PASTURES AND THEIR MANAGEMENT IN SOUTH-CENTRAL BRAZIL[1]

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ABSTRACT. — Although the cattle industry of south-central Brazil is of great importance to the economy of the country and the nutrition of the people, present pasture practices have only short term viability. The continuing decrease in productivity of pasture lands has led to consideration of legumes and fertilization to satisfy the primary need for nitrogen. Both alternatives are examined and in conclusion the establishment of legumes is economically viable depending on site conditions and distance from market. Adequate provisions for seasonal shortages, and the establishment of rotational grazing systems are also essential.

Index terms: **pastures; pastures management, nitrogen fertilization economics of fertilization; forrage species adaptation.**

INTRODUCTION

Brazil's cattle industry is extensive, with over 18% of the country — 150 million hectares — in natural and planted pasture. Unfortunately, cattle often require 4 to 5 years to reach slaughter age. Death losses average 10% per year, and only 55% of the cows reproduce per year. The slaughter rate is 12 to 13% for the nation, and in some regions is actually below 9% (Miller *et al.* 1972). In 1960, the urban sector of the population consumed 43kg of beef per capita, whereas the rural portion consumed only 5kg (Pardi 1965).

The low production efficiency results from the current state of animal care and selection, further reduced by the poor quality of most pastures. Generally forages have low nutritive value and low productivity; there are seasonal shortages from drought or frost; and problems result from continuous overgrazing.

The central south contains by far the largest number of animals and provides a somewhat homogeneous land mass. In 1963, this region had 49 million cattle, 6,2 million horses, 1,4 million goats, and about a million sheep (Grossman *et al.* 1965). For cattle, the average carrying capacity per hectare of pasture was 0.42 head for the region as a whole, and 0.81 head for the state of São Paulo (Roston 1976).

Three climatic regions can be identified across south-central Brazil. The northern parts of Mato Grosso and Goiás have a tropical monsoon climate, with 4 to 6 months very dry (Fig. 1). From the southern tip of Mato Grosso through the northern part of Paraná and the southern part of São Paulo the growing season is limited more by cold weather than by lack of moisture. Between is a region where winter growth is limited somewhat by both low temperature and rainfall deficiency.

All over this area, altitude is more important than latitude in determining the extremes of heat

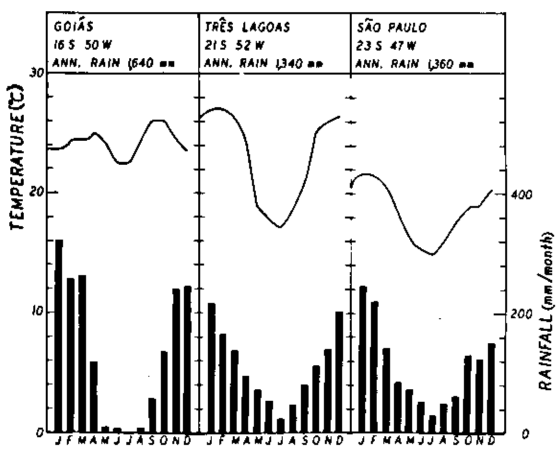

FIG 1. **Normal temperature and rainfall in Goiás (tropical), Três Lagoas (intermediate), and São Paulo (cool) in south-central Brazil (Meteorological Office, London, 1967).**

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and cold. Some 200m increase in elevation makes a difference of 3 to 4°C in average annual temperature, with correspondingly more rainfall. The "Pantanal" complex in western Mato Grosso is excluded from the present discussion because soil and water conditions there differ from those in the rest of central Brazil.

Natural pastures

The natural pasture lands of central Brazil are called "cerrado", "campo cerrado", and "campo limpo", depending on the extent of the woody species (Goodland 1971). These have considerable natural fire resistance, persisting and leafing out again shortly after fire has passed through the area. The cerrado growth varies from short forest to thicket and is only partially open underneath the openings varying from a few spots of grass to a dominant covering of grass. Campo cerrado and campo limpo are basically grasslands. Campo cerrado has ocassional trees and clumps of trees. Resident grass genera include *Panicum, Paspalum, Tristachya, Setaria,* and *Andropogon*, and a few species of the legumes *Desmodium, Arachis, Teramnus,* and *Stylosanthes* also occur. The campo limpo, with its wide expanses of grassy plains, is by far the most beautiful of the natural grasslands. In the south of Mato Grosso the campo limpo is an open bunchgrass formation with few trees. Common there are "grama-batatais" (*Paspalum notatum*) and "barba-de-bode" (*Aristida pallens*). The campo cerrado and campo limpo are noted for their low forage value.

Various authors have argued that the scant vegetation on the various cerrados and campos is a result of: 1. scarcity of water; 2. low soil fertility; or 3. periodic fires. The first hypothesis has been thoroughly discredited. Low soil fertility and periodic burning as causal factors, however, are still matters of some speculation (Goodland & Pollard 1973). Whatever the cause, the cerrados have been the way they are for a long time.

There are cerrados which have formed over ancient basalt rock. Most nutrients, as well as silica, have been leached out of such soils. What is left are granulated soils made of iron and aluminum oxides. In some places, such soils are 20 or 30 feet thick, with little differentiation in soil profile beyond the surface layers. Cerrados also have formed over many other types of parent material.

