# PRODUCTION POTENTIAL OF SOUTH AMERICA GRASSLANDS

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Grasslands exisst all over the world under a wide range of climates, soil types, topography conditions and seasonality. The South America grasslands cover a wide range of ecosystems and vegetaion types, going from desert areas to steppes, subhumid temperate, subtropical and tropical savannas embodying also portions of the tropical rain forest environment, and represent one of the Earth's largest expanses of natural rangelands (Oesterheld et al., 1992). They represent developed ecosystems requiring acquaintance to accept sound agronomic and ecological activities. The diversity of vegetation determined by the latitudes 6$^{o}$N, down to the southern most tip of the continent at 55$^{o}$ 58' S originated a spectrum of users and uses without knowledge of its potential, imposing pressures upon the natural resources, seeking more profit, and jeopardizing its sustainability, since it encompasses a wide range of contrasting situations and conflicts in resource use (Deregibus, 2000).

The grassland resources were defined as ecosystems where the dominant vegetation components comprise herbaceus species, which includes planted pastures as well as native pastures (Hadley, 1993). They are culturally and economically important to the mankind because it can be harvested by the herbivores and transformed into saleable products for farmers, into usefull fibers and healthy food for humanbeing, to be preserved for recreation and environmental protection, to develop tourism, to feed the industries and has no substitute for conservational purposes and a reliable substrate for ecological studies. Lands that are too poor or too erodable for cultivation become productive once they are considered with wisdom. Natural grazing is a form of land use of those unsuited areas to more intensive exploitation because poor soil, unsuitable topography or short growing season.

The sustainable development of grasslands involve activities to meet the needs of the present, without compromising the ability of future generations. And the concept of "needs" goes to the essential needs of the world's poor. But today's "needs" are much more than survival, and some products have to be obtained to cope with population conservation and health. Despite the concern about the deterioration of pastoral vegetation over wide areas, most grazed plant communities have great resilience and power to recover, if rested and properly managed. Native pastures reabilitation can be sought under grazing management methods, making provision for water catchment, rather than the costly reseeding and tree-planting techniques which is advocated in aid programs without thoughts in economics or sustainability. Mismanagement of grazing causes damage which is not limited to the pasture, since the increased erosion and run-off causes serious harm to arable land and infrastructure lower in the catchment, as well as siltation of irrigation systems and reservoirs. The preservation of wildlife habitat, its recreational purposes, as source of useful and medicinal products, and as *in situ* reserves of genetic material, all contribute to the importance of this natural grassland resource. The examples refered by Riveros (1993) from Xinjiang Altai, in China, and from the Sahel, in Africa, are worth to consider for critical ecosystems of South America.

The South America grasslands will continue to be a major source of feed for all grazing animals in arid, flooded, montane or remote areas as far as one can foresee it. The intrusions of cropping will continue locally, but for what remains as natural pasture (NP), exploitation by grazing will continue to be the major flow for economic returns.The grassland managers are in an increasing fast race to maintain sustainable systems over the grasslands of South America due to the changes that are occurring because of human activities. The challenges are numerous and include saving some of the intact pieces of natural systems in order to finish working out the puzzle of the role of biotic interactions and diversity in maintaining ecosystem functioning and stability. They have to develop the capacity to predict how the natural systems will respond to the many challenges that are occurring. Also have to use today's knowledge to predict the response of systems to combinations of stress that have not occurred in the past, e.g., tourism in rural areas. There is the need to develop and evolve adaptive management schemes to maintain production systems.The management alternatives being evaluated in the "Cerrados" area of Brazil with partial removal of the vegetation, followed by burning, disking and direct seeding pasture species for animal production changed the physiognomy of vast areas (Macedo, 1997). This practice allowed to move from 0.3 beast $ha^{-1}$ to 1.0 beast $ha^{-1}$ by replacing the native vegetation with introduced grasses. Today there are more than 40 million ha of savannas sown into *Brachiara sp* and turned into degraded pastures, with the advanced stages causing damage to the environment.

In the subhumid temperate grasslands the technological levels of animal husbandry are more developed than the remaining pastoralism of some remote tropical areas. The animals are maintained under pasture conditions most of the year, rarely fed suplements, and efforts are devoted to improvement of animal status; herds are organized into categories, ranches are fenced and paddocking is largely practiced, the provision for drinking water is abundant, health care is a rewarding investment, predators and parasites are controlled, and breed purity is highly appreciated (Oesterheld et al., 1992). The biomass of livestock supported per unit of primary production is accompanied by an increase in average herbivore body size. The proportion of small herbivore biomass decreased, whereas the proportion of cattle increased along the productivity gradient. The heavier herbivore load supported by South America grasslands over the last two centuries may be a factor contributing to the vulnerability of those subhumid NP (Hadley, 1993), as well as for the tropical savannas of central Brazil (Barcellos et al., 1978; Barcellos, 1996; Macedo, 1997).

## The Natural Grasslands of South America

Most of the natural South America grasslands evolved under low soil fertility conditions. The vegetation types encountered by the colonizers might have not being too much attractive, but was what the region had for the explorers (IICA, 1994). Except for the Pampas of Argentina, southern Chile and the southern portion of Uruguay, the greater part of South America lies on very poor soils. And the characteristic environments of various regions are very vulnerable to excessive use. Although the temperature and light factor are favourable, and the water regime is abundant, the soil factor sets the limits for development. Table 1 summarizes some informations pertaining to the grasslands of the southern continent, reflecting the actual conditions for the secondary production suited to the capabilities of the region. Toledo (1993) observed that the extent of the degradation process of these savannas could be larger than what occurred in other savannas of the world. Their fragility would reflect also less resilience due to the weackness of the natural resources and the abusive utilization. The grasslands of Colombia and "Cerrados" evolved with the adoption of management practices, with the introduction of legumes as protein bank and the establishment of new cultivated species, which brought substantial increments in productivity, as observed with the *Brachiaria sp* that influenced most the decisions of producers toward the species to be sown for animal grazing. To restore and preserve what was left, research has to be conducted on an holistic approach including the ecosystem processes, social, economical, political, educational and general human awareness and consideration.

## Physiognomic Aspects of the South America Grassland

Most of South America displays a grassland physiognomy, where grasses grow and cattle graze year round, allowing for plenty grass-fed beef production. The temperate grasslands of the cool semi-desert of Patagonia in southern Argentina and Chile are covered by $C_3$ species with most of the native flora being temperate grasses used by the grazing animals. The fertile soils, short and mild summers, are all essentials for $C_3$ grasses and temperate legume species to grow during the cooler season and alternate with species of the other photosynthetic pathway (Deregibus, 2000). The cool season forage species thriving are grasses of the *Agrosteae*, *Aveneae*, *Festuceae*, *Phalarideae* and *Stipeae* tribes. The warm season components are the $C_4$ grasses of the *Panicoideae*, *Chlorideae*, *Andropogoneae* and *Oryzeae* tribes, that are water efficient, nutrient thrifty and low quality forage species. The seasonal combination of species maintain the grasslands greenness yearlong and is ideal for resource utilisation in a variable climate environment, with mild water deficits during summer. These temperate grasslands of South America can embrace production systems in which financial imputs are minimal, being represented by those that produce year round grazing, with minimal or no imputs such as supplementary feeding, herbicides, fungicides, fertilisers, antibiotics and growth promoters (Gomez and Jahn,1993). These systems in general are located in non-industrialised zones and away from pollutants, but not immune to them. Up to parallel 33$^o$ S, in the humid subtropical, warm and cool season species exhibit their growth in alternation along the appropriate seasons, according to variations in humidity and soil fertility.

