Impact of Grazing Management on Productivity of Tropical Grasslands

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IMPACT OF GRAZING MANAGEMENT ON PRODUCTIVITY OF TROPICAL GRASSLANDS

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Beef and dairy cattle enterprises from tropical pasture-based systems are notoriously of low productivity. The low soil fertility, the exploitation of native grasslands, the low genetic potential of the animals and the poor management of soil, pasture and animal components are all arguments used to explain these "low-productivity systems". In fact, research has consistently indicated up to 50% increase in calving rate when animals grazing unfertilized pastures were supplemented with trace-mineralized salt (Table 1) but unfortunately less than 90% of Brazilian farmers use this management strategy (Tosi, 1997). However, a recent survey conducted by São Paulo State government showed that almost 90% of farmers in the State use mineralized salt as a supplement (São Paulo, 1997). Similarly, well-fertilized and managed tropical pastures frequently have enough phosphorus in plant tissues to meet mineral requirements of most grazing animal categories (Table 2) and this might represent a significant reduction in mineral supplementation costs. Nevertheless, farmers do not frequently adopt use of fertilizers. A 1997 survey revealed that only 663.000 tons of NPK fertilizers were annually applied to 90 million ha of introduced pastures in Brazil, e.g., ca. 7,4 kg of NPK fertilizer/ha of pasture per year (ANDA, 1996/1997, cited by Ferreira et al., 1999).

The long payback time on cattle production systems compared to other agricultural enterprises also restrains technology diffusion and adoption. As a result, the financial policy in several developing countries is to focus investment on crops other than pastures to allow farmers to have their investment back as soon as possible. Low productivity indexes associated with cattle enterprises in the tropics (Table 3) also encourage governments to apply financial resources in a range of agricultural crops but not on pasture-based enterprises.

Overall costs for a corn crop in Brazil ranges from US$ 400 to US$ 500/ha and similar amounts of money should be invested in intensively managed pasture systems. However, on intensive cattle enterprises a further investment of about US$ 500 to US$ 700/ha should be practiced to cover animal acquisition costs, meaning that beef and dairy cattle operations are at least twice as costly as a corn crop. A farmer producing corn should invest US$ 100.000 annually in a 200-ha farm but if the same farm were set to cattle production the investment would rise to over US$ 200.000 per year. Further, the corn-producing farm would have the investment back in about 4 to 5 months, while a beef-producing farm, for example, would have to wait at least 18 to 24 months to have the investment back.

In developing countries land and animals work as a capital reserve, i.e., it is a way to ensure oneself against risks. This is obviously another limiting factor to technology diffusion and adoption on tropical pasture based systems and under many circumstances the animal products are by-products rather than products. In this context, capitalized farmers and companies usually face incomes generated in large areas of exploitation as reasonable ones while poor smallholders livestock farmers are unable to adopt the necessary technology to survive in the activity.

This paradigm is more easily understood when one considers that a 5.800-ha extensive stocking and fattening beef farm in the humid tropics typically yields US$ 60.000/year. The same economic output could be obtained from a 500-ha intensive stocking and fattening beef farm (Table 4). A similar picture could be drawn from dairy production systems where the same US$ 60.000 income might be observed with the exploitation of 4.000-ha and 150-ha for extensive and intensive production systems, respectively (Table 5).

The higher production costs, the longer time to have the investment back, and the lack of financial investments and well-defined production systems might lead to the erroneous idea that successfully cattle operations can only be profitable when practiced by capitalized farmers or companies. Nevertheless, productivities exceeding 25.000-kg milk/ha/year and 900 kg live weight gain/ha/year, yielding economic returns of US$ 750 (Vilela et al., 1996) and US$

250/ha/year (Esteves, 2000), respectively, are usually observed in intensively managed tropical pasture systems.

The following sections outlines critical aspects regarding the productivity of tropical grasslands and discusses their weakness and their role in increasing the profitability and efficiency of beef and dairy cattle enterprises on tropical and subtropical regions. Several grazing systems can be found in these regions but this paper deals primarily with intensive managed tropical pastures.

1 Focus on technology diffusion

In the late 80's a Brazilian survey indicated that to collect 46.000 t of milk (the amount to feed 42% of São Paulo city for a month) it was necessary to travel 3.400 million kilometers per month. This corresponds to 85 times a round trip around the Earth during a month, or 2,8 trips per day (Corsi & Nussio, 1993) and implies that only 13,5 kg of milk was collected in each kilometer traveled. This amazing (and absurd) data reflected the overall low milk productivity as well as the inefficient milk storage and collection system in the country, obligating dairy industries to collect milk on daily schedules. Extension support associated with logistical approaches in milk storage and collection reduced the traveled distance in eleven times in Minas Gerais State, and nowadays, 1,96 t of milk are collected in 40.066 km or 49 kg of milk/ kilometer traveled (CCPR/Itambé, 2000; Table 6). It is possible to conclude that the higher milk yield played a vital role in this process since the number of Brazilian dairy farmers decreased in this period (Table 7). Farmers assisted by trained professionals demonstrated significant improvement in productivity levels and also reductions in production costs and consequently milk collection system experiment significant improvements (Table 8). The increase in milk yield was a consequence of new approaches to several components of the systems including improved techniques on animal nutrition, reproduction, and health. Attention paid on better data collection and on progresses toward a better farm administration also played an important role in the intensification process.

