	…	…
Feed energy balance, Mcal ME/d[m]	-2.1	2.4	1.5	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.

Table 8.11.7 (Continued)

[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorgum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 2331 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.8
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of little rains (January 1) under baseline nutrition management during lactation and supplementation with sorghum grain during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Little rain	Early rains	Late rains	Scarce rains	Little rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	2.9	5.4	7.6	9.2	11.1
Other forage[c]	3.5	0.9	…	…	…
Supplement[d]	3.5	5.2	3.5	…	…
Sorghum[e]	…	…	…	…	…
Total DMI, kg/d	9.9	11.5	11.1	9.2	11.1
Total dietary energy, Mcal ME/d	22.2	24.9	23.6	19.0	23.0
Total ME supply, Mcal/d[f]	24.2	24.9	23.6	19.0	23.0
Initial body weight (BW), kg[g]	532	498	525	548	563
Mean BW, kg	515	512	537	556	581
End BW, kg	498	525	548	563	599
Initial body condition score (BCS)[h]	2.75	2.25	2.75	3.00	3.00
End BCS[i]	2.25	2.75	3.00	3.00	3.50
Total energy requirement, Mcal ME/d[j]	24.2	23.1	22.2	17.8	20.8
Maintenance requirement, Mcal ME/d[k]	14.5	14.8	16.1	16.9	15.4
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	9.8	7.9	5.6	…	…
Feed energy balance, Mcal ME/d[m]	-2.0	1.8	1.4	1.2	2.2

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.

Table 8.11.8 (Continued)

[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Sorgum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 2097 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.9
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of early rains (June 1) under baseline nutrition management during lactation and good quality harvested forage with sorghum grain fed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Early rains	Late rains	Scarce rain	Little rain	Early rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	5.6	2.7	1.7	8.3	…
Other forage[c]	…	2.9	4.6	…	…
Supplement[d]	3.1	3.9	3.1	1.4	1.4
High quality harvested forage[e]	…	…	…	…	5.3
Sorghum[e]	…	…	…	…	1.4
Total DMI, kg/d	8.7	9.5	9.4	9.7	8.1
Total dietary energy, Mcal ME/d	18.7	21.2	20.0	20.5	19.9
Total ME supply, Mcal/d[f]	21.0	21.2	20.0	20.5	19.9
Initial body weight (BW), kg[g]	426	385	420	440	495
Mean BW, kg	406	403	430	468	501
End BW, kg	385	420	440	495	506
Initial body condition score (BCS)[h]	2.75	2.00	2.75	2.75	2.75
End BCS[i]	2.00	2.75	2.75	2.75	3.00
ME allowable growth, kg/d[j]	…	…	0.21	0.42	…
Total energy requirement, Mcal ME/d[k]	21.0	19.1	20.0	20.5	19.9
Maintenance requirement, Mcal ME/d[l]	13.1	11.9	12.2	13.7	13.6
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[m]	8.4	6.8	4.8	…	…
Feed energy balance, Mcal ME/d[n]	-2.3	2.1	0.0	0.0	0.0

Table 8.11.9 (Continued)

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silo. Sorghum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 1800 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.10
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of late rains (August 1) under baseline nutrition management during lactation and good quality harvested forage with sorghum grain fed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Late rains	Scarce rain	Little rain	Early rains	Late rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	4.5	2.2	2.7	8.3	…
Other forage[c]	1.5	4.5	4.7	…	…
Supplement[d]	3.4	3.7	3.1	1.4	…
High quality harvested forage[e]	…	…	…	…	5.1
Sorghum[e]	…	…	…	…	3.4
Total DMI, kg/d	9.4	10.4	10.5	9.7	8.5
Total dietary energy, Mcal ME/d	20.0	21.9	22.1	19.1	21.4
Total ME supply, Mcal/d[f]	22.6	21.9	22.1	19.1	21.4
Initial body weight (BW), kg[g]	440	398	440	460	483
Mean BW, kg	419	419	450	472	495
End BW, kg	398	440	460	483	506
Initial body condition score (BCS)[h]	3.00	2.25	3.00	3.00	3.00
End BCS[i]	2.25	3.00	3.00	3.00	3.00
ME allowable growth, kg/d[j]	…	…	0.22	0.17	0.24
Total energy requirement, Mcal ME/d[k]	22.6	19.2	22.1	19.1	21.4
Maintenance requirement, Mcal ME/d[l]	13.6	11.4	13.7	15.7	13.6
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[m]	9.1	7.4	5.2	…	…
Feed energy balance, Mcal ME/d[n]	-2.6	2.7	0.0	0.0	0.0