Around 33$^o$ S up to 26$^o$ S, embodying north of Uruguay, north and northeast Argentina, southern Brazil, south of Paraguay and the mediterranean portion of Chile, the low soil fertility, low soil pH and bellow critical P levels and shallow soils, the legumes account for the presence of few individuals of *Adesmia sp*., *Vicia sp. Lathyrus, Trifolium sp, Medicago sp.Desmodium sp*., and *Rinchosia sp*. *Aeschynomene sp, Arachis sp, Vigna sp,* The whole of the region enjoys the same thermal effects of the climate, encompassing a wide range soil types and elevations, and where the moisture is abundant the dominant tall grasses, such as *Andropogon sp, Schizachyrium sp, Setaria sp, Bothriochloa sp, Paspalum sp, Stipa sp, Aristida sp, Axonopus sp,* restrain the growth of the legumes. As a consequence, the massive dry matter (DM) production during the long warm season is of low quality (< 60 % digestibility), the species diversification and selective grazing along the seasons of the year makes that growth to accumulate, senesce and loose quality further more during the winter and often requires to be burned before the onset of the following spring season (Deregibus, 1988). This accumulation overtops cool season grasses and prevents its growth, determining scarce forage production and quality feed supply during the winter. There are marked seasonality in DM production where the spring-summer season is responsible for 60-85 % of the forage yield, and the short days and low temperatures of the winter preclude growth of the $C_4$ plants. Throughout the region there is the recognition that SR is the dominant pasture management practice determining production and stability of the NP. But very few research centres accept to evolve from fixed SR to the flexible and reliable procedure of stocking the pastures according to the growth pattern of the pastures. And this still happens in those areas where estimates of daily dry matter accumulation rate already exist. It seems to be just a matter of pasture research philosophy and of applying knowledge into it.

North of parallel 26$^o$ S and up to 22 - 23$^o$ S there is a transition zone crossing along the Paraná River and Paraguay River basins, which receives adequate rainfall in the eastern portion, and less precipitation moving westwards. As one gets closer to the Andean Mountains, differences in soil drainage (Blanco, 1994) determine distinct grassland potential, with the livestock raising activity being very extensive, since the bushy savannah vegetation represents the most important natural resource for animal production. Relatively large portions of north Argentina, South of Bolivia and NW of Paraguay are covered by short trees like *Prosopis sp, Acacia sp, Caesalpinia sp, Lithraea sp,* and bushes, intermingled with herbaceous species of $C_4$ type, where *Paspalum sp, Elyonurus sp, Trachypogon sp, Aristida sp, Sorghastrum sp, Schizachyrium sp, Bothriochloa sp,* helped in shaping the "Chaco" vegetation. The aboveground DM of this vegetation lignifies along the season imposing limitations to animal performance, and burning has been a reliable tool to renovate those substrates for grazing.

The "Chaco" is a savannah within the zone of summer forage production due to the concentration of rain in that season (Toledo, 1993). Fire was the main ecological factor in forming the structure of the "Chaco" landscape. In the past, the surplus of biomass in late season were periodically or occasionally burned as a result of electrical storms in the spring, or later by indian burning. In this way the tall grassland intermingled with patches of forest developed the typical "fire climax savannah", analogous to many other ecosystems worldwide. With the settlement of the region, watering points were created and made for most of the herbage produced to be consumed, leaving little or none to be burned. So, the "fire climax savannah" turned into an area of increased scarcity of forage through increased livestock grazing pressures and growth of unpalatable woody species. The range of grazing extension set by the watering points, whose number is reduced for the yearly round-up, worsening the effects of grazing pressure and heavy grazing. This maintained scattered trees with almost no grass, creating a condition known as "Peladeros". The suppression of fire and reduced grazing pressure (GP) tend to lead the "Chaco" to a very undesirable and destructive situation.

North of the Tropic of Capricorn one approaches the scenario the developed world has about the tropics in Latin America. Within the savannah grassland, this huge environment known as the "Cerrados" area of Brazil deserves special attention since it occupies an area from 6$^o$ N to 25$^o$ S where *Trachypogon sp, Leptochoryphium sp, Paspalum sp, Axonopus, Andropogon, Leersia sp, Elyonurus sp, Aristida sp,* together with *Poa sp, Stipa sp, Agrostis sp, Festuca sp, Bromus sp*, contribute to the herbaceous plant cover. Between the parallel 10$^o$ and 24$^o$ S (38$^o$ and 58$^o$ W) lies ca. 70 % of the "Cerrados" and 40 % of the beef cattle herd of Brazil. The main grasses for this region are *Echinolena sp*, and other *Paniceae*, and the *Aristida sp, Arthropogon sp, Axonopus sp, Paspalum sp, Schizachyrium sp, Andropogon sp.*. The legumes are represented by *Arachis, sp, Centrosema sp, Desmodium sp, Stylosanthes sp, Macroptilium sp, Rinchosia sp.* which in combination with grasses and other species made up for the natural pastures of the region. The existing DM during the dry season is the main limiting factor, lengthening the productive cycle in the cattle raising activity (Bracellos et al., 1978; Macedo, 1995; Barcellos, 1996; Zimmer, 1997). For most of the area there was no technological support for ranchers who stands away from farm administration, and livestock was practically raised by nature. The cow-calf operation was the main activity for the use of those natural resources. In the last 25 years the green revolution was initiated and most of the "Cerrados" vegetation were replaced by agriculture, and after one or two years of growing crops, the areas were turned into sown tropical pastures (Macedo , 1995). Most of the applied knowledge came from Australia and CIAT, (IICA,1978), and the SRs were increased several fold. After a few years they were no longer feeding the initial 1.2 AU $ha^{-1}$ on the improved pastures. They were degenerating very rapidly soon after the establishment year. This raised the suspicious that land use for farming followed by pasture establishment and the intensive management imposed to those environments were not suited to their sustainability (Macedo, 1995; Zimmer, 1997).

In the eastern portion of Brazil, most of the animal production is based on pastures developed on cleared pastureland, where *Melinis minutiflora* predominated on poorer soils of the steep slopes, whose forage mass was of accepted nutritive value but supported low carrying capacity ( Rocha et al., 1983). The pastures based on *Hiparrhenia rufa* were persistent, but the productivity was also low. On some of the remaining fertile soils, *P. maximum* (guineagrass) strived and still is the main beef pasture for the region. In the last 20 years the *Brachiaria sp*. took over the region and the cultivar Marandu is being strongly recommended due to its resistance to the spittle bug disease (*Deois flavopicta* and *Manarva sp.*). Either the "Cerrados" and the eastern Brazil make low usage of fertilisers for the introduced pastures that are grazed under high SRs, and the high GPs determine a weakening condition, and soon those pastures degenerate. Tropical legumes are scarcely used, and the highly seasonal DM production do not compromise forage quality with animal demands (Pereira et al., 1995).

According to Leite et al. (1994) the semi-arid region of NE Brasil with a dry season of 8 - 9 month, and an average rainfall of 400 - 600 mm per year uses a mixed livestock and compromise the use of the natural resources. The main genus for the region are *Mimosa sp, Caesalpinia sp, Dalbergia sp, Paspalum sp, Setaria sp, Cenchrus sp, Aristida Sp, Elyonurus sp, Zornia sp, Stylosanthes*, *Centrosema sp,*. In the short rainy season the herbaceous vegetation and green leaves of trees compose the forage mass. With the onset of the long dry season the leaves of the trees become dried and fall into the ground and serve as source of feed to the animals. By the middle of the dry season 62 % of their diet is made of dead leaves of the woody vegetation and up to 28 % is from the standing herbaceous vegetation. Early in the rainy season, green leaves of trees comprise 65 % of the diet and the herbaceous vegetation the other 35 %. Due to the importance of the fodder trees for the diets of the grazing animals, manipulation of that vegetation is very important, and is a common practice to cut the old branches of the trees and the top of the trunk to develop new sprouts and branches from where the goats get most of their feed. Thinning off the stand is also practiced, and gradually they get trunks height with less 0.50 m from the ground, when all leaves are at reach of the animals, increasing the foraging substrate. Under natural conditions of the "caatinga" vegetation, mixed grazing of cattle, sheep and goats are more productive. By thinning that vegetation, cattle and goats are favoured. But when that canopy is manipulated, the trunks are cut close to the ground for new branching, and cattle alone or cattle and sheep make better use of those natural resources.