Increased productivities resulting from a good overall farm management was also observed for beef cattle operations. A 125-ha beef cattle farm established on sandy soils and located in the central part of São Paulo State showed stocking rates increase from 0,8 to 4,5 animal units (AU = 450 kg of live weight) in 3 years (1987 – 1990) when pastures were managed in a rotational system and soil was limed and fertilized. Similar trends were observed in Goiás State, Brazil (Table 9), however, in large size farms increases in stocking rates occurred at slower rates, mainly due to the high investments in cattle and facilities.

2 Focus on pasture and animal management

The increased stocking rates in the previous examples reflected both, higher grazing efficiency and higher pasture dry matter (DM) yield. The first step in introducing the "new technology" on these farms was the use of rotational grazing using a small number of paddocks, allowing the pasture to be more efficiently grazed. Stocking rates increased 50% (from 0,8 to 1,2 AU/ha/year) on Maria Ofelia farm (Pereira Barreto, São Paulo State, Brazil), mainly due to the better grazing efficiency associated with rotational grazing. This simple approach was very effective in reducing the herbage losses typically observed under set stocking conditions on moderate to high soil fertility sites. Nevertheless, after this initial increase in stocking rate soil fertility becomes increasingly more important and fertilizers are usually applied in best-management farms to ensure pasture sustainability and productivity while maintaining stocking rates at high levels. However, when fertilizers are used on tropical grasses a more skilled pasture manager is required due to the difficulties in utilizing high producing grasses (Figure 1), considering the potential for high herbage losses and inevitable decline in nutritive value with age.

On the other hand, the nutritive value of tropical pastures under rotational grazing can further improve animal performance when compared to the "mismanaged" continuous stocking scheme commonly verified in the tropics (Table 10) where pastures, mainly in the dry season, can have a high percentage of senescent material of low nutritive value. Benefits from rotational grazing came mainly through increase in stocking rate, but they could be even greater than the increase in stocking rate alone, because under this set of condition high-quality forage would be grazed.

It should be born in mind that continuous stocking is as good as rotational grazing when stocking rates are low, generally up to the range of 1,2 – 2,0 AU/ha/year depending on pasture management and site specific conditions (Corsi & Martha, 1998). On the other hand, as the pasture growth rate increases above certain limits, the rotational grazing is the only feasible solution to efficiently manage this "extra herbage" produced (Corsi et al., 2000), because higher post-grazing residues will be left under continuous stocking. This in turn, will lead to decreasing grazing efficiencies as growing season proceeds, as well as to deleterious changes in pasture structure and quality (reduction in leaf to stem ratio, high decomposition and senescence losses, decrease in potential pasture intake and nutritive value, etc.).

Tropical grasses growing in well-fertilized soils show high growth rates. Mombaça grass (*Panicum maximum*) presented herbage accumulation rates varying from 130 to 196 kg DM/ha/day during the growing season (Santos et. al., 1999). This contrasts with information in temperate regions where pasture growth rates (e.g. *Lollium perenne*) rarely exceeds an average of 50 to 70 kg DM/ha/day during the growing season.

Such a high pasture growth rate in tropical pastures is obviously accompanied by high leaf elongation rates, up to 5 – 7 cm/leaf (lamina)/day as observed in *Panicum maximum* cultivars (e.g. Tanzânia and Mombaça) (Santos, 1997). In a management where animals return to the same paddock with regrowth height of 10 to 15 cm it is possible to conclude that the occupation period should be up to 2 days for the grass regrowth not to be grazed and that to maintain a resting period of 30 days it will be necessary to work with 16 paddocks (Table 11).

While in temperate regions varying resting periods is a well-established pasture management, in tropical environments the benefits of this technology is still controversial. Grass species have a genetically determined leaf lifespan, implying that once a certain number of leaves in a tiller are attained the oldest leaf begins to die (Lemaire & Chapman, 1996). In *L. perenne* up to three green leaves are supported in a tiller and when the fourth leaf appears the first one initiate to die. As the youngest and dying leaves are roughly of the same size, no significant net herbage accumulation will be verified above this point.

In contrast, the dying leaf in Tanzânia grass and Mombaça grass (both are *Panicum maximum*) is much smaller than the appearing new leaf (Santos, 1997) and net herbage accumulation was maintained for more than a 100 days in this species (Gomide & Gomide, 1997). With prostrate growing species (e.g. *Cynodon* spp.) under high grazing pressures net herbage accumulation varied from “temperate-like to tropical-like” patterns (Pinto, 2000).

Therefore, it seems that the basis for tropical grass management should be established on characteristics other than tissue flows exclusively. It should be emphasized the maintenance of a given nutritive value and/or pasture structure, in order to keep animal and pasture performances at high levels while minimizing herbage losses.

The high herbage accumulation rate in tropical grasses favors stockpiling practices. However, stockpiling as well as grass-legume mixtures are options for low-input systems using up to 1,2 – 2,0 AU/ha/year. Tropical grass-legume mixtures are usually of higher quality than exclusively grass pastures, but differences in physiological characteristics and on management needs make this option appropriate for extensive/semi-intensive systems. Cowan & Sttobs (1976) showed that commercial dairy farms that have high stocking rates were unable to use tropical grass-legume mixtures above 1,6 cows/ha.

On the other hand, the use of stockpiling practice limits animal productivity for quantity and quality reasons. Long regrowth periods without grazing (or cutting) are prone to excessive herbage losses and in extreme cases the forage damps-off. It is also well established that long regrowth periods are deleterious to forage quality given the reductions on the potential pasture intake on the nutritive value of the forage.

To better utilize the standing low-quality forage some farmers are feeding protein supplements (0,1-% of animal live weight) containing ionophores to correct nutritional deficiencies during the winter period (dry and cold). While some nutrients are indeed corrected, results seem to indicate live weight gain is primarily a function of the additive rather than the supplement (Table 12). This idea is supported by the typical response of live weight gain to ionophores (80 g/head/day) reported in a range of pasture conditions (Table 13).