As a consequence of the advanced aging, these soils have very low cation-exchange capacity, strong to very strong acidity, and extremely low fertility (Table 1). Cattle on these lands have malnutrition resulting directly from the poverty of the soil. Phosphorus, calcium, molybdenum, and zinc are almost universally deficient. Aluminum in quantities toxic to plants is frequently present in cerrado soils.

Cerrado soils are obviously very costly to improve since they require large imputs of macro- and micronutrients as well as limestone. Hence,

TABLE 1. **Campo cerrado and campo limpo soil analyses.**

Localities	Depth	pH	OM (%)	N (%)	PO_4^- (meq/100g)	K^+ (meq/100g)	Ca^{++} (meq/100g)	Mg^{++} (meq/100g)
Campo cerrado								
Anápolis, Goiás[a]	0–15 cm	4.7	2.4	.12	.03	.02	Tr.	.20
	20–40 cm	4.9	1.4	.07	.02	.01	Tr.	.20
	50–100 cm	5.1	1.0	.06	.02	.04	Tr.	.20
Pradópolis, S.P.[b]	0–15 cm	4.7	2.90	.12	.76	.26	1.3	–
Matão, S.P.[b]	0–15 cm	4.7	1.62	.08	.06	.06	.9	–
Anápolis, Goiás 3[b]	0–15 cm	5.3	3.58	.12	.07	.16	1.8	–
Anápolis, Goiás 5[b]	0–15 cm	5.3	2.17	.10	.04	.18	.9	–
Anápolis, Goiás 6[b]	0–15 cm	4.5	4.45	.13	.07	.11	1.0	–
Anápolis, Goiás 7[b]	0–15 cm	5.3	2.65	.12	.05	.33	1.0	–
Campo limpo								
South Mato Grosso 1[c]	0–25 cm	5.1	2.2	–	.03	.14	2.3	Tr.
South Mato Grosso 2[c]	0–25 cm	5.0	2.8	–	.01	.13	1.0	Tr.
South Mato Grosso 3[c]	0–25 cm	5.1	2.4	–	.01	.10	.8	Tr.

[a] Miller *et al.* (1972), [b] McClung *et al.* (1958), [c] Senior author's unpublished data.

these areas have been used for extensive cattle grazing, but have never been integrated into productive Brazilian agriculture. Only now are some owners starting to bring them up to a level of fertility sufficient for highvalue crops such as fruits and vegetables near urban centers, or soybeans and wheat where climate and topography are suitable. Improving these lands for pasture, however, is still not considered economically feasible.

Traditional development of planted pastures

Planted pastures have been derived from lands previously farmed. Farming regions have been carved from the "cerradão" or heavily forested land, of sufficient virgin fertility to be cleared for crops. Traditionally such land was used for a few years or decades, and then abandoned for new land further in the interior.

As Brazilian farmers and land speculators have slowly colonized outward from the coastal cities, the primary objective has almost always been to open new lands for growing coffee and, more recently, cotton and cereal crops. Most of these lands are eventually utilized as artificial pastures.

The virgin forests are cut typically in April, May, and June, so as to dry out before burning time, in August or September. Earlier fellings lead to regrowth and leaf fall, greatly reducing the effectiveness of the burn. In preparation for burning, vines and underbrush are cut out first and then the trees are felled. Land clearing leaves fields that are filled with stumps, logs, and heavy branches that do not decay for decades. These seriously hamper cultivation and pastures that follow, limiting management options.

The crops are more valuable than pasture, so they are planted by small land holders as long as they produce economic returns. Fertilizer is seldom used for the land is usually fertile when first cleared of the dense hardwood forest.

If the land is not useable for coffee, large land holders are more likely to have the land planted to pasture before its productive capacity for agriculture has been exhausted. Land renters typically have to pay 20 to 30% of their yield to the land owner for use of the land. So, many owners and renters agree that where the renter clears the land, cultivates it for 3 years, and plants pasture before he leaves, his use of the land for the 3 years will be rent free.

The grasses usually planted are colonial guinea grass (*Panicum maximum*), hyparrhenia (*Hyparrhenia rufa*), molasses grass (*Melinis minutiflora*), and signal grass (*Brachiaria decumbens*). Hyparrhenia, molasses grass, and signal grass are planted in less fertile areas. Colonial guinea grass and hyparrhenia resist fire (see appendix for Portuguese and English equivalents). Colonial guinea grass is interplanted vegetatively from 2 x 2 to 4 x 4m among the crop before harvest. The grass goes to seed after the crop is harvested; and cattle are turned in to help shake out the seed, trample it into the ground, and get the benefit of eating some of the grass and weeds in the field. The next spring and summer the pasture is usually not used, but after a full year's growth the pasture is allowed to dry and then burned, helping to reduce the quantity of logs, stumps, vines, and forest regrowth in the pasture. Afterward, regular use of the pasture begins and the new area is incorporated into the one extensive pasture of the farm. For hyparrhenia, molasses, and signal grasses the predominant method of establishment is by seed. Aerial seeding of colonial guinea grass or drilling the seed with single superphosphate have become more popular recently.

When the pasture becomes very weedy, or when prices for crops are better than usual, pastures may be planted to crops again. If soils are particularly poor to begin with, only one succession of cropland to pasture may occur. If the land has good initial fertility, the land may be cycled from cropland to pasture three or four times before it is exhausted. The modifications of this practice are many and varied.