The vast amazonian region occupies an area almost half of the Brazilian territory (Falesi and Veiga, 1986). The climate is wet and hot in the northern 2/3 and wet-dry in southern 1/3 of the region, with temperatures ranging from $8^o$ - $40^o$ C. It lies on very acid soils, with extremely low P levels and exhibits low CEC, besides other mineral deficiencies. The high P fixing capacity of those soils contributes to reduced opportunities for pasture development. Guineagrass and *H. rufa* are more responsive to P than *B. humidicola*, and tropical legumes may be more tolerant than the grasses to lower levels of P. The lowland grasslands are subjected to periodic inundations, where species of *Echinochloa sp, Hymenachne sp, Oryza sp, Leersia sp, Luziola sp and Paspalum sp*, cover poorer soils over huge areas in the region. The upland grasslands which represent around 60 % of the region, display a similarity in its botanical composition, where the *Andropogon sp, Axonopus sp, Trachypogon* and *Paspalum sp*, sets the productivity and forage quality, extending in the wet/dry savannas of Guyana and Venezuela (Serrão and Simão Neto, 1975). Also important are the legumes *Pueraria sp, Centrosema sp* and *Dolichos sp,*. This ample substrate produces forage with a lower quality than the lowland grasslands. Within those grasslands nutrient cycling is the driving force for their sustainability.

After clearing sections of the tropical rain forest, pasture development brought significant ecological changes to that environment. Initially there was an increase in soil fertility due to the ashes. The rapid establishment of guineagrass, *Brachiaria humidicola* and *Andropogon gayanus* pastures encoraged intensive grazing and within three years, signs of degradation were evident. But the more leniently grazed pastures could be maintained for more than ten years. The P levels of those soils imposed limitations to pasture productivity, although Serrão and Simão Neto (1975) showed five to six fold (up to 25 - 36 t DM $ha^{-1}$) increase in pasture responses of the upland areas when fertilised and sown to cultivated species. The evaluation of those pastures were in terms of animals carried and LWG $ha^{-1}$, with no indication of DM production and animal performance. This left no single message about what would be the animal product being produced by the new pastures. Although the guineagrass pastures produced better on the heavier soils but degraded earlier under high SR, irrespective of the grazing methods, this fact detracted against the suitability of the specie for the region.

This tropical rain forest when converted to pastureland maintained the stable forest C pool, showed a rapid decline of labile forest C but a much faster accumulation of labile crop C, which contributed to the return of the organic C levels to previous levels of the forest, before the deforestation seven years ago Noordwijk et al. (1997).

## Ecophysiological Features of Some South America Grasslands

According to Deregibus (1988) in the humid and subhumid regions, mismanagement, burning and other aggressive abuses on the NP would not eliminate herbaceous vegetation, but partially would affect the water infiltration rate. The dead plant material that dropped at the soil surface is decomposed by soil microrganisms, whose activity is determined by reliable moisture conditions. In the semi-arid or arid ecosystems the NP is much more unstable and the water availability is the regulating factor. The dead plant materials laid in the soil surface undergoes oxidation (do not decompose). So, leaves and stems remain static until physically removed or burned. When associated with alkaline soils, and adequate water, there are excellent production. When the water is limiting, the smaller number of plants grow sparsely, with plant litter covering the bare ground.

The grazing regime may cause reduction in the plant biomass by affecting its vigour, especially during the long dry period. In this way the more palatable perennial species are being eliminated and the canopy is thinned, leaving space and opportunity for the bushes or herbaceous annuals. The uncovered bare spots develop a smooth and hard surface between the sparse plants as a result of the continuous processes of moistening and desiccation of those thin plant parts laid on the ground. These spots become crusty, almost impermeable to water rainfall, which limits further the biomass at that site. This causes rainfall runoff and is appointed as responsible for the loss of productivity and degradation of the NP in those unstable ecosystems. The effectiveness of rainfall in this environment allows to understand the low productivity of regions in the range of 500 - 800 mm precipitation, where some flooding do occur. This situation seems to be not too far apart from the Brazilian “Cerrados” ecosystem. The edaphic component allow for a small number of species to grow in the area, and the erosion process was already established long before the agriculture enlarged it (Macedo, 1997).

Among various studies on the soil as a source or deposit of Carbon $CO^2$, Corazza et al. (1999) observed C reserves in natural systems and in the agroecological systems practiced in the "Cerrados". One third of the C was located within the 20 cm of the top soil layer, and the disturbances brought in by disking or plowing reduced it markedly. On the other hand, tree plantings, cultivated pastures and direct seeding promoted increasing C reserves in the soil. Practices that do not mobilize the top soil layers would contribute to increase the C in the soil, and perennial pastures seems to be effective on that, at very low costs. The contribution would be rewarding if one considers the inclusion of an adapted tropical forage legume, with a potential of 2.5 to 5 fold increase in carbon sequestration. Since nitrogen was the limiting factor to the carbon fixation by plants, and to incorporate it into the soil (Fisher and Trujillo, 1999). Poorly drained soils are a common feature in many areas, and can deposit more carbon in the organic matter as related to what occurs in the better drained soils of the tropics. Similar conditions were observed by Bertol et al. (1998) where increased forage on offer on NP added different quantities of organic matter to the top soil, without any fertilization. There was 10 % increase in soil OM of the top layer, while by resting during summer increased 8 % the soil. Within integrated systems where farming and livestock production are practiced more intensively, Jones (1996) suggested the reconstruction of the top soil layer as an important component from pasture production. The interrelationship between soil, plants and animal mean that the livestock production will be sustainable after the systems of soil utilization overcome the "acceptable" losses of the top soil

In the humid subtropical region, there is a combination of thermal amplitude that allows temperature conditions for $C_4$ and $C_3$ types of plant to grow on the same area, where the $C_4$ type predominates in summer and the $C_3$ type in the winter season. Where the growth rate is high, the plants are not grazed accordingly, become coarse and ranked. The uneaten and remaining older leaves preclude the development of new leaves and tillers, since they avoid the incident light to trigger bud initiation. The ranked biomass accumulation dilutes N and reduces the forage potential of those NP, although it is suited to feed brood cows, but not adequate for finishing slaughter animals. As the winter temperatures do not impose limitations to the growth/or stay alive of the subtropical species, this competes and limits the incident light that would promote the growth of temperate species. As a consequence, there is no seed production and no contribution of $C_3$ plants. This reduces the NP productivity since during winter and early spring they are standing but not growing.

The proportion of species in each group of plants depends on the length of the warm season, on soil conditions, on the presence of trees, on botanical composition, pasture management and associated animal production. They allow for yearlong grazing since there is no interruption in forage production and supply along the year. Once seasonal humidity does not limit plant growth these pastures can be maintained evergreen, and the yellowish in winter or summer is due to weak pasture management that did not promote the species that would make their best growth in that particular season. Forage quality *per se* is high due to the presence of *Aveneae, Agrosteae, Phalarideae, Festuceae* and *Stipeae,* and since there is a continuous regrowth on those pastures, the available forage for grazing is also rich and with high digestibility. These characteristics render those grasslands to abuse, and heavy grazing is a constant and closer to irrationality than approaching to what would be called grazing efficiency. At present days, a clear and sound understanding of ecophysiology and grazing ecology must be present as was brought in by the International Symposium on Grassland Ecophysiology and

Grazing Ecology held at the Federal University of Paraná, 1999, (Lemaire, Hodgson, Moraes, Carvalho, Nabinger, 2000) for the appropriate use of this bountiful natural resource.

## The Missing Link

Since a long time ago, the livestock industry in Latin America was large in terms of numbers but not healthy in productivity. Extensive grazing determined low calf crops and increased time to produce a market-weight animal (Cox, 1966). The existing human resources, animal nutrition, pasture production and range management were very important, and not enough grains were produced to satisfy the demands of the population. So ruminant production would be based on pasture forage and, perhaps, some entirely new system of concentrate utilization. Either the winter or the dry season causes serious animal weight losses, reaching up to 25 % of the body weight during these long stress periods, the animals gain it back in the spring, add some more weight during the summer, then lose again during the next stress period. If those weight losses could be reduced lots of improvement would be achieved.