Grazing animals can also benefit from feeding supplements during the summer/autumn period. The use of supplements at this time of the year has the objective of improving individual performance as well as the output of animal products per unit area. In dairy enterprises this strategy has been widely used and it seems that a similar average response of 1,4 kg of milk/kg of concentrate supplementation might be expected for lactating cows on temperate and tropical grasses (Santos, 2000). Davidson & Elliot (1993) pointed out that only 0,3 to 0,6 kg milk/kg of grain were recorded in short-term experiments (< 2 months) in Australia, whilst whole-farm input-output studies and long-term experiments revealed higher responses (0,7 to 1,4 kg milk/kg of grain) to concentrate feeding. However, data derived from commercial farms in Brazil showed that better financial returns were observed with increasing amounts of concentrate feeding (Santos, 2000).

For beef cattle better responses to concentrate (and possible degradable fiber) supplement feeding seems to occur in late summer/autumn compared to the beginning of the grazing season (Table 14). At this time supplemented animals grazing tropical grasses are expected to show live weight gains above 1 kg/head/day, though feed conversion is a function of the supplement type (Table 15). Information regarding the synchronism between carbohydrate and protein fractions in the rumen and, consequently, the substitution of pasture DM for concentrate DM, and the high concentrate prices in tropical regions seems to be the most limiting factors restraining the adoption of supplementation programs on best-managed farms.

During the summer (wet and warm) tropical pastures are able to support high stocking rates, peaking up to 15 AU/ha. This carrying capacity is much lower during the winter (dry and cold), averaging 10 to 40% of summer values. Therefore the intensification of tropical pasture based systems during the summer must consider the utilization of conserved forages or by-products during the winter in order to guarantee the balance between food supply and demand during the whole year. Options such as silage (corn, sorghum or perennial tropical grasses), hay (perennial tropical grasses), and several by-products (sugarcane, citrus, brewer’s grain, etc.) are available.

Recent simulations revealed that intensive grazing and intensive silage-making systems gave the best economic output compared to several intensive – extensive scenarios (Nussio et al., 2000; Table 16). The authors pointed out, however, that grazing intensification should come before conservation intensification and that the area for forage conservation should not exceed 20% of the total area (Figure 2). It is opportune to stress that substituting corn silage for tropical perennial grass silage has some drawbacks, markedly the lower quality and the high moisture material to be managed. Silage from perennial tropical grasses does not have the same quality as silage from temperate grasses or from corn plant, but reasonable animal performances can be observed when balanced diets are used. On the other hand, high investments in facilities seem to be the greatest constraints associated with tropical grass silages (Table 17).

Feedlot during the winter is also an alternative to allow high carrying capacities on tropical grass pastures during the summer. However, feedlot is economically questionable when practiced under small scales, high grain prices and low availability of by-products. Recently, irrigated tropical pastures have been used to enhance carrying capacity for both beef and dairy enterprises. A farm in Goiás State (Brazil) showed productions costs of about US$ 0,9/kg carcass weight in irrigated tropical pastures by the same time selling prices was US$ 1,36/kg carcass weight. A cost analysis study indicated that adoption of irrigated tropical pasture depends on production costs in the dry pasture system, overall production costs and selling price and the increase in productivity in the irrigated system (Figure 3).

3 Focus on soil fertility

Soil fertility is a major factor limiting tropical pasture productivity, however pastures established on sites of low soil fertility can be as productive as pastures growing on high fertility sites, given the limiting constraints are eliminated. Frequently, information about soil fertility under tropical pastures has focused on acidity and phosphorus deficiency. Whilst these topics are clearly important, some other issues are also important.

Nitrogen (N) is one of the key management tools to increase pasture productivity, but the levels of N fertilizers used in the tropics are quite low, though the responsiveness of tropical grasses to N additions is high, linear responses occurring up to 400 – 600 kg N/ha/year (Vicente-Chandler et al., 1974). Teitzel (1991) found economic advantage for a tropical grass fertilized up to 300 kg N/ha/year compared to a grass legume-mixture. In fact, the author pointed out that to grass-legume mixture be more economically viable than the N fertilized grass it would be necessary that urea costs rise at least 2,8 times (from US$ 350,00/metric ton to approximately US$ 1.000,00/metric ton).

While from an economic and agronomic point of view N fertilizers can (and should) be used in greater amounts than those actually been practiced on pastures growing in tropical and subtropical regions, it is important to keep in mind the need to balance the often conflicting goals of profitable production and environmental protection (Jarvis et al., 1995). This means that there is a need to increase the efficiency of the N fertilizer applied on tropical grasses in order to guarantee agronomic and economic advantages by the same time the environment (soil, water and atmosphere) is being protected.

The limited data regarding the balance of ^{15}N fertilizers on tropical grasses ecosystems indicates many opportunities to improve N use efficiency, since the ^{15}N recovery in shoots is typically low, generally less than 40 % (Catchpoole et al., 1983; Impithuska et al., 1984; Impithuska & Blue, 1985; Martha, 1999). Gaseous losses (ammonia volatilization and denitrification) seem to be the main problem regarding N conservation in tropical pasture systems, since the leaching process is limited by the high ability of tropical grasses in removing large quantities of nutrients from the soil (Corsi et al., 2000). For example, one study showed that when urea was applied (100 kg/ha) on the non-vegeted portion of a tussock-forming tropical pasture in late summer, losses as ammonia equivalent to 80% of the N-fertilizer applied were observed, however, the ^{15}N balance study carried out by the same time on the tussocks demonstrated that less than 4 % of the ^{15}N-fertilizer was found in the 10 – 25 cm layer of the soil (Martha, 1999).