Results of traditional use of planted pasture

The pasture is established on land that once supported lush trees and afterward gave bountiful harvest, but the soils are now impoverished. It is not surprising that grass grown under these conditions is of low quality, and that the quantity of grass diminishes progressively. First plantings of guinea grass on good soil support 1.6 to 2.5 head of cattle per hectare. After several years, the carrying capacity declines to about 0.7 head per hectare, and after 30 to 40 years it may fall as low as 0.2 head per hectare.

Fire is used because of its ability to clear the land of unpalatable growth and control weeds.

Burning the grass minimizes the effort and cost of pasture maintenance. Since nitrogen in the grass is lost as a volatile product of burning, the soil is rapidly depleted of nitrogen, with the shortage very evident every spring less than a month after regrowth begins.

After the land has become largely "esgotada" (exhausted), the colonial guinea grass or hyparrhenia grass no longer performs well. Pangola, signal, or molasses grass is planted to compete better with the weeds and revive the "sick" pasture. Still later, batatais grass may provide beautiful ground cover and considerable vegetative production on very exhausted soils; but it has lower palatability and productivity than many other pasture species, and in more progressive sections of São Paulo, batatais is considered a pest. Thus planted pastures pass through a succession from colonial guinea grass and Jaraguá, to pangola or molasses grass, to batatais grass, and finally to a mixture of weeds and cerrado grasses, including batatais.

Not only does the quantity and quality of the grass leave much to be desired, but the shortage of forage becomes particularly acute during the dry or cool season. The usual precaution to prevent such an occurrence consists of running fewer cattle on the pasture all the year, so that the pasture can almost support all the cattle in the dry period. Alternatively, ranchers may plan on the cattle going hungry, losing weight during the shortage period, and compensating for the weight loss during the rainy season. The only common practice to supplement shortages is to grow sugar cane or elephant grass (*Pennisetum purpureum*) for feeding dairy and breeding stock (since this feed is harvested at a mature stage it produces large yields of dry matter, though the protein levels are very low.) Other supplement practices might include feeding hay, silage, or concentrates, but such practices are not used much.

Improved management of planted pastures

Fortunately the beef market, transport facilities, fertilizer availability, land valuation, and credit availability are improving. Thus, economic preconditions for improved pasture management are ocurring, even though the sociological preconditions are not present in all areas. Lacking is an integrated program of pasture technology to optimize productivity. Such technology should have high priority because: 1. adequate protein per capita could be produced for Brazilian consumption each year; 2. large quantities of excess beef could be exported; 3. pasture land would be more productive and hence more nem would be employed at better wages than at present; and 4. clearing new land and copping it to exhaustion would no longer be necessary since the present population could develop a reasonable standard of living on land that is already cleared. Of course, unrestrained population growth could negate such advances.

Nitrogen and phosphorus are the chief nutrient deficiencies. Responses to potassium and sulfur fertilization and liming are frequent also. Results of studies with planted pasture grasses show that protein, phosphorus, and cobalt are frequently too low even in the middle of the growing season for normal growth, milk production, and animal health (Table 2).

Numerous experiments have been done to demonstrate that productivity is vastly increased when pastures are fertilized with large applications

TABLE 2. Analysis of three planted pasture grasses (Jardim *et al* 1965).

Grasses	Protein (%)	Ca (%)	P (%)	Co (ppm)	Cu (ppm)
Feb. or March at Barretos, SP.					
Guinea grass	8.2–13.0	.23–.39	.13–.18	.04–.08	17–29
Hyparrhenia	6.1–11.8	.39–.49	.13–.15	.04–.06	17–29
December at V. do Paraíba					
Molasses grass	5.5–11.4	.18–.33	.09–.16	.04–.09	15–25
Critical level					
Beef cattle	10	.15	.15	.06	3
Milk cattle	16	.20	.20	––	––

of nitrogen, all other nutrients being sufficient. Results have been best with pangola, colonial guinea, and napier grasses.

For the first 100kg/ha nitrogen, the usual response to fertilization is an increase in green-matter productivity of about 15 tons per hectare per year (Miller *et al.* 1972) equivalent to about 4 tons dry weight. Assuming 70% utilization an increase of about 2,800kg/ha/yr dry weight would be consumed, and with a conversion factor of 14.5 to 1 assumed, the live-weight gain of 190kg/ha/yr would result from the 100kg nitrogen (Fig. 2).

The theoretical increased live weight gains of 190kg/ha/yr per 100kg of applied nitrogen/ha/yr are realizable in Brazil. On the Fazenda Jangada, Araçatuba, São Paulo, pastures receiving 200 kg/ha/yr of nitrogen responded with 345 kg/ha/yr increased live-weight gain or 1.72 kg of live-weight gain per kilogram of nitrogen applied over a five year period. (Quinn *et al.* 1970). 1.72 kg of live weight per 1 kg of nitrogen is an underestimate since the residual effect of these fertilizations continued several years after applications were discontinued.

Costs of nitrogen fertilization

Nitrogen fertilization costs include those for the fertilizer, transportation, application, and added management, as well as interest on the investment up to the time of returns. An indirect added cost is the more rapid depletion of other nutrients (potassium, phosphorus, etc.) from the soil. The soils of south-central Brazil already have acidity problems, and an increase in acidity from nitrogen fertilization could make phosphorus, in particular, less available, and increase problems with aluminum toxicity. A good portion of the cation-exchange capacity, which is generally low, is pH-dependent, with acidification decreasing the capacity of the soil to hold cations. The negative effects of the various nitrogen sources can be neutralized with agricultural limestone (Table 3). This cost should also be included. Nitrogen fertilization must thus be considered in the context of its entire ecological consequences and the increased material and management costs.