Table 8.11.10 (Continued)

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silo. Sorghum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 1953 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.11

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) under baseline nutrition management during lactation and good quality harvested forage with sorghum grain fed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	0.0	2.7	4.3	…	…
Other forage[c]	4.4	4.7	0.6	…	…
Supplement[d]	3.9	3.1	4.8	…	…
High quality harvested forage[e]	…	…	…	5.7	2.8
Sorghum[e]	…	…	…	1.6	5.0
Total DMI, kg/d	8.3	10.5	9.7	7.3	7.8
Total dietary energy, Mcal ME/d	18.5	22.2	21.2	17.8	20.6
Total ME supply, Mcal/d[f]	20.7	22.2	21.2	17.8	20.6
Initial body weight (BW), kg[g]	426	385	430	446	484
Mean BW, kg	406	408	438	465	495
End BW, kg	385	430	446	484	506
Initial body condition score (BCS)[h]	2.75	2.00	2.75	2.75	2.75
End BCS[i]	2.00	2.75	2.75	2.75	3.00
ME allowable growth, kg/d[j]	…	…	0.17	0.29	0.23
Total energy requirement, Mcal ME/d[k]	20.8	19.4	21.2	17.8	20.6
Maintenance requirement, Mcal ME/d[l]	11.9	11.5	13.7	13.6	13.1
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[m]	9.3	7.5	5.3	…	…
Feed energy balance, Mcal ME/d[n]	-2.3	2.8	0.0	0.0	0.0

Table 8.11.11 (Continued)

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silo. Sorghum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 1989 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.12

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for primiparous cows in Genesis[a] herds calving in the season of little rain (January 1) under baseline nutrition management during lactation and good quality harvested forage with sorghum grain fed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Little rain	Early rains	Late rains	Scarce rain	Little rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	1.8	3.8	6.2	9.4	…
Other forage[c]	3.5	0.9	…	…	…
Supplement[d]	3.1	4.8	3.1	…	…
High quality harvested forage[e]	…	…	…	…	6.3
Sorghum[e]	…	…	…	…	2.4
Total DMI, kg/d	8.4	9.5	9.3	9.4	8.7
Total dietary energy, Mcal ME/d	18.4	20.9	19.7	19.4	21.1
Total ME supply, Mcal/d[f]	19.9	20.9	19.7	19.4	21.1
Initial body weight (BW), kg[g]	410	384	416	428	473
Mean BW, kg	397	400	422	451	490
End BW, kg	384	416	428	473	506
Initial body condition score (BCS)[h]	2.50	2.00	2.50	2.50	2.50
End BCS[i]	2.00	2.50	2.50	2.50	3.00
ME allowable growth, kg/d[j]	…	…	0.13	0.34	0.36
Total energy requirement, Mcal ME/d[k]	29.9	18.9	19.7	19.4	21.1
Maintenance requirement, Mcal ME/d[l]	11.5	11.8	13.1	13.8	11.8
Pregnancy requirement, Mcal ME/d	…	…	…	0.90	5.00
ME allowable milk production, kg/d[m]	8.3	6.7	4.7	…	…
Feed energy balance, Mcal ME/d[n]	-1.5	2.0	0.0	0.0	0.0

Table 8.11.12 (Continued)

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).
[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silo. Sorghum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a primiparous cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (second) calving.
[j]Growth was assumed to be enabled (could occur) after recovery of initial BW and BCS at calving.
[k]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[l]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[m]Predicted 270-d lactation milk production was 1773 kg.
[n]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.13
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of early rains (June 1) under baseline nutrition management during lactation and good quality harvested forage with sorghum grain fed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Early rains	Late rains	Scarce rain	Little rain	Early rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	7.2	4.1	3.2	8.9	…
Other forage[c]	…	2.9	4.6	…	…
Supplement[d]	3.5	4.4	3.8	1.9	1.9
High quality harvested forage[e]	…	…	…	…	6.9
Sorghum[e]	…	…	…	…	…
Total DMI, kg/d	10.7	11.4	11.6	10.8	8.8
Total dietary energy, Mcal ME/d	23.0	25.5	25.1	22.9	21.0
Total ME supply, Mcal/d[f]	25.3	25.5	25.1	22.9	23.8
Initial body weight (BW), kg[g]	550	510	546	596	636
Mean BW, kg	530	528	571	616	624
End BW, kg	510	546	596	636	612
Initial body condition score (BCS)[h]	3.00	2.50	3.00	3.50	4.00
End BCS[i]	2.50	3.00	3.50	4.00	3.75
Total energy requirement, Mcal ME/d[j]	25.3	23.1	21.7	19.3	23.8
Maintenance requirement, Mcal ME/d[k]	16.6	15.4	15.5	18.4	18.4
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	9.1	7.3	5.7	…	…
Feed energy balance, Mcal ME/d[m]	-2.3	2.4	3.4	3.6	-2.8