In this context, it seems that the key to increasing N-use efficiency within pasture-based systems is to maximize the utilization of those amounts of N already circulating within the system (Jarvis et al., 1998). In fact, more than 60% of the ^{15}N derived from fertilizer may be recovered in pastures components other than shoots, such as root system, litter and soil, suggesting that in the long-term the N retained in these components would become available to the system, increasing its potential to sustain new pasture growth (Martha, 1999).

The N being mineralized from the root system might be very important in supplying N for pasture growth (Geens et al., 1991). It is possible, however, that decomposition characteristics of these materials pose limits to mineral nutrients subsequently put available in the system, since 43% - 47% (N content from 1% to 1,6%) and 54% - 62% (N content from 0,3 to 0,6%) of root carbon of tropical legumes and grasses, respectively, would not decompose even at infinite time given their recalcitrant nature (Urquiaga et al., 1998).

Thomas & Asakawa (1993) investigating the decomposition of leaf litter found average N contents of 0,41%; 0,60%; 0,46% and 0,48% and average C:N ratios of 130; 88; 126 and 117 for *Andropogon gayanus*, *Brachiaria decumbens*, *B. dictyoneura* and *B. humidicola*, respectively. The point is that the immobilization of plant-available N by large quantities of grass litter of high C:N ratio may be one of the major factors limiting the sustainable production of tropical pastures (Boddey et al., 1996). This happens because when plant litter with a high C:N ratio slows down N cycling and reduces N availability via microbial immobilization, this leads to further N limitation of plant growth, and, in many cases, further decreases in tissue N concentrations (Wedin, 1996).

In contrast, on well-fertilized pastures the amount of N put available in the system through litter decomposition would be high, given the higher N contents in shoots and roots that decrease the immobilization potential of the system (Ball & Ryden, 1984; Holland et al., 1992). In the work of Martha (1999) the relatively high N content (1,1 – 1,3%) in the litter fraction of the pasture might indicate that the N mineralization-immobilization processes will soon turn towards mineralization in the studied system. Further, this material is composed by an easily degradable fraction that might fuels an active microbial biomass (Resende et al., 1999). However, one must keep in mind that C:N ratio exclusively is not a good index for organic materials transformations on soils and other characteristics related to plant litter (lignin concentration, polyphenols, etc.) might better explain litter decomposition dynamics.

The gap in knowledge about the mineralization/immobilization of soil organic matter or organic materials added to soil is certainly the most limiting factor to refine N fertilizer recommendations. This seems to be a consequence of multiple mechanisms operating in the system that restrict the overall understanding of the processes. Hence, studies about soil organic matter dynamics and organic materials recycling in tropical pasture ecosystems will become increasingly more important, especially because there is opportunity for increasing N use efficiency and for decreasing the potential for the nutrients released from these material to be lost to the environment.

The larger amount of organic matter in grassland than in arable soils reflect a greater input of organic matter in dead plant material and animal excreta, combined with a slower rate of decomposition in the grassland soils (Whitehead, 1995). However, accumulation of N is finite, being asymptotic, with an equilibrium at the point where additions of organic residues are balanced against oxidation and losses (Ball & Ryden, 1984). Also, the supply of N from grassland soils to forage plants seems to be greater under long lasting good management pasture conditions (Hatch et al., 1991; Hassink, 1992, Gill et al., 1995).

In this context, Jarvis (1998) pointed out that forage cutting systems should receive around 12% more N fertilizer than grazing systems in temperate regions. On the other hand, Teitzel et al. (1991) indicated that milk production from tropical pastures increased linearly in the range of 150 to 600 kg N/ha/year in new pastures, but this relationship becomes curvilinear after three years with near optimum production from annual applications of 200 kg N/ha/year. In other words, N rates might be variable for different situations, e.g., different ecosystems, but it seems consistent that lower N rates are necessary for grazed pastures compared to cutting forage conditions (Hassink, 1992).

4 Conclusions

1. Animal production based on tropical pasture-based systems has a high plant and animal productivity potential when soil fertility is adequate (e.g. fertilizers are used) and more than 25.000-kg milk/ha/year and 900-kg live weight gain/ha/year can be obtained.

2. Technology diffusion in these systems is constrained due to the fact that animals and land are used as a capital reserve and animal products (milk and meat) in these situations are by-products rather than products. Economic policies toward cereal/legumes crops instead of high-costly cattle enterprises also constrain technology diffusion. This fact frequently makes smallholders livestock farmers unable to adopt the necessary technology to efficiently and intensively explores beef and dairy enterprises. On the other hand, capitalized farmers and companies have already reasonable economic outputs in extensive systems having no interest to adopt more intensive ones.
3. Stockpiling practices and grass-legume mixtures are pasture management options when stocking rates are low, generally up to 1,2 – 2,0 AU/ha/year. Stocking rates above this limit are necessary to efficiently use the high herbage growth rate potential of tropical pastures. Higher stocking rates during the summer should consider the use of rotational grazing and the need to plan winter feeding, e.g., the utilization of conserved forages, feedlots, or irrigated tropical pastures.
4. Tropical grass management (mainly for tussock-forming grasses) seems to have different characteristics compared to temperate pasture management. As herbage accumulation rate in tropical species increase above 100 days, the tropical pasture management should be oriented toward forage quality and/or pasture structure.
5. The supplementation of grazing animals during the summer/autumn periods in tropical environments can be a valuable tool to increase the individual animal performance and the overall pasture output.
6. The use of fertilizers seems to be a pre-requisite to sustain high pasture productivities. Practices that increase the pasture productivity while maintaining the environment quality should be emphasized.