Discounting against nitrogen fertilization the costs of the resultant lime, phosphorus, and potassium necessary for fertility maintenance, we have plotted the relative costs of nitrogen per kilogram,

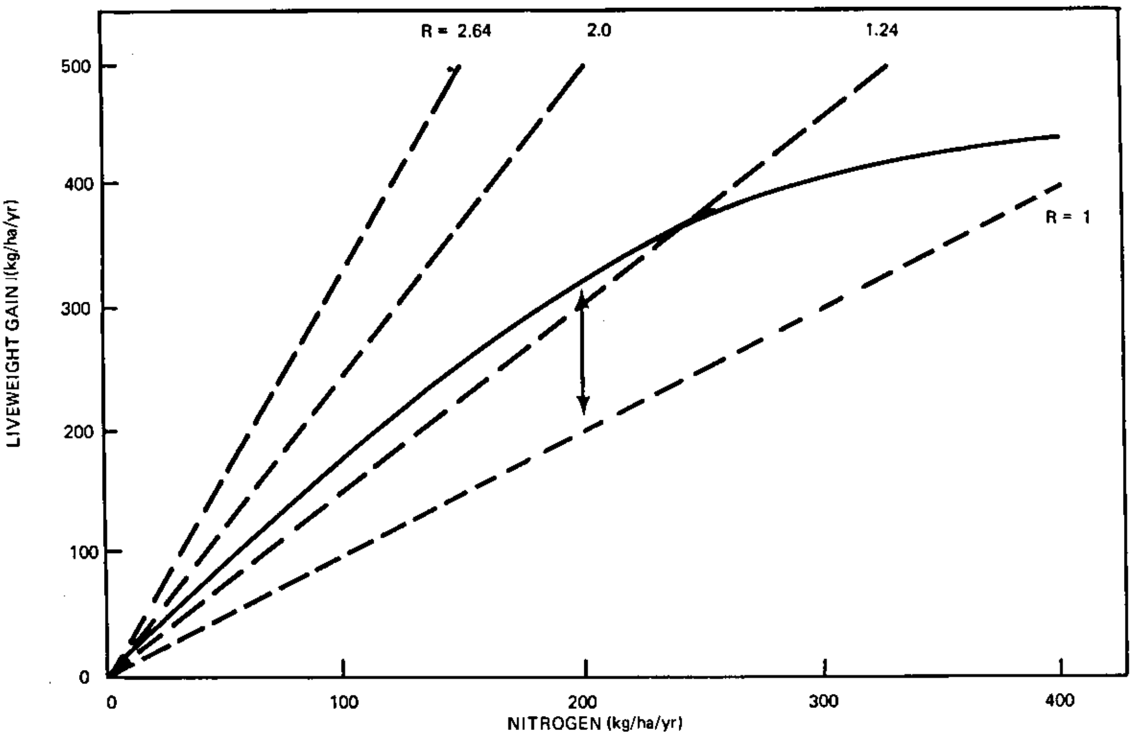

FIG. 2. Response of live weight of cattle to nitrogen fertilization of pastures (solid line) and several relative cost ratios (R) of nitrogen to live-weight produced (dashed lines). Vertical arrow indicates maximum return where R = 1.

TABLE 3. Ground limestone necessary to neutralize N fertilizer (Vicente-Chandler *et al.* 1964).

Fertilizers	N (%)	Limestone requirement	
		kg/kg N	ton/ton fertilizer
Ammonium hydroxide	23.6	6.1	1.5
Urea	46	2.0	1.0
Ammonium nitrate	33.5	1.9	.6
Sodium nitrate	16.5	0	0
Ammonium sulfate	21	5.8	1.2

C_n, and the value of live weight of beef per kilogram, C_1, on the nitrogen response curve. We let relative costs $R = C_n/C_1$. The return from nitrogen applications is then the difference between the nitrogen response curve and the applicable R line (Fig. 2). When R = 1 the maximum return per hectare per year is attained with a nitrogen application of 200 kg of nitrogen per hectare per year. R values are extremely sensitive to transport costs, and as transport and beef marketing facilities improve, R values will change. Hence it is possible that uneconomic practices today may become highly profitable in the future. It is evident that nitrogen fertilization is not a solution to the low levels of pasture productivity, given today's relative prices of beef and nitrogen fertilizer (Table 4). At greater distances from the industrialized centers such practices become less economic, and losses could be large in remote regions (e.g. Table 4 – Cuiabá). Thus, at present, nitrogen fertilization is limited to areas close to industrial centers where fertilizers and lime are relatively inexpensive and meat is relatively expensive.

Even where nitrogen fertilization is economic, the critical minimum restraints on the productive capacity of a property may not be related to

TABLE 4. Estimated annual added cost, added net income, and R values from the application of 100 kilograms of nitrogen per hectare per year (Cr$ 15/US$).