Important aspects about the technical activities that conducted most of the grasslands of South America to the mismanagement situation of present days, are unknown to most of the new generation, as it was also to me. Tergas and Sanchez (1978) coordinated a seminar on the savanna grasslands of Latin America, in a period when the CIAT was trying to figure out its working agenda, inviting technicians from the tropical areas of South America and from abroad to discuss tropical pastures evaluation. Most of the conclusions and suggestions ended up as rules of thumb scattered all over the tropical savannas, as well as for the cultivated pastures. At that time Paladines (1978) reported on the productivity of the grasslands developed under the orientation researched within the CIAT and being used at the eastern Llanos of Colombia. As showed in table 2, there was an array of superior results in terms of individual animal performance and opportunities for live weight gain per unit area. It showed that the tropical legume based pastures could have a viable solution o obtain the needed increase in livestock production in a sustainable way. But that would need P fertilization, and that would mean cost increase to produce quality feed, and the resulting animal gains would be feasible when animal with potential for live weight gain would be also used. An interesting point to consider was the meaning of low input technology against no input at all. But low input were to be considered, and so, the grasses without fertilization became the option, and the LWG $ha^{-1}$ would mean much more than any other pasture attribute. What was low input for the establishment of a legume based tropical pasture plus fertilizer application, against grass pasture under no fertilization? What was the meaning of applying fertilizers for establishment and not fertilize the pasture after that? It seemed that the demands of the increase in SR, would not raise maintenance costs of the growing herd, because it would allow less DM for animal growth. And that happened on most of South America!

Several factors might have contributed along the evolution of the savanna grasslands to the major presence of grasses. The predominance of grasses might have developed the belief that they constituted the major feed supply to the grazing animals, which also succeed in many situations where management practices favor the grasses, reducing and eliminating the legumes. Roberts (1978) mentioned that the best parameter to determine SR was the legume contribution to DM yield. A sound approach would be to reduce SR as soon as one would observe a reduction in the legume content of the pasture. The inflexible rotational grazing was disastrous to the tropical twinny legumes and advocated a form of flexible continuous stocking, where the grazing pressure would be the appropriate procedure to maintain the legumes under grazing in equilibrium with the grasses. Based on the economics of pasture improvement Nores and Estrada (1978), recommended for the cow-calf operation to consider physiological state and body condition of the breeding cows of the herd, as Stuth and Maraschin (2000) also recommend with detailed information.

## Evolving Concepts and Policies

Most of the savannah grasslands of South America are characterized by low soil fertility, receiving seasonal regular rainfall, with more or less unpredictable fire incidence over a fragile substrate. In mid-latitudes richness of species in the savannas seems to be associated not with forest systems, but with grassland and pastures. Here grazing systems are manipulated by humans to meet a diverse set of production goals (Briske and Heitshmidt, 1991) and the most pervasive of these goals is the maximization of livestock production or profitability on a sustainable basis. The strategies used to attain the desired production goals vary along a continuum of managerial involvement that can be categorized as either extensive or intensive, although limited by several constraints intrinsic to ecological systems. The recognized inverse relationship between animal production per individual and production per unit land area with increasing grazing intensity is a fundamental production response within all grazed systems. This response originates from the combined effects of the following processes: 1) decreasing efficiency of solar energy capture, since primary production decreases because a reduction in the availability of leaf area to intercept solar energy.; 2) increasing efficiency of forage harvest by a large number of animals per unit land area to consume plant material before it becomes senescent and turn into litter; and 3) decreasing conversion efficiency (i.e. the efficiency with which ingested energy is converted into animal products) as grazing intensity increases, since there is strong forage intake restriction per individual animal limiting nutrient and energy availability for growth and performance.

The end result is that production per animal decreases as grazing intensity increases while maintaining expectations of production per unit land area to increase. From the beginning, livestock production per unit area increases with grazing intensity because it is dependent upon both individual animal performance and the total number of animals. After the peak, production per unit area decreases rapidly with increasing grazing intensity because increasing livestock numbers are no longer able to compensate for the limited production per individual animal. Therefore, the grazing intensity which maximizes sustainable animal production per unit area is that which optimises the processes of solar energy capture, harvest efficiency, and conversion efficiency within a system (Briske, 1991).And this is no longer occurring!

In ecosystem function biodiversity is important in maintaining system structure and the efficiency of resource utilization. The diverse substrate tends to improve forage supply to a reduced number of predators as the SR is reduced. At the same time the differential ageing of leaf material and plant parts occur, and this causes grazing to be more selective. So grazing pressure will increase on some species, reducing its vigour and productivity, and more plant parts are diverted to the recycling stream, with chances of being burned. On the other hand, the impact of diverting nutrient cycling and energy flow from the detritus pathway to the grazing pathway through the design of grazing systems which maintain lower herbage allowances are recommended for rangelands where stability of its natural ecosystem is critical, such as in the fire dependent savannah (Stuth et al., 1981).

Any action on carrying capacity must be linked with the environment, and a single SR is inappropriate to the management of grazing systems not in equilibrium. Effective tracking of fluctuations in rangeland productivity requires the ability to rapid diestock and restock rangelands (a practical case of understanding GP, or to provide the inefficient feed supplements and credit policies. Failure in the past was to omit people in planning savannah management (Hadley, 1993). New policies shall be based on better understanding of existing management systems and especially land capabilities, including proper assessment of existing cultural and ecological constraints to development and of all costs and benefits of proposed changes. And Stuth et al. (1997) stressed the diversity of perceptions and goals of farmers, herders, ecologists and rangeland manager, economist and development planners that also affect grassland use and management. A multi-approach will have much more resilience than one based upon a single paradigm. Deregibus (1988) made very precise comments about the characteristics of southern South America grasslands. And a very strong one was that the NP should receive deferred rest rotation grazing to recover or rejuvenate, and to increase biomass productivity and the frequency of desirable species for the site. Another point considered was the reduction in SR and sowing cultivated species. The simple action of reducing SR slows down the rate of degradation but not the trend toward degradation, since the grazing animals will continue to overgraze preferred species within the selected plant communities. The introduction of cultivated species is feasible once there are provisions against the limiting factors that might jeopardize the new pasture.

In the grassland scenario the pastures can supply a given amount of forage feed to the grazing animals. And that depends on the dry matter being produced, from what is available for grazing and also on the nutrients flow in the system. The influence of grazing intensity in the energy flux within the pasture system and corresponding animal yield is roughly exemplified in Table 3. The primary production depends on the photosysnteticlly active radiation that is absorbed by the pasture canopy. It is well understood that where more dry matter can be produced there is an increased potential for animal production. And this secondary production represents the efficiency of use of the natural resource actually harvested and materialized from the primary production by the grazing animal, and can effectively be used as animal production. This depends on the type of animal, distance from markets, and the animal product sought by the consumer. The available forage dry matter will be grazed and consumed according to the dry matter on offer, or GP, but each one being applied with the implications of their usages. The dynamics of DMO is the driving force that will be determining determining how much DM can be removed from the. pastures, and is strongly linked with the sustainability of that system. DMO, the amount removed by defoliation under grazing and the remaining stubble condition after grazing are determinants of the dry matter accumulation rate for the next regrowth (Marschin et al., 1997*a*). It is also recognized that under heavy grazing the residue left after grazing weakens the pasture, reduces regrowth and adds very little to the soil organic matter status (Bertol, et al., 1998). However, under more lenient grazing and controlled gazing pressure, one can measure and detect strong increments in the soil organic matter, which allows for opportunities in soil improvement at very low cost.