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Table 1. Effect of supplementation with trace-mineralized on calving rate.

Country	Control[1]	Control+mineral supplement
Bolivia	67,5	80,8[2]
Bolivia	73,8	86,4[3]
Brazil	55,0	77,0[4]
Brazil	49,0	72,0[2]
Brazil	25,6	47,3[2]
Colombia	50,0	84,0[4]
Panama	62,2	68,8[5]
Panama	42,0	80,0[2]
Peru	25,0	75,0[6]
Philippines	57,0	79,0[4]
Philippines	76,0	80,0-82,0[4]
South Africa	51,0	80,0[2]
Thailand	49,0	67,0[2]
Uruguay	48,0	64,0[2]
Uruguay	86,9	96,4[2]
Uruguay	27,0	70,0[3]
Venezuela	45,3	59,5[4]
Venezuela	34,1	49,6[4]

1-Control animals received only common salt (NaCl); 2-Bone meal; 3-Complete mineral mixture; 4-Dicalcium phosphate+triple superphosphate; 5-Dicalcium phosphate+cooper sulafate. Source: Several authors cited by McDowell et al. (1993).

Table 2. Range of phosphorus content in tropical grasses.

Species	P range (g/kg DM)[1]
Brachiaria brizantha, Brachiaria decumbens *Panicum maximum, Pennisetum purpureum*	0,80-3,00
Andropogon gayanus	1,10-3,00
Paspalum notatum, Melinis minutiflora	1,00-3,00
Cynodon spp.	1,50-3,00

[1]- on well-managed (and fertilized) pastures it is expected P content in plant tissues in the range of 1,80 to 3,00 g P/kg of dry matter. This range of P in the grazed plant tissue will meet most of the phosphorus requirements for growing animals and dry cows (NRC, 1989; NRC, 1996). Source: Adapted from Werner et al. (1996).

Table 3. Productive indexes for cattle enterprises in Brazil.

Index	Brazilian average
birth rate, %	60%
mortality up to weaning, %	8%
weaning rate, %	54%
mortality post-weaning, %	4%
age at first breed, months	48
interval between parturition, months	21
slaughter age, months	48
slaughter rate, %	17%
carcass weight, kg	200
carcass productivity, %	53%
stocking rate, head/ha/year	0,9

Source: Zimmer & Euclides (1997).

Table 4. Area to be explored under extensive and intensive beef production systems in the tropics to yield US$ 60.000 per year.

	Extensive scenario				
	Number of heads			Av. stocking rate	
	Year 1	Year 2	Year 3	(AU/ha/year)	
	100	100	100	0,4[1]	
		100	100	0,6[2]	
			100	0,9[3]	
Average				0,63	
Av. stocking rate (AU/ha/yr.)					0,50
Av. stocking rate (hd./ha/yr.)					0,79[4]
Output (ha basis), US$					10,4[5]
Area needed (ha)					5769[6]
	Intensive scenario				
	Number of heads			Av. stocking rate	
	Year 1	Year 2	Year 3	(AU/ha/year)	
	100	100	-	0,64[7]	
		100	-	0,95[8]	
Average				0,80	
Av. stocking rate (AU/ha/yr.)					5,0
Av. stocking rate (hd./ha/yr.)					6,25[9]
Output (ha basis), US$					125[10]
Area needed (ha)					480[11]

[1] – Weight range: 130-230 kg (year 1); [2] – Weigh range: 230-350 kg (year 2); [3] – Weigh range: 350-480 kg (year 3); [4] – 0,5/0,63; [5] – 0,79 hd./ha x 0,33 (slaughtering rate) x US$ 40 (output/animal); [6] – US$ 60.000/US$ 10,4; [7] – Weigh range: 200-380 kg; [8] – Weigh range: 380-480 kg; [9] –5,0/0,80; [10] – 6,25 hd./ha x 0,50 (slaughtering rate) x US$ 40 (output/animal); [11] – US$ 60.000/US$ 125;

Table 5. Area to be explored under extensive and intensive dairy production systems in the tropics to yield US$ 60.000 per year.

Variable	Index
Extensive scenario	
Average stocking rate (AU/ha/year)	0,50
Proportions of milking cows in the herd	0,315
Milk production/cow/lactation (kg)	1.000
Productivity (kg of milk/ha/year)	157,5[1]
Margin per liter of milk (US$)	0,05
Amount of milk required (kg)	1.200.000[2]
Area needed (ha)	7.619[3]
Intensive scenario	
Average stocking rate (AU/ha/year)	5,00
Proportions of milking cows in the herd	0,54
Milk production/cow/lactation (kg)	3.000
Productivity (kg of milk/ha/year)	8093[4]
Margin per liter of milk (US$)	0,05
Amount of milk required (kg)	1.200.000[2]
Area needed (ha)	148[5]

[1] – 0,5 (AU/ha) x 0,315 x 1.000 kg of milk; [2] – US$ 60.000/US$ 0,05/kg of milk; [3] – 1.200.000 kg of milk/157,5 kg of milk/ha; [4] – 5 (AU/ha) x 0,54 x 3.000 kg of milk; [5] – 1.200.000 kg of milk/8093 kg of milk/ha.

Table 6. Average milk production per farm and kilometers traveled to collect milk in Minas Gerais Sate Brazil.