Cost component	Araçatuba São Paulo	Dourados Mato Grosso	Cuiabá Mato Grosso
Fertilizer applied at the rate of 100–30–20 of $N-P_2O_5-K_2O$ per hectare	Cr$ 1348	Cr$ 1348	Cr$ 1348
Cost of limestone to neutralize nitrogen fertilizer acidity	30	30	30
Transport costs	117	236	405
Cost of application and management	176	176	176
Increased costs per hectare per year, C_n	1671	1789	1959
Value of 100 kg live weight, C_1	832	797	745
Value of live-weight increase (190 kg)	1581	1514	1416
Increase in net income/ha/yr as a result of nitrogen fertilization program	– Cr$ 90 (loss)	– Cr$ 275 (loss)	Cr$ 543 (loss)
$R = C_n/C_1$	Cr$ 1671	Cr$ 1789	Cr$ 1959
	Cr$ 832	Cr$ 797	Cr$ 745
Relative costs (R)	2.00	2.24	2.64

pasture vigor or value. Increased grass production will be futile where stock water, disease, or intestinal worms are not provided for, where no financing is available, or where stocking rate cannot be increased. Yet the vast majority of south-central Brazil nitrogen fertilization is not now economically feasible, and pasture legumes need to be considered as a source of nitrogen.

Tropical legumes

The establishment of tropical legumes in association with grasses can be an inexpensive way of supplying nitrogen and high-protein forage (Williams 1967, Hutton 1970). The legumes suggested most frequently for south-central Brazil are *Centrosema pubescens, Glycine wightii, Macroptilium atropurpureum, Desmodium intortum, Stylosanthes guyanensis, Pueraria phaseoloides,* and *Calopogonium mucunoides.* They are cited because of their capacity to fix 50 to 250kg/ha/yr nitrogen (McIloroy 1972, Thomas 1973).

The establishment of legumes when pastures are renewed adds approximately Cr$ 1069/hectare in expenses in addition to the cost of preparing the land and planting grass. This figure includes the cost of fertilization for the first year but only a fifth of the cost of the legume seed and seeding which is prorated over a 5-year period. However, the increased management cost and the faster depletion of soil fertility with more intensive practices must also be considered. If we obtain 100kg/ha nitrogen fixed by a good legume grass mixture we can calculate our costs and returns as before (Table 5).

These figures are valid only under the common circumstances where pastures must be renewed and the land is going to be prepared anyway for a new planting of grass. Further, another assumption is that a legume exists that is capable of fixing nitrogen in the soil near its present level of fertility. The fertilization mentioned in the "cost of legu-

TABLE 5. Estimated annual added cost, added net income, and R values from the stablishment of pasture legumes in renewed pastures (Cr$ 15/US$).

Cost component	Araçatuba São Paulo	Dourados Mato Grosso	Cuiabá Mato Grosso
Cost of legume seed, innoculant, and overseeding procurated for 5 years	Cr$ 100	Cr$ 100	Cr$ 100
Fertilization with 00–60–20 of N–P_2O_5 K_2O per hectare per year plus sulfur and micronutrients[b]	819	819	819
Transport costs	74	148	296
Application and management costs	176	176	176
Increase in cost per hectare per year, C_n	1069	1143	1291
Value of 100 kg live weight, C_1	832	797	745
Value of live weight increase (190 kg)[a]	1581	1514	1416
Increase in net income/ha/yr as a result of legume stablishment	Cr$ 512	Cr$ 317	Cr$ 125
$R = C_n/C_1$	Cr$ 1069 / Cr$ 832	Cr$ 1143 / Cr$ 797	Cr$ 1291 / Cr$ 745
Relative costs (R)	1.28	1.43	1.73

[a] This figure is based on legume nitrogen fixing efficiency of 100kg of N/ha per year. If the legume is more efficient, the profitability is greater. If the legume is less efficient, the profitability is less. The added weight gains per hectare per year stimulated by legumes through better availability of high quality forage, especially during stress periods, has not been taken into consideration in these calculations.

[b] When after one to five years such high soil fertility maintenance levels are no longer necessary to sustain high forage yields and high nitrogen fixation, the long term establishment of a mixed legume grass pasture becomes more profitable due to lower annual maintenance costs.

me" calculations is better than what is needed to maintain fertility under the increased pasture utilization intensity created by the legumes's nitrogen fixation and resultant pasture vigor.

The practical problems of establishing effective legumes should not be underestimated. No studies have provided recommendations as to which legumes to use under various conditions of soil fertility and structure, pests, and climate, and additional research is needed here. Legume-grass associations need to be tested as to their campatibility and adaptation. If several legumes and grasses fit these criteria, so much the better, for having several species of legumes and grasses will lower the risk of pasture losses from diseases, insects, nematodes, and other pests that attack one or another species. The type of research needed for Brazil has already been done for much of subtropical and tropical Australia (Davies & Hutton 1970), and that experience may provide clues as to which grasses and legumes will do well together in Brazil.

Although the exact combinations suitable for Brazil cannot be deduced from Australian experiences, many technical results are of immediate benefit. Rhizobia have been found and cultured that make each legume a success in its appropriate environment. Micronutrient studies have been completed on the requirements for molybdenum, cobalt (both necessary for rhizobial nitrogen fixation), zinc, and copper. Also, techniques for production of legume seeds have been developed.