## Carrying Capacity

The NP and savannas of South America were always under pressure and increased exploitation and use, as if those resources were endless. Herbivory and grazing comprised an ubiquitous feature, since domestic livestock and indigenous herbivore provide the basics for rural communities. The concepts of carrying capacity and herbivory load, as discussed by Hadley (1993) come from researchers interested in the sustainability of range management in an African context. This can no longer be determined solely by botanical considerations, but must also take account of the management objectives of rangeland users. The concept developed within the classical range management based on the plant succession theory, assumes that a single climax vegetation will dominate a particular site, and seeks to balance grazing pressure against natural plant regeneration through identification of the stocking density at which a stable subclimax vegetation yields a flow of animal products. The view of Stuth and Maraschin (2000) feed this approach and make much more evident the action of technically prepared human resources. The concept developed by wildlife population biologists examines the relationship between plant and wild herbivore populations at alternative SR and contrasts ecological carrying capacity with economic carrying capacity. At this ecological carrying capacity, livestock may be plentiful, but they will not be in particularly good condition, nor will vegetation be as dense as necessary, although composed of the same species as it would be in the absence of animals.

Another implication lies in the exponential relationship between livestock biomass and primary productivity reported for the region. In fact carrying capacity of any grazed plant community implies in obtaining optimal animal performance in that particular environment (Maraschin et al., 1997*a*). It reduces costs of production, defines the area of pastureland per animal and best compromise ADG $an^{-1}$, pasture production and LWG $ha^{-1}$ (Moore,1980). This is true for domestic livestock as for wild herbivores, either under cultivated pastures as well as for NP. The dimension of the restraining impact of SR was unknown only to the practitioners in those times, as it is today. The net and clear results of animal number philosophy is plain and worse than pastoralism. At least the pastoralism moves the herd from that area, while high SR forces the concentration of animals over the remaining better plant communities (Cauhepe, 1994).

Keeping animals on the farm or ranch along the year exposes oneself to failure. Removing the animals that cannot be fed at the property, is a very nice way of avoiding losses and applying GP principles very judiciously. And this, I believe, is a single act of administration. Selling and buying is a big part of the business, and the producer has to cope with it. Low cost enterprise is one aspect poorly practiced in most of the animal raising process. The complete system approach was thought to be the answer for most of the simple problems brought by misunderstanding the seasons of the year and what it would mean to the livestock industry. However, matching the type of animal to the quality of the forage available along the seasons of the year still have to be compromised.

The known lower carrying capacity of the tropical legume based pastures seems to make them unwanted by those who believe that stock numbers are determinant of livestock yield per area. This might be related to the existing confusion within what would be the “optimum grazing pressure, the optimum range condition, or the optimum SR”. They mean a lot in pasture management but do not promote the same effects in animal product output. Roberts (1978) discussed adjustments based on the model of Mott (1960) and that of Jones and Sandland (1974) through a supposition of reducing 30 % GP or the SR on either one. Based on his knowledge of the relationship, he suggested more benefit to be obtained from the Jones and Sandland model. The big mistake was that he took the wrong optimum to base his arguments. He started from the optimum SR for LWG $ha^{-1}$ from the model of Jones and Sandland (1974), but from the optimum ADG $an^{-1}$ from the model of Mott (1960). However if one also departs from the optimum GP for LWG $ha^{-1}$ from the Mott’s model, he will be offering more forage feed to the grazing animal to graze more selectively, and will increase intake of pasture nutrients and opportunities for higher

ADG $an^{-1}$, from the Jones and Sandland's model he just will reduce the competition for forage feed among the grazing animals, but still very far apart from the unknown optimum SR for ADG $an^{-1}$, that inexists in Jones and Sandland's model, nor has provision for obtaining it. The author did not consider the money value attached to the animal's product in his suppositions. But for planned animal production enterprises market price relationships are always involved, and specified animal product have advantages, as well as have the pastures derived from such sustainable management practice. It is worth to remember the concept of "Optimum range condition" where the pastures are stocked to perform a level of defoliation not more than 35 % of leaves of the preferred species on that NP (Stuth et al., 1997). The wealth of the NP is preserved as well as the animals have high intake, since they are favored by the natural selective grazing.

## Tropical Legumes

In the subtropical regions of South America there are ample opportunities to use forage legumes, since they are endemic to the area. For other marginal areas in the double story vegetation of herbaceous plants and *Acacia caven*, the deciduous foliage of the trees replenished the soil mineral removed by the herbaceous species being grazed subtropics (Ovalle and Squella, 1988). Even at the lushly growth of the trees, the herbaceous under that shading were luxuriant relative to those under full sunlight. The trees got most of the water they need from deeper soil layers, allowing more to the herbaceous vegetation that explore the top layers of the soil. Lots of similarity are also encountered in the NE Brazil within the "Caatinga" vegetation (Leite et al., 1994).

Tropical America is the centre of diversity for many important tropical forage legumes, but the evaluations were limited to a few species, marginally adapted to the edaphic conditions prevailing in major livestock areas of the region (Lascano, 2000). Tropical legumes are also important in recuperating lands degraded by imprudent cropping or grazing. These pastures, although contributing, are often unstable, and the management to maintain an adequate proportion of legume still is little understood. The efforts developed to select grass and legume germplasm with adaptation to acid soils found in important ecosystems such as savannas and humid tropical forests revealed *Stylosanthes capitata* Vogel, and *S. guyanensis* (Aublet) Sw. for the savannas and the humid tropical rain forest, and the *Arachis pintoi* Krapov. & D. Gregory compatible with aggressive and stoloniferous grasses and very persistent under heavy grazing. Also show potential for the tropical rain forest environment the legume *Pueraria phaseoloides* and *S. capitata* whose forage the animals select in the dry season. Important was the development of technologies for local seed production to feed the legume based forage systems. Evaluations under grazing yielded results from 200 - 400 kg $ha^{-1}$ in locations with dry-season stress, and up to 500 - 600 kg $ha^{-1}$ in areas with no dry-season stress. Deserves attention the spectacular increase in individual animal performance when grazing legume-based cultivated pastures compared with native savannah grassland (Lascano, 2000; Paladines, 1978). The contribution of 30 % legume DM to the improvement of forage quality was sharp, since the ADG per animal on grass-legume pastures was twice as high as that recorded on grass pastures. Even with 10 % forage legume in the pasture DM, the contribution to ADG was 35 % higher in relation to that obtained on grass alone. Also Norman (1970) introduced *Stylosanthes humilis* (HBK) into native pastures and obtained a linear relationship between the amount of townsville stylo lucerne and ADG $steer^{-1}$ for $9/10^{th}$ of the year.

Selective grazing of the well accepted legumes and/or grasses to the grazing animal, when growing in mixture is advantageous (Lascano, 2000). For the mixture *A. pintoi-Brachiaria* *decumbens* both are eaten at equivalent proportions irrespective of season, but when the grass is *B. humidicola* there is a 65 - 79 % preference for the legume in the dry seasons. For the legumes of low acceptability to the grazing animal such as *Desmodim ovalifolium* the animals select against the legume, irrespective of legume DM availability. Among the suggestions for managing tropical legumes he recommended deferred or rotational grazing during the wet season, together with adjustments in SR, to favour recovery of the grass in mixture with *D. ovalifolium*. The same might happens with *Calopogonium mucunoides* in the "Cerrados" of central Brazil. From his conclusions arose the robust effect of the climate and the undefined dry season, where those unpalatable legumes tend to dominate under continuous stocking. On the other hand, the well adapted and aggressive legumes in areas with short dry seasons will require some form of rotational grazing to prevent legume dominance. Frequency of grazing might be necessary to maintain the balance between grass and legume without the costs of the rotational grazing method, since higher plant survival of *S. scabra* cv. *Seca*, and higher recruitment of new seedlings resulted from more leniently grazing obtained with 0.25 than 0.5 animals ha$^{-1}$ (Orr and Patton, 1993). The P fertilisation of these species (Coates et al., 1993) showed beneficial effects of stylo in diet quality and DM intake, due to the N content of the legumes. The contribution continued while the legume maintained up to 1.0 % N in forage DM. Also, cattle exhibited increased preference for the legume from mid wet season well into the dry season, increasing LWG in 50 kg an$^{-1}$ y$^{-1}$. And with the more palatable and less aggressive legumes, frequent grazing or continuous stocking may be required to reduce competition from the grass and to favour the legume in the mixture. Fisher et al. (1993) have observed *S. capitata* to perform better on sandy soils, while *A. pintoi* is better on heavier soil; *Centrosema acutifolium* has wide adaptation to soil texture and can be a common legume. Many evaluations were conducted based solely on animal responses, and now the stability of pasture components has being included, as showed by the *Stylosanthes* selection for resistance to anthracnose (Grof et al., 1997). For the new technologies being used, no longer fixed SRs or grazing frequency are employed, rather they are adjusted depending on pasture parameters, namely, grazing pressure and proportion of legume in pasture DM, residual green DM, and grazing deferment.