Local	km/ month	kg of milk/month	average milk production (kg/farm/day)	kg milk collected/km traveled
15 regions	40.066	1.961.228	325	48,95

Source: CCPR/Itambé (2000).

Table 7. Evolution of milk production and milk farmers in a selected region of Minas Gerais State.

	1985		1996	
	Farmers (number)	Milk production (1.000 kg/day)	Farmers (number)	Milk production (1.000 kg/day)
less than 50 kg				
quantity	12.128	99.019	10.645	95.515
%	64,4	22,1	52,8	12,9
from 50 to 500 kg				
quantity	6.520	294.861	8.877	454.625
%	34,6	65,7	44,1	61,4
higher than 500 kg				
quantity	186	54.962	633	190.268
%	1,0	12,2	3,1	25,7
Total				

Source: Data from CCPR/Itambé, after Jank and Galan (1997).

Table 8. Evolution on farm milk collection in Sete Lagoas (MG) region from 1995 to 1999.

Variables	Can collection	Bulk collection – initial phase (Jan/99)	Bulk collection – logistical approach (Oct/99)
Farmers (numbers)	1286	831	899
Truck (numbers)	49	17	19
kg of milk collected/day	16.000	181.500	208.000
km traveled/day	4.436	4.023	4.441
Milk (kg) collected/km	36	45	47

Source: CCPR/Itambé (2000).

Table 9. Stocking rate evolution in a large farm in Goiás State, Brazil.

	1994	1995	1996	1997	1998	1999	2000	2001**
area (ha)	3.400	3.400	3.400	3.400	3.400	3.400	3.400	3.400
number of heads	2.462	2.947	3.468	3.604	4.437	5.134	6.714	7.580
stocking rate (hd./ha)	0,7	0,9	1,0	1,0	1,3	1,5	1,9	2,2
amended area (ha)*	-	200	250	200	300	370	500	?
irrigated area (ha)	-	-	-	50	50	50	50	?

* - fertilizer was used at pasture establishment and/or to sustain a given stocking rate level.

** - estimated projection.

Table 10. Nutritive value of tropical grasses managed under continuous or rotational grazing.

Species	Grazing method	CP (%)		IVOMD (%)	
		Wet season	Dry season	Wet season	Dry season
B. decumbens cv. Basilisk	continuous	7,7	5,8	57,7	50,8
B. brizantha cv. Marandu	continuous	8,1	5,5	58,8	50,6
P. maximum cv. Tanzânia	continuous	10,6	8,0	59,5	52,0
B. brizantha cv. Marandu	rotational	10,1	9,9	61,9	8,5
P.maximum cv. Mombaça	rotational	10,5	11,5	54,1	55,3

Source: Euclides et al. (1996); Thiago et al. (2000).

Table 11. Rotational grazing: effect of the herbage growth rate on number of paddocks.

Herbage accumulation rate [1]		Stocking rate	Days to return to the	Period (days) of		Number of
kgDM/ha/day	cm/ha/day	(AU/ha)[2]	plant[3]	Occupation[4]	Resting	paddocks
20	0,5	1	30,0	30,0	30	2
40	1,0	2	15,0	15,0	30	3
60	1,5	3	10,0	10,0	30	4
80	2,0	4	7,5	7,5	30	5
100	2,5	5	6,0	6,0	30	6
120	3,0	6	5,0	5,0	30	7
200	5,0	10	3,0	3,0	30	11

[1] - Herbage density of 40 kg DM/cm/ha; [2] - Intake of 10 kg DM/AU/day and grazing efficiency of 50 %; [3] - Assuming the animal returns to the same plant community when regrowth is about 15 cm; 4 – Assuming the animal must not return to a given plant community faster than the established period of time. Source: Adapted from Penati et al. (1999).

Table 12. Performance of grazing animals supplemented with protein-mineralized salt mixture (PS) or protein-energy-mineralized salt mixture (PES)[1].

Treatment[2]	Live weight gain (kg/head/day)	Initial av. weight	Final av. weight
Control	0,57 B	330 ± 1,8	402 ± 1,6
PS	0,64 AB	326 ± 1,9	407 ± 1,7
PES	0,70 A	323 ± 2,0	413 ± 1,7

[1] – *Brachiaria* spp. pasture grazed from December/97 to April/98; [2] - PS: 25% crude protein + monensin; PES: 46,10% crude protein; 10% urea + 10% mineral supplement + 80% corn gluten feed. Source: Balsalobre et al. (1999).

Table 13. Performance of grazing animals supplemented with ionophores[1].

Ionophore	Experimental period (days)	InitialWeight (kg)	Live weight gain (kg/head/day) Control	Live weight gain (kg/head/day) Ionophore	Response (g/day)	Response (%)	Number of experiments
Monensin	111	237	0,65	0,72	70	10,8	18
Lasalocid	101	339	0,60	0,69	90	15,0	9
Tetronasin	110	253	1,09	1,19	100	9,2	2
Bambermicin	104	250	1,10	1,16	60	5,5	2
Lisocelin	107	249	1,15	1,23	80	7,0	1

[1] – Includes temperate and tropical pastures. Source: Adapted from data summarized by Martha & Corsi (2000).

Table 14. Live weight gain of steers supplemented with cottonseed meal (CSM).