Brazilian experience shows that a number of legumes have potential. *Glycine wightii* is adapted to areas with above 1,300mm of rainfall per year, and will produce well during the dry season if not subjected to frost or alowed to go to seed, but Glycine does poorly in soils below pH 5.5, or deficient in phosphorus. It is perphaps the most common pasture legume planted in south-central Brazil. Its spread has been limited by its narrow soil requirements. Other Glycine varieties from Australia, such as the late perennial soybean cultivar "tinarro glycine" are more resistant to drought, have latter flowering responses to photoperiod, and may extend the range. The late perennial soybeans are very productive of high protein dry matter during the drier, colder season in São Paulo, southern Minas Gerais and southern Mato Grosso.

Centro (*Centrosema pubescens*), the native "Jetirama" of equatorial Brazilian forests, has been utilized since research in Australia indicated its promise as a pasture legume. Centro is adapted to much poorer, acid soils than are Glycine species. It is also better adapted to regions that are truly tropical, i.e., where rainfall is high (greater than 2,000mm annually) and temperatures remain high.

Siratro (*Macroptilium atropurpureum*) is adapted to regions that are drier than the ideal range for *Glycine wightii*. Siratro is susceptible to root rot, mildew and other fungi in the wetter areas which limit its range of adaptability. Siratro is more palatable than centro, is deeply rooted, withstands drought, and resists attack by various nematode species. It also becomes established faster than many pasture legumes. Siratro should be well adapted to poor-to-good soils in the intermediate rainfall zone.

Greenleaf desmodium (*Desmodium intortum*) is probably indicated for colder areas subject to frost. Desmodium species grow better in the cooler weather of spring and fall than do most other tropical legumes. Desmodium resprouts rapidly after frosts, providing new vegetation of high nutritive value. Silverleaf Desmodium is clearly inferior to Desmodium greenleaf since it does not produce as late in the fall. The Australian experience indicated that, of the Desmodium species, greenleaf is the best of those tested so far, and should be adapted to the mountainous and cooler parts of south-central Brazil.

"Alfafa do Nordeste" or "estilosantes" is the legume known as stylo in English (*Stylosanthes guyanensis*). Stylo and Townsville stylo (*Stylolosanthes humilis*) like centro, have traveled from Brazil to Australia and back again. They are better adapted to drier regions than those discussed above, and have been observed to produce well on soil of very poor fertility.

Kudzu (*Pueraria phaseoloides*) is a vigorous legume of intermediate palatability. Kudzu grows best in the northern most parts of south-central Brazil and further north in the Amazon where rainfall is high. Kudzu is tolerant of poor soil fertility and will probably become one of the most important pasture legumes for Brazil. Kudzu does not seed adequately in the cooler parts of south-central Brazil and encounters difficulty in persisting.

Calopo (*Calopogonium muconoides*) is found growing spontaneously from São Paulo to the

Amazon region. It has poorer palatability than most other legumes. Calopo manages to survive in very poor soils. It is considered a pest by some ranchers but the unconsumed summer growth provides valuable feed during the dry season. Calopo does not seed prolifically in the colder areas and is hurt by cold weather short of frost.

Although the Australian studies do not provide us with a ready-made handbook to apply to Brazil, by combining such information with results from local trials of legumes and grasses, it should be possible to derive reasonable strategies for introduction of legumes in wide areas within 1,500km of São Paulo.

So far we have delineated methods whereby a large portion of south-central Brazil can reverse the traditional trend of everdecreasing fertility and yield. No solution is currently available for regions which are remote from the industrialized centers so that all inputs are uneconomic, or in which the soil is so acid or poor that improvements are uneconomic.

Seasonal variation in forage

Maximal use of the improvements outlined for pasture productivity will require that the forage produced in summer be actually consumed. Much less forage is produced in "winter", because of cooler temperatures or lack of rainfall. If the stocking rate is determined by the capacity of the pasture to produce forage in the cooler, drier part of the year, carrying capacity will not be high, nor will weight gains be as large as desired. Yields of pasture grass closely accompany the seasonal fluctuations in climate. As temperature or water availability decline, forage yields drop dramatically and protein levels are low.

The most common practice used in meeting seasonal shortages is to let the animals lose weight. The rancher hopes that the weight lost will be rapidly regained in the beginning of the spring flush of growth, but the result is that animals require 4 to 6 years to reach slaughter size. Another option is to sell stock and keep the stocking rate low. This inefficient option is exercised where there are extensive pastures and little working capital to invest in livestock. Standing sugar cane and napier grass used by some as feed for periods of shortage are neither very nutritious nor palatable, but their use is still better than the practices of most ranchers (Butterworth & Arias 1965, Andrade & Gomide 1971).

A solution frequently put forward in Brazilian literature is the use of high-protein supplements (Bisschoff *et al.* 1971). By this method, cattle can gain weight continually and rapidly throughout the winter. But the value of the increase in weight is seldom sufficient to offset the cost of the supplement.

Another alternative is to make hay during the Summer flush of growth. Nutritious hays have been made from pure stands of tropical legumes. For example, a common perennial soybean hay might have 13% protein, 72% digestibility, and high levels of minerals and total digestible nutrients (Menegario, undated). But the flush of summer growth that might be used for making hay coincides with periods of high humidity and rainfall.

Silage from napier grass or other elephant grass cultivars is becoming popular. If the silage is harvested so that the second cutting comes fairly early in March, a third cutting will be at optimal growth and reasonable protein content during June. In this way, the earliest seasonal shortages may be met by elephant grass without making it into silage. Silage can then be used from the middle of July through September. Within the monsoon region the most viable solution is probably silage, but the labor costs of silage preparation and distribution are high.