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 8.11.13 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silo. Sorghum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 1989 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.14

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of late rains (August 1) under baseline nutrition management during lactation and good quality harvested forage with sorghum grain fed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Late rains	Scarce rain	Little rain	Early rains	Late rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	5.9	4.3	4.2	7.7	…
Other forage[c]	1.5	4.5	4.7	…	…
Supplement[d]	3.8	4.1	3.5	1.9	…
High quality harvested forage[e]	…	…	…	…	5.9
Sorghum[e]	…	…	…	…	3.0
Total DMI, kg/d	11.2	12.9	12.4	9.6	8.9
Total dietary energy, Mcal ME/d	24.0	27.6	26.6	19.3	22.0
Total ME supply, Mcal/d[f]	26.6	27.6	26.6	20.8	22.0
Initial body weight (BW), kg[g]	550	505	571	608	594
Mean BW, kg	528	538	590	601	594
End BW, kg	505	571	608	594	594
Initial body condition score (BCS)[h]	3.00	2.50	3.25	3.50	3.50
End BCS[i]	2.50	3.25	3.50	3.50	3.50
Total energy requirement, Mcal ME/d[j]	26.6	23.3	23.9	20.8	22.0
Maintenance requirement, Mcal ME/d[k]	16.4	14.1	17.3	19.9	16.6
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	10.7	8.7	6.1	…	…
Feed energy balance, Mcal ME/d[m]	-2.6	4.3	2.7	-1.5	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 8.11.14 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silo. Sorghum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 2295 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.15
Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of scarce rain (October 1) under baseline nutrition management during lactation and good quality harvested forage with sorghum grain fed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Scarce rain	Little rain	Early rains	Late rains	Scarce rains
Dry matter intake (DMI), kg/d					
Grazed forage[b]	1.6	4.1	5.8	6.8	…
Other forage[c]	4.4	4.7	0.6	…	…
Supplement[d]	4.4	3.5	5.2	…	…
High quality harvested forage[e]	…	…	…	3.3	6.9
Sorghum[e]	…	…	…	…	1.8
Total DMI, kg/d	10.4	12.3	11.6	10.1	8.7
Total dietary energy, Mcal ME/d	23.0	26.5	25.3	19.7	21.1
Total ME supply, Mcal/d[f]	25.1	26.5	25.3	19.7	21.1
Initial body weight (BW), kg[g]	550	515	550	572	572
Mean BW, kg	533	533	561	572	572
End BW, kg	515	550	572	572	572
Initial body condition score (BCS)[h]	3.00	2.50	3.00	3.25	3.25
End BCS[i]	2.50	3.00	3.25	3.25	3.25
Total energy requirement, Mcal ME/d[j]	25.1	24.1	23.8	19.7	21.1
Maintenance requirement, Mcal ME/d[k]	14.5	14.8	17.1	18.8	15.7
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	10.9	8.8	6.2	…	…
Feed energy balance, Mcal ME/d[m]	-2.1	2.4	1.5	0.0	0.0

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 8.11.15 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silo. Sorghum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 2331 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit.

Appendix Table 8.11.16

Expected body weights, body condition scores, metabolizable energy (ME) allowable milk production, energy requirements and supplies, and feed energy balances throughout the calving interval for multiparous cows in Genesis[a] herds calving in the season of little rains (January 1) under baseline nutrition management during lactation and good quality harvested forage with sorghum grain fed during the dry period.