## Managing Grazing Intensities

It comes from long ago the information that lower GP, or high dry matter on offer (DMO), allowed for very high levels of ADG an$^{-1}$ either for NP or cultivated tropical pastures around the tropics. Values ranging for NP: 0.690 - 1.00 kg an$^{-1}$d$^{-1}$ and for cultivated tropical pastures: 1.500 - 1.270 kg an$^{-1}$ d$^{-1}$. This encourages grazing management practices that use lighter GP on tropical pastures (Smith, 1970). Pasture evaluation within the agenda of the "Red Internacional de Evaluación de Pasturas Tropicales" "(RIEPT)", coordinated by CIAT, was discussed by Pizzarro and Toledo (1986). The emphasis was in the determination of maximum productivity of the pastures through the optimisation of DMO. They defined exactly the meaning of stocking rate where a level of grazing intensity would be applied, without concern about forage availability as compatible to extensive grazing. Where pasture persistency was important, as in extensive to semi-extensive pasture utilisation, socking rate would be appropriate. In such a situation, selective grazing is implied and have to be promoted to actually characterize a managed grazing system. With that approach no pasture measurements are taken, but pasture stability is maintained, with advantages to the producer. When one's concern is on grazing intensity based on available forage, the approach on DMO showed to be an easy way of applying GP in grazing studies (Maraschin et al., 1983). The advantage comes from studies of pasture attributes as related to individual animal productivity, and to opportunities to optimise it. Once greater productivity is achieved the concern will be with the sustainability of the system.

In the evaluation of secondary production, Thomas and Rocha (1986) stressed the dominant effect of SR on animal productivity on the long run, and discussed SR and pasture stability, mentioning the acceptability of three or more SR to determine the optimum SR. They criticised the SR approach, since it expresses only animals per hectare without defining what constitutes an animal, although a defined Animal Unit of 400 kg was being used at the EMBRAPA/CPAC, Brazil. This value also was quite different from the old definition of AU, and far away from the 500 kg LW of today's standard (Allen, 1989), but in that way it was easier to get a higher number to attach to a tricky, and false, pasture potential. And if nothing was known in the area, one was free to take results from other regions as a guide to establish the SR in the new environment. The range of SR would go from an unknown lower up to two or three times the lowest SR level. And the lower applied SR has showed not to be a very low level of SR. It has not been observed for the low SR values the opportunity for the grazing animal to have feed available in an amount as required to reach intake potential (Gibb and Treacher, 1976). They also presented worldwide arguments and view-points about fixed or variable rate of stocking, stating that variable stocking would be difficult to implement in the tropics due to the high growth rate of the tropical grasses. To accomplish with the variable rate of stocking frequent observations of the pastures and animals were required, as well as additional labor, and the very critical qualified human resources to deal with subjective decisions. Well, these observations were new to those south american technicians attending that meeting in Peru, in 1986. And may be they were too much motivated by the mistaken appreciation of Roberts (1978) about the Mott versus Jones and Sandland models. Despite the array of information already available at that time, the concepts presented led to the widely adoption on an inadequate and very limited approach to evaluate tropical pastures under grazing. Here lies one of the discomfort in pasture management because fixed SR do not warrants pasture persistency, neither enough animal productivity, especially in regions with marked seasonality as occurs all over South America grasslands. Defenders of the easily applied SR are afraid of being acquainted with the environment and of optimising animal performance, and being on the direction of sustainability of the ecosystem. As they pretend to get much more from the pastures, they move toward abusive attitudes as if nature has to bend herself to satisfy one's ambition.

Increases in SR modifies botanical composition, reduces DM production with increasing forage quality, but also reduces the annual species, leading to bare ground and soil erosion, with permanent effects on production (Mcivor, 1993). Contributing to this fact Thomas and Rocha (1984) reported that a SR of 1.11 animals per hectare maintained an equilibrium between tropical grass and legume at 50 % each. The observed productivity were of an animal performance of 180 kg $an^{-1}$ and an increase of 200 kg LWG $ha^{-1}$. But when the SR was raised to 2.96 animals $ha^{-1}$ the legume percentage dropped from 26% to 6% after three years of grazing while the weeds went up to 46 %. With the increase in SR, the LWG $ha^{-1}$ increased in next year, and determined a notorious decline in the legume component of the pastures, causing sharp reductions in ADG per animal, ending with and average of 59 kg of gain $an^{-1}$ and 178 kg mean LWG $ha^{-1}$ for the four years of the study. As a consequence the LWG $ha^{-1}$ at the high SR was smaller than the 88 kg LWG $ha^{-1}$ obtained at the lower SR. Not only livestock production per area was lost, but the legume component disappeared from the pastures at the high SR, that showed not to be adequate, and caused further losses in productivity. On the other end, Seligman (1993) showed that a 20 - 40 % destocking policy in a drought year could be financially worthwhile in sheep production.

Grazing experiments are not difficult to conduct once they are linked to a defined final product. They just continue to require knowledge, intelligence, criteria, perception, are strongly influenced and determined by the physical environment, and do not compromise with ignorance and false paradigms, as being advocated elsewhere. It is already recognized that the determinant of legume content in tropical pastures, and hence legume selection by livestock, is the GP used to manage the pastures (Maraschin et al., 1997 *a* and *b*). However, by increasing SR in tropical grass-legume pastures there is a concomitant reduction in the legume component, although the creeping legumes seem to tolerate high SR (Lascano, 2000). Maybe this unknown creeping habit of some tropical legumes will become a positive increment in researching for legume persistency, as Brummer and Bouton (1991) described for the outstanding performance of the alfalfa alfagraze, bred for heavy grazing under continuous stocking. Taller and short growing grasses may influence selectivity of species, but the acceptability and maturity stage of those tropical species are a reality and the researchers shall be aware of, as well as the effects of the seasons of the year, and the GP imposed, that can be easily controlled by plant height, number of intact leaves per tiller, pasture biomass, ADG and body condition score of the grazing animals (Maraschin et al., 1997 *b*; Stuth and Maraschin, 2000). The emission of methane by the grazing animals depends on the forage quality and performance of the individual animal. And the performance is never convincing under heavy grazing, since it uses most of the available forage energy for maintenance. Humphreys (1997) comments on a convincing model developed by Howden et al. (1994), indicating advantages of using conservative SR, or adequate amount of DMO, to increase animal output and reduce methane emissions. Their study showed 52 kg of methane being produced by a 300 kg live weight animal per year, eating an assumed 2.5 % LW $d^{-1}$ as DM.

## Native Pastures Management

Selective grazing of plant communities was showed for temperate grasslands by Cahuepe (1994), that identified the preferred species as well as those with greater potential associated with seasons of the year. Grazing according to the suitability of the plant community induces favorable changes in that vegetation. He observed that up to 60-80 % increase in the pasture potential of those plant communities, was due to the high frequency of the species ranked as excellent and very good ones. The carrying capacity also increased from 0.5 to 0.8 AU $ha^{-1}$ and the gain per area jumped from 75 to 135 kg LWG $ha^{-1}y^{-1}$. Stuth et al. (1997) point out that the proportion of utilisation of the forage is very important for ranking those plant communities. In fact, Cahuepe (1994) observed higher preference for plant communities on the soils with better drainage conditions, and less utilisation for those thriving on wet soils. He recalled for the grazing strategies of the ruminant animals over seasons on those more uniform plant communities, and when this was taken into consideration, has increased animal productivity within NP forage management feeding systems. Similar trends for the temperate grasslands has been also observed in Chile (Siebald, 1994) and in Uruguay (Berretta et al., 1998).