Experiment 1 (initial live weight: U - 137 kg; S - 155 kg)[1]						
Intake of CSM (g/d)	0	250	500	750	1.000	1.500
Live weight gain (kg/d)						
U	0,10	0,46	0,56	0,70	0,73	0,94
S	0,13	0,49	0,58	0,64	0,80	0,95

Experiment 2 (initial live weight 233 kg)[2]					
Period 1: Intake of CSM (g/d)	0	290	570	1.160	1.700
Live weight gain (kg/d)	0,85	0,64	0,85	0,95	1,03
Period 2: Intake of CSM (g/d)	0	290	610	1.170	1.860
Live weight gain (kg/d)	0,02	0,19	0,40	0,59	0,74

[1]- Brahman-crossbred steers initially supplemented with 0,5 kg/d CSM over the dry season (S), or unsupplemented (U) so as to reach two different live weights and the supplemented with increasing CSM up to 1,5 kg/d; [2] - Santa Gertrudis steers, Period 1, 5 weeks with green leaf on offer, Period 2, 6 weeks when little green leaf available.
Source: McLennan et al. (cited by Poppi & McLennan, 1995).

Table 15. Steer performance and feed efficiency when grazing *Brachiaria brizantha* during the summer/autumn period and supplemented with protein or protein-energy supplements.

Tratment[1]	Gain in the period (kg/head)	Live weight gain (kg/head/day)	Suppl./gain
control	57,50	0,51	-
protein supplement	128,50	1,14	5,8:1
protein/energy supplement	121,20	1,07	3,0:1

[1] – protein supplement: cottonseed meal (expeller), 0,6% of live weight; protein-energy supplement: 25% cottonseed meal (expeller) + 75% balanced, 1,0% of live weight.
Source: Peruchena (1998, cited from Peruchena, 1999).

Table 16. Meat production (arrobas, @) and net income from simulated production systems based on Tanzania grass (*Panicum maximum*) pasture or silage managed under extensive or intensive conditions.

Production system[1]	Productivity	Prod. Cost	Stocking rate	Live weight gain	Animal output	Cost/@	Net income
Extensive grazing Extensive silage	4,5	53	0,7	0,5	6	26	80
Intensive grazing Intensive silage	20,0	67	3,5	0,7	44	24	673
Extensive grazing Intensive silage	7,6	47	1,5	0,5	14	21	242
Intensive grazing Extensive silage	16,9	72	2,7	0,6	32	28	350

[1] – productivity: tons of DM/ha; production costs: R$/ton of DM; stocking rate: AU/ha; live weight gain: kg/head/day; animal output: @/ha/year; cost/@: R$/ha/year; net income: R$/ha/year (1 R$ ~ US$ 1,9).
Source: Nussio et al. (2000).

Table 17. Estimated facilities requirements for corn silage and perennial tropical grass silage feeding.

Variable	Corn silage	Perennial tropical grass silage
Silage density (fresh basis)[1]	300	200
Silage density (DM basis)	90	40
Intake (DM/head/day)	5.000	5.000
Wagons	9,2	20,8

[1] – Silage density on fresh basis or on dry matter basis are expressed as kg/m^3; intake considers 5 kg/head/day for a 1.000-herd; 6-m^3 wagons. Source: Corsi et al. (2000).

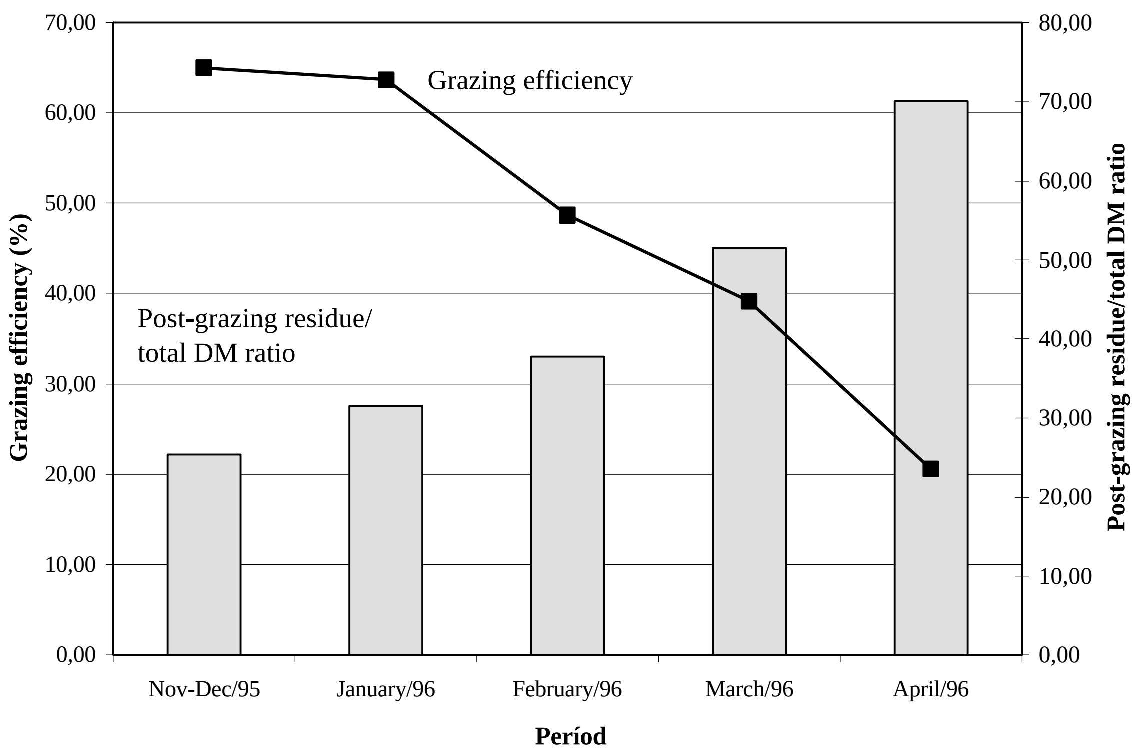


Figure 1. Decreasing grazing efficiency and increasing post-grazing residue/total dry matter ratio as grazing season proceeds. Source: Adapted from Teixeira (1998).