In the intermediate region, considerable weight gain instead of loss can be obtained from standing feed containing a legume component. A live-weight gain of 40kg per head during a 60-day period from June 10 to Augusto 9 (when animals usually lose substantial weight) was obtained by planting a row of pigeon peas (*Cajanus cajan*) every 20 m in the pasture several months before it was to be grazed (Von Schaaffhausen 1965). The substantial weight gain induced by a small quantity of high-value legume makes it seem likely that legume-grass pastures may be adequate for year-around sustenance of cattle. The perennial soybean and desmodium green-leaf would be particularly well suited to provide standing feed in winter in the monsoon region.

Farther south there is greater risk of several months without adequate forage from frosts top-burning the pasture. Pasture production is also severely limited by cool temperatures even when adequate soil moisture and sunlight are present, so that the development and introduction of pasture cultivars productive in cooler weather is a promising solution (e.g. green panic, glycine, and galactia). Both elephant grass silage and legume hay are possibilities. The southern parts of São Paulo, Mato Grosso, and Paraná have distinct dry periods in the rainy season that would allow haymaking. Glycine is a superior legume for making into hay because it remains green, with high protein, minerals, and digestibility, for an extended period, providing more flexibility in timing hay cutting.

Choosing a strategy to provide for seasonal shortages is difficult since not enough research has been done to indicate optimal strategies for making silage or hay, and the costs involved. However, if seasonal shortages of feed can be overcome, beef productivity can improve sharply.

Grazing management

The traditional grazing pattern, one of continuous grazing, is almost invariably associated with overgrazing (Chiarini *et al.* 1967). Where the stocking rate is too high the grass becomes weakened, and weeds begin to invade. Erosion increases, and the grasslands lose their important characteristics of conserving topsoil.

When feed is adequate and stocking rates are low, certain grasses, such as *Panicum maximum* and *Pennisetum purpureum*, still develop overgrazing symptoms in patches. Part of the grass is not initially comsumed, and it becomes coarse and less palatable while originally grazed patches are regrazed repeatedly. Pangola and molasses grasses respond to undergrazing by maintaining excellent ground cover and palatability. Even with these grasses, undergrazing introduces inefficiency, especially when the land necessary per cow is usually at least twice as valuable as the animal itself.

Other significant limitations from continuous stocking are the inability to plan standing forage reserves to help with dryseason shortages, and the impracticality of utilizing legumes as a source of nitrogen. Invariably either the legume or grass will be more palatable than the other. For example, cattle will rapidly select siratro out of a colonial guinea grass pasture. The same pasture, continually grazed, will become overrun by kudzu or calopo as the cattle select out the guinea grass.

Legume-grass association failures can be traced to factors other than palatability. Some legumes or grasses are particularly sensitive to trampling. Both tropical kudzu and molasses grass are easily trampled out of pastures. The sucessful mixture of kudzu and molasses grass in the mountains of Puerto Rico reflects good rotational pasture management (Vicente-Chandler *et al.* 1964). Legumes are sensitive to micronutrient deficiencies like zinc and frequently need shizobium inoculation. Failure of legume-grass mixtures can also be traced to differential needs for macronutrients, especially phosphorus and lime, between the legume and grass involved.

Rotational grazing can provide an alternative to current weed-management practices of roguing by hand or allowing the pasture to dry and burning. Under rotational grazing one objective would be to allow the grass to overgrow the weeds, and then let the animals graze only to the extent that the grass can recover rapidly and dominate. Burning is not completely incompatible with rotational grazing. A badly infested pasture might be excluded from the rotation and burned before the land is reworked and returned to rotation. Rotational grazing can permit higher stocking rates through more efficient utilization of the grass produced, and offer the possibility of saving standing surpluses in some climatic regions. Rotational grazing is essential for maintaining legume-grass associations. However, few definitive results have been obtained as to yield efficiency of Brazilian pastures under continuous vs. rotation grazing.

Integrated approach to pasture management

Legume establishment, fertilization, rotational grazing, and the provision for seasonal shortages which we have proposed to improve animal production efficiency cannot be considered as isolated improvements. These practices complement each other and attain their potential productive capacities only if integrated.

If fertilizer is deleted from legume development and maintenance, the legume will run into trouble. The high productivity of the pasture will fall, and the investments in the establishment of the legumes, water resources, and pasture subdivisions may become uneconomic. If the legume is deleted, for many regions there is no economic way of providing nitrogen for the pasture. With low nitrogen levels, grass viability declines and weeds get the upper hand. If seasonal shortages are not provided for, the pasture suffers a severe strain in the spring, when grass is eaten as quickly as it appears and unpalatable weed seedlings establish themselves readily. Without rotational grazing, returns on investments in legumes and fertilizer will be difficult to realize.

With integration of these concepts, it is possible to raise to 2.5 head/ha the carrying capacity of most land now in artificial pastures within 1,500 km of São Paulo. This would be in marked contrast to the current average carrying capacity of 0.81 head/ha for the state of São Paulo and 0.42 head/ha for south-central Brazil in general. Cattle could be slaughtered in 2 1/2 to 3 years, rather than 4 to 5 years, and efficiency of production would increase greatly.