Lenient grazing has promoted 50 % increase in the rate of DM accumulation for the temperate grasslands of southern Argentina (Cahuepe, 1994), while relatively light GP encourages *Lotus tenuis* contribution. When a forage availability of 3300 kg DM $ha^{-1}$ was reduced to 1500 kg $ha^{-1}$, the ingested forage dropped from 62.6 DIVMS to 56.2 DIVMS with a concomitant reduction in energy intake, and a decreased efficiency in the forage used for production, since a larger portion of it was diverted to maintenance. The ADG was 0.560 kg $an^{-1}d^{-1}$ at the higher forage availability against 0.300 kg $an^{-1}d^{-1}$ for the low DM availability $ha^{-1}$. The high forage quality of those temperate grasslands allows for an intake of 1.45 % BW as digestible DM for an ADG of 0.560 kg $an^{-1}$ what is compatible with the ADG in fescue pastures. Maintaining high forage DMO is the way to obtain 0.750 to 0.900 kg ADG $an^{-1}d^{-1}$ for calves or finishing steers in the summer and 0.500 to 0.600 kg ADG $an^{-1}d^{-1}$ in the winter-spring seasons. Maintaining higher DMO to the weaned calves has promoted better body condition scores and higher market values.

The natural grasslands of southern Brazil are the main feed resource for an equivalent of 15 million AU. The traditional pastoralism predominates in the use of these pastures, whose feed is being used most for maintenance purposes. However the ranching philosophy of pasture utilisation, coupled with defined conditions for animal output is at his infancy in the region despite the strong support of research results (Maraschin et al., 1997 *a* and *b*). Lenient defoliation at higher DMO levels increases rate of DM accumulation and total DM yield (Stuth et al., 1981). Defoliation efficiencies greater than 50 % occurring at daily herbage allowance levels from 13 to 18 kg DM $100^{-1}$ kg LW $d^{-1}$ with peak efficiencies occurring from 6 to 9 kg DM $100^{-1}$ kg $LWd^{-1}$. Daily herbage allowance values bellow 20 kg $AU^{-1}d^{-1}$ allows for 4.4 kg DM per 100 kg LW and restricted intake of a 454 kg mature cow.

For the semi-arid grasslands of Argentina, Deregibus (1988) suggested the deferred rest rotation grazing to recover or rejuvenate that NP and to increase the biomass productivity and the frequency of the desirable species for the site. Reduction in SR and sowing cultivated species would be another alternative. By reducing SR one slows down the rate of degradation but not the trend toward degradation, since the grazing animals will continue to overgraze the preferred species within the selected plant communities. This is an ever present event, and can be a critical one, where the pasture biodiversity is not counterbalanced by different species of grazing animals. On the other hand, the introduction of cultivated species is feasible once there are provision against the limiting factors that might jeopardize the new pasture. Where soil moisture and temperature are not limiting, a higher residual DM mass would favour plant recovery after grazing. The increase in dead plant parts may suggest losses in photosynthetic efficiency, but favours soil organic matter and enhances $CO^2$ sequestration (Bertol et al., 1998). The structural differences developed within the pasture profile and the constraints at the higher DMO levels allow for increased forage quality within the selective grazing, and also enhances high quality forage DM being harvested per animal and per unit area. These higher ADG per animal can assure capitalisation, since the animal converts forage DM into bodyweight, at the cost of grazing.

On the NP of southern Brazil ($33^o$ - $24^o$ S), the subtropical grass species dominate the scenario and produce forage DM for 210 - 240 days of the warm season. The distinct pasture canopies ranged from prostrate forms of growth on the heavier grazing pressures, to a ranked vegetation on the more leniently grazed pasture treatments. Maraschin et al. (1997 *a*) reported an accumulation rate up to 16.3 kg DM $ha^{-1}d^{-1}$along the season for the NP maintained at the optimum carrying capacity determined to be at a DMO of13.5 % LW per day, which was equivalent to maintain existing DM at the level of 1400-1500 kg DM $ha^{-1}$ at any time. The conversion efficiency of this ecosystem in capturing radiation energy from the sun light to transform it into primary production (Table 3) ranged from 0.20 % for the DMO of 4.0 % LW, increased to 0.33 % with the DMO of 8.0 % LW, went up to 0,36 % with the 12.0 % LW, which represented an 80 % increase in efficiency, and was reduced to 0.32 % at the DMO of 16.0 % LW, as a consequence of the natural DM accumulation and the build up of dead plant material in the pasture profile. It is very true that the relationship of ADG ($R^2$ = 0.95) and LWG $ha^{-1}$ ($R^2$ =0.78) are strongly related to DMO (Figure 1) in a **curvilinear** fashion (Maraschin et al., 1997a).

A very interesting observation was that the curve for the rate of DM accumulation $ha^{-1}d^{-1}$ was parallel to the curve of ADG $an^{-1}$, which got its maximum of 0.500 kg $an^{-1}$. These events happened for the DMO of 13.5 % LW, the point at which the optimum carrying capacity was also determined. The LWG $ha^{-1}$ exhibited a curve of gain parallel to the DM production for the season, with its maximum at the DMO of 11.5 % LW, slightly lower than the DMO that allowed for maximum animal performance. These values and relationships were well documented along the six years of the experiment, under continuous stocking. In practical terms it means that the productivity of those grasslands can be increased to 130 - 150 kg $ha^{-1}y^{-1}$ at the cost of harvesting the forage by the grazing animal, at no cost increase.

In the northern Uruguay and NE Argentina the NP under fixed SR have yielded more LWG per hectare under high rate of stocking. However, higher ADG $an^{-1}$ and better carcasses were exhibited at the leniently grazed pasture treatments (Berretta et al., 1998; Pizzio et al. 1994). There are strong evidences for larger areas of the subtropical South America grasslands, that more lenient grazing will promote animal performances, as well as will be much more productive in terms of animal products.

## Native Pasture Fertilization

It is well documented and recognised the common feature that the **levels of available P in the soils are extremely low**. The use of fertilisers to increase DM and quality of the NP production took too long to be accepted by those involved with livestock production, although the cultivated pastures were fertilised for the establishment, but not for maintenance. For the NP nothing was done all over South America until 1955, when a large grazing experiment was established to evaluate the effects of phosphorous application on livestock production of the NP in southern Brazil (Barcellos et al. 1980). At that time 160 kg $ha^{-1}$ P was applied broadcast, and continuous versus rotational grazing were under evaluation. After 11 years of grazing, there was 10 % increase in livestock production from the rotational grazing against the continuous stocking method. However the outstanding response was to P fertilisation, that showed an increase in productivity around 4.95 kg LWG $ha^{-1}$ $kg^{-1}$ of applied P. After 11 years the fertilised NP was producing 70 % more than the unfertilised NP. No doubt, there was a very lasting and contributing effect of the P application. Inasmuch the benefits, that unexpected and misunderstood pasture response was not considered for a very long period of time. But many doubts disappeared after Scholl et al. (1976) fertilised the NP to introduce oats and clover for winter grazing, and the NP was also fertilised, showing convincing response to N fertilisation during the summer (Maraschin and Jacques, 1993).

Trying to elucidate aspects of pasture fertilisation, Lobato et al. (1986) sowed the sharp residual effects of P fertilisation on forage DM production of subtropical pasture mixtures, with increased legume contribution as the P levels were increased. However, the P levels in the soil were gradually being reduced due to extraction by the plants since there were no P reposition, and after five years it was reduced to 1/5 th of what it was at the beginning. On the other hand, annual fertilization of a mixture of guineagrass, Siratro, *Glycine wigthyi* and *S. guyanensis* maintained that pasture productive for more than ten years. The annual application of 20 kg $ha^{-1}$ of P helped in maintaining pasture production while the application of 40 kg $ha^{-1}$of P increased 30 % the pasture production, whereas under no fertilisation production dropped at a rate of 15 % annually. They also indicated *Panicum sp* as responsive to fertile soils, where high levels of P were applied, while *S. capitata*, *S. guyanensis* and *Zornia*, besides *B. humidicola*, *H. rufa*, *A. gayanus* as species with good performance on soils with low P supply. They emphasized the development of a philosophy of pasture productivity to take advantage of fertiliser use and applied knowledge in pasture management all over the country to benefit from the improvement brought by the fertiliser applications. It seems that Brazil makes little use of fertilisers on pastures because other countries do not use it.