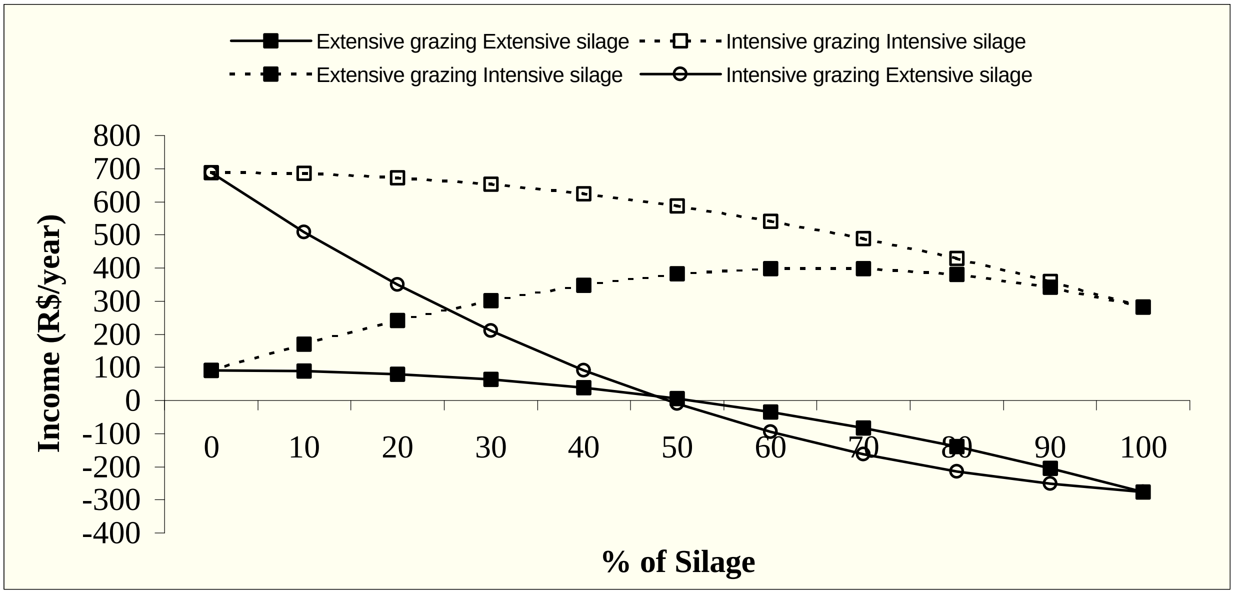
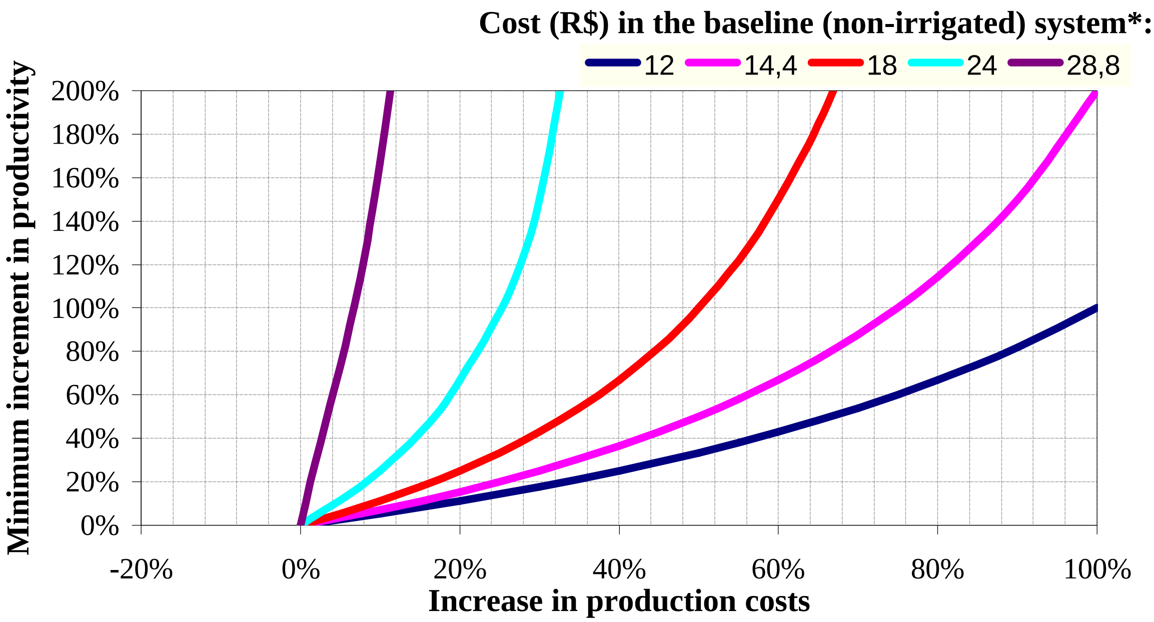


Figure 2. Projected net income for extensive and intensive grazing and silage systems considering the explored area (1 US$ = 1,9 R$). Source: Nussio et al. (2000).



* Considering 1@ (30 kg LW) = US$ 18,95; 1 US$ = 1,9 R$.

Figure 3. Relationship between the increase in production costs in the irrigated system and the minimum required increment in productivity. Source: Corsi et al. (2000).