APPENDIX 1

Grasses for South-Central Brazil

Portuguese	Scientific name	English
Capim-barba-de-bode	*Aristida pallens*	
Grama-missioneira	*Axonopus compressus* var. jesuitica	Carpet grass
	Brachiaria brizantha	
(Brachiaria)	*Brachiaria decumbens*	Signal grass
Capim-do-arame	*Brachiaria dictyoneura*	
Quicuio-do-amazonas	*Brachiaria humidicola*	
Capim-fino, C. angola	*Brachiaria purpurascens*	Para grass
(Tannergrass)	*Brachiaria radicans*	Tannergrass
	Brachiaria ruziziensis	Ruzi grass
(Capim buffel)	*Cenchrus ciliaris*	Buffel grass
Capim-de-rodes	*Chloris gayana*	Rhodes grass
(Grama coastal bermuda)	*Cynodon dactylon*	Coastal bermuda grass
(Grama swannee bermuda)	*Cynodon dactylon*	Swannee bermuda grass
Coast cross bermuda)	*Cynodon* sp	Coastcross bermuda
Capim-estrela	*Cynodon plectostachyus*	Giant star grass
Capim-pangola	*Digitaria decumbens*	Pangola grass
	Digitaria swazilandensis	Swaziland finger grass
Capim-pangola-gigante	*Digitaria valida*	
Capim-chorão	*Eragrostis curvula*	Weeping love grass
Capim-jaraguá	*Hyparrhenia rufa*	Hyparrhenia
Capim-gordura	*Mellinis minutiflora*	Molasses grass
Capim-macaricari	*Panicum coloratum*	Makarikari grass
Capim-colonião	Panicum maximum *sp*	*Colonial guinea grass*
Capim-guiné	*P.m.* var. typica	Guinea grass
Capim-sempre-verde	*P.m.* var. gongyloides	
Capim-tanganica	*P.m.* sp	
(Green panic)	*P.M.* var. trichoglume	Green panic
	Paspalum dilatatum	
(Capim ramirez)	*Paspalum guenoarum*	
Capim-gengibre, grama pernambuco	*Paspalum maritimum*	
Grama-batatais	*Paspalum notatum*	Batatais grass
Pensacola bahia	*Paspalum notatum*	Bahia grass
(Plicatulum)	*Paspalum plicatulum*	Plicatulum
Capim-quicuio	*Pennisetum clandestinum*	Kikuyu grass
Capim-elefante	*Pennisetum purpureum* sp	Elephant grass
(Capim napier)	*P.P.* var. napier	Napier grass
Setaria	*Setaria anceps*	Setaria
Sorgo-forrageiro	*Sorghum vulgare*	Sudam grass
Capim-guatemala	*Tripsacum fasciculatum*	Guatemala grass
Capim-amargoso	*Trichachne insularis*	

APPENDIX 2

Pasture Legumes for South Central Brazil

Portuguese	Scientific name	English
Feijão-guandu	*Cajanus cajan*	Pigeon pea
(Calopogonium)	*Calopogonium mucunoides*	Calopo
Centrosema; jetirama	*Centrosema pubescens*	Centro
Cunhã, clitória	*Clitorea ternatea*	Butterfly pea
(Cratylia)	*Cratylia floribunda*	
	Desmodium adscendens	
	Desmodium canum	
	Desmodium intortum	Greenleaf desmodium
	Desmodium uncinatum	Silverleaf desmodium
(Galactia), galaxia	*Galactia striata*	Galactia
Soja-perene	*Glycine wightii* var.	Perennial soybean, glycine
Soja-perene-tardia	*Glycine wightii* var.	Late perennial soybean, glycine
(Lablab)	*Lablab purpureus*[a]	Dolichos, lablab
Leucena	*Leucaena leucocephala*	Leucaena
Lotonônis	*Lotononis bainesii*	Miles lotononis
Siratro	*Macroptilium atropurpureum*	Siratro
	Macroptilium bracteatus	
	Macrotyloma axillare	Cv. Archer
(Kudzu tropical)	*Pueraria phaseoloides*	Kudzu, puero
Estilo, (stylosanthes)	*Stylosanthes guayanensis*	Stylo, Schofield stylo, Oxley fine-stem stylo
Alfafa-do-nordeste	*Stylosanthes humilis*	Townsville stylo
Teraminus	*Teramnus uncinatum*	
	Vigna luteola	Dalrymple vigna
Feijão-de-corda, feijão catador	*Vigna sinensis*[a]	*Cowpea*

[a] Only occasionally used for forage.

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RESUMO. – AS PASTAGENS E SEU MANEJO NO CENTRO-SUL DO BRASIL
A indústria pecuária do centro-sul brasileiro constitui importante contribuição para a economia nacional e para a alimentação das populações. Contudo, percebe-se que os atuais métodos de pastoreio não podem continuar por muito tempo. A produtividade das pastagens vem diminuindo constantemente; e isso levou a pensar no uso das leguminosas e na fertilização das terras, para suprir a necessidade primária de nitrogênio. Ambas as alternativas foram examinadas, concluindo-se que o estabelecimento de leguminosas é economicamente viável, dependendo das condições da localização e distância do mercado; mas é necessário também fazer provisões para os períodos de escassez, bem como implantar o sistema da rotatividade dos pastos.

Termos para indexação: **pastagem, manejo de pastagem, fertilização com nitrogênio, economia da fertilização, adaptação de espécies de forragem.**