For southern Brazil, the thorough credit on NP fertilisation came with Moojen and Maraschin, 2000 (unpublished); Gomes et al. (1998), when lime and a compound N:P:K fertilizers up to 220 kg of P were surface applied. It raised the top soil $p^H$, reduced $Al^{+++}$ toxicity down to the 7.5 - 20.0 cm soil depth, and promoted five-fold increase in soil P at the firt 2.5 cm of the soil top layer. This soil amelioration reduced the contribution of coarse species and also the dead plant material from the ranked growth of the uneaten species. There was an increase in frequency of prostrate species, where *P. notatum* predominated, and boosted *D. incanum* contribution to DM yield from a low 3.3 % up to a high 24.4 % of native legumes forage. With this impulse Nabinger et al. (2000) applied N to *P. notatum*, avoided the summer water stress and obtained 12.0 t DM $ha^{-1}$, and adjusted the DM yield to the model: **Kg DM $m^{2\ -1}d^{-1}$ = 0.44.Rs(1-exp(-0.0031.ST)) +R,** where **Rs** is global solar radiation, **ST** is degree days and **R** is residual green DM after grazing. The information based on these two environmental variables when taken into the field, caused a deep impact in the research program with lots of promotion to NP fertilisation.

Those previous responses of the NP fertilised motivated fellows from other countries to fertilise their pastures and get new invigorating information to remove soil fertility limitations to plant growth and DM production from the NP. Cahuepe (1994) observed a very lasting contribution of the fertilisers applied to the NP, oversown for the introduction of cultivated temperate species. The cultivated sown species increased their frequencies and total DM yield allowing for higher DMO. The SR was increased from 0.8 - 1.0 AU $ha^{-1}$, the ADG was raised over 0.500 kg $an^{-1}$ $d^{-1}$ with a LWG between 250 - 300 kg $ha^{-1}y^{-1}$. However, to break even with the use of inputs for high productivity in the area required 350 kg LWG $ha^{-1}$ of yield increase. Possibilities to increase or anticipate forage accumulation of wheatgrass pastures was showed by Greco et al. (1997) with nitrogen applied to temperate NP despite differences in soil behaviour. In Chile, pasture fertilisation (Siebald,1994) raised the ADG to 1.00 kg $an^{-1}$ and increased livestock yield by 60 %, reaching 1000 kg LWG $ha^{-1}y^{-1}$, while GOIC (1994) increased LWG $ha^{-1}$ by 60 % due to increased ADG of ewes and 50 % increase in weaning rate of lambs, and Acuña (1993) observed 60 % increase in DM production, kept the same ADG $an^{-1}$ and increased 56 % the LWG $ha^{-1}$. The P applied increased also the biological N fixation by the legumes. And along the years highly fertilised legume based pastures maintained yields up to 18 - 20 t DM $ha^{-1}y^{-1}$. In the NE Argentina, P increased 38 % the LWG $ha^{-1}$ while compound N:P:K increased it by 78.5 % (Pizzio et al., 1994). The efficiency of P fertilisation was 4.58 kg LW $ha^{-1}$ $kg^{-1}$ of applied P, while for N fertilisation was 1.60 kg LWG $ha^{-1}$ $kg^{-1}$ of applied N, close to the 2.00 kg LWG $ha^{-1}$ reported by Boin (1986) for tropical pastures in central Brazil. The magnitude of responses is associated with the SR, experiencing sharp declines in LWG $ha^{-1}$ as the SR was increased. All over the South American temperate grasslands low SRs have increased the energy intake of the grazing animal as compared to those under high SRs (Cauhepe, 1994; Torres et al., 1994). Animals from high SRs pasture treatments have also exhibited low degree of carcass finishing.

The pleasing scenario of the NP fertilized and managed according to combined levels of N and green DMO under grazing, brought lots of new knowledge for pasture management, when evaluated according to its ecophysiological traits. It is already known that plants divert high proportion of photosyntates to build structures suitable to respond to stress conditions (Briske, 1986). The *P. notatum* dominated NP increased stolon mass as a response to increased levels of either N or green DMO. The plants developed these structures to store N for new plant tissue production (Lemaire and Gastal, 1996), and particularly in *P. notatum* this reaches up to 54 % of the aerial DM being produced. Under low levels of both N and green DMO, the strategy was to develop structures related to environmental adaptation, and in this case is the stolon, which function as a reservoir of meristems for new shoots development. There also is a clear indication that a rich NP condition can be developed by increasing the residual green DM after grazing, when dealing with low levels of N. However, fertilising with N increases the number and weight of tillers and changes the structure of NP, determining different residual DM for equal DMO. The higher LAI left after grazing, as N application was increased, was associated with less leaf mass removal by grazing at the higher DMO. This renders the grasses much more competitive against the native legume component at the presence of N. However, when no N is applied, higher DMO encourages the legume contribution to the pasture mass yield. The total DM production will be less than that fertilised with N. However, 30 kg $ha^{-1}$ $d^{-1}$ of green DM obtained at no cost, just by increasing DMO, emphasizes the importance of grazing management on the potential productivity of the nitrogen fertilised NP.

## Grazing of Cultivated Pastures

It is well documented that grazing may be limited by the presence of some undesirable component in the lower layers of the sward (Barthram, 1981; Dougherty et al., 1992). The grazing is confined to the layer which contains only green leaf material, i.e, grazing was always above the layer containing sheath and dead leaf. Despite the leaf sheath does not represent an impenetrable barrier, its presence effectively inhibits the depth of grazing even in swards rich in the young leaves. In taller swards grazing apparently was not restricted. In evaluating swards it is important to determine the distribution of pseudostems within the sward canopy. Also Beranger (1985) discussed increased production efficiency in plant-animal system emphasizing that a large proportion of ingested grass has to be used above maintenance for production of milk or live weight gain, which requires productive animals able to express their potential. Grazing at optimum SR is a compromise between maximum intake and individual production and maximum animal production per hectare, since intake decreases when available herbage per animal decreases. When forage availability do not limit animal intake, animals with high yield potential can express their growth near maximum, without supplementation, lowering costs of production. In all conditions (environments) it is necessary to find the best compromise in combining these three factors: **plant growth**, **plant utilization** and **animal performance** to reach the maximum efficiency taking into account the costs of production. It is recognized that improved pastures have showed to greatly increase rates of gain and calf crop percentages. When dealing with productivity the entire system has to be considered, with both seasonal and annual variations included. And Moore (1980) evidenced that increase in ADG $an^{-1}$ under grazing is the best way to reduce animal production costs, showing that animals per hectare express the rate of stocking that allows for the optimum individual animal performance.

Results from grazing trials conducted in eastern and central Brazil, in the “Cerrados” area were presented by Rocha et al. (1983). Different grazing methods were employed, and the “put-and-take” technique for adjusting grazing intensity was utilised. The effects of different SR were noticed but unable to make estimates for maximum output. The application of advanced technologies into farm practice revealed that fertilized pastures increased yield of cultivated pastures from 150 to 400 kg $ha^{-1}$ in the “Cerrados” area of Brazil, irrespective of the final animal product. They also suggested to be of paramount importance the search for cheap sources of nitrogen to supply the pasture ecosystems and obtain livestock production at low cost. Very interesting was their comments about the contributions made by *Cenchrus ciliaris*, introduced into the native pastures of the dry NE Brazil, promoting a two fold increase in the LWG $ha^{-1}$, but with no changes in the ADG $an^{-1}$. For the southern South America grasslands Maraschin and Jacques (1993) revealed interesting features for yield products from cultivated pastures under different environmental conditions, showing a potential yield of 1.0 t LWG $ha^{-1}$ under grazing. Fertilizers and improved plant material are essential components of the scenario, implying high costs and demands for skilled applied knowledge, and the chances of its use depends on price structure for beef and on the efficiency of the producer.

The program for pasture improvement in