	Lactation			Dry period	
Item	Early	Mid	Late	Early	Late
Forage season	Little rain	Early rains	Late rains	Scarce rains	Little rain
Dry matter intake (DMI), kg/d					
Grazed forage[b]	2.9	5.4	7.6	9.2	11.1
Other forage[c]	3.5	0.9	…	…	…
Supplement[d]	3.5	5.2	3.5	…	…
High quality harvested forage[e]	…	…	…	…	…
Sorghum[e]	…	…	…	…	…
Total DMI, kg/d	9.9	11.5	11.1	9.2	11.1
Total dietary energy, Mcal ME/d	22.2	24.9	23.6	19.0	23.0
Total ME supply, Mcal/d[f]	24.2	24.9	23.6	19.0	23.0
Initial body weight (BW), kg[g]	532	498	525	548	563
Mean BW, kg	515	512	537	556	581
End BW, kg	498	525	548	563	599
Initial body condition score (BCS)[h]	2.75	2.25	2.75	3.00	3.00
End BCS[i]	2.25	2.75	3.00	3.00	3.50
Total energy requirement, Mcal ME/d[j]	24.2	23.1	22.2	17.8	20.8
Maintenance requirement, Mcal ME/d[k]	14.5	14.8	16.1	16.9	15.4
Pregnancy requirement, Mcal ME/d	…	…	0.20	0.90	5.40
ME allowable milk production, kg/d[l]	9.8	7.9	5.6	…	…
Feed energy balance, Mcal ME/d[m]	-2.0	1.8	1.4	1.2	2.2

[a]The Genesis farmer organization is part of a larger association called Grupo Ganadero para la Validación y Transferencia de Tecnología (Cattlemen's Validation and Technology Transfer Group).

Table 8.11.16 (Continued)

[b]Average chemical composition of *Cynodon plectostachyus* and *Andropogon gayanus* grasses for the seasons of early and late rains, and *Andropogon gayanus* for scarce and little rain seasons.
[c] *Brachiaria ruziziensis* x *Brachiaria brizantha* (Mulato) hay, maize silage and sugar cane bagasse for late rains, scarce rain and little rain seasons, respectively (amounts shown in Table 8).
[d]Forage-based diets supplemented with poultry manure, molasses and commercial concentrate (amounts shown in Table 8).
[e]Harvested forage was supposed to have the same chemical composition as *Andropogon gayanus* of season two; it could be fed as hay or silo. Sorghum from CNCPS v. 6.1 Tropical feed library.
[f]Total ME supply = dietary ME plus ME from catabolized body tissue reserves.
[g]Body weight at calving corresponded to the expected weight and BCS for a third calving cow with mature BW = 550 kg and BCS = 3.0. Average body weight loss in early lactation was 0.75 units of BCS (based on information in Appendix 8.6).
[h]BCS at calving was the consensus judgment of a professional panel. Other BCS were predicted from assumed BW changes based on NRC (2000) and Fox et al. (2004).
[i]The ending BCS during late gestation corresponds to the expected score at next (fourth) calving.
[j]Total ME requirement during lactation includes the energy required for body maintenance and milk production. During the dry period it includes the ME required for maintenance, repletion of tissue reserves, growth (if it is enabled), and pregnancy.
[k]Maintenance requirement was a weighted average of those for the parental (Brahman, Brown Swiss) breeds (NRC, 2000; Fox et al., 2004). Basal maintenance was adjusted for changes in BW and BCS.
[l]Predicted 270-d lactation milk production was 2097 kg.
[m]Feed energy balance = feed energy supply (intake) minus total energy requirements for maintenance, lactation, pregnancy and growth (if enabled). A negative value during lactation represents the expected amount of ME supplied from catabolized body tissues to support milk synthesis. Positive feed energy balance signifies the amount of dietary ME available for tissue repletion (and growth). During late gestation (dry period), a negative value signifies a dietary energy deficit, which means diverting maternal tissue energy to the fetal unit

Appendix Table 8.12
Quantities of sorghum grain and supplemental forage of good quality required during the dry period to obtain target body condition scores at next calving for primiparous and multiparous cows calving in different forage seasons of the year.

Calving season	Sorghum[a], total DMI, kg	Sorghum[b], total DMI, kg	Difference[c]	Harvested forage[b], total DMI, kg
Early rains				
Primiparous[d]	207	126	81	477
Mature[e]	108	0	108	621
Late rains				
Primiparous[d]	405	306	99	459
Mature[e]	369	270	99	531
Scarce rain				
Primiparous[d]	861	655	206	982
Mature[e]	297	162	135	842
Little rain				
Primiparous[d]	288	216	72	567
Mature[e]	…	…	…	…

[a]Quantity of sorghum grain required during the dry period without additional dietary changes.
[b]Quantity of sorghum grain and harvested forage of good quality required.
[c]Additional sorghum grain required without harvested forage.
[d]Early dry period for primiparous cows is 128 d and for multiparous cows is 67 d.
[e]Late gestation for all cows (90-d period preceding parturition.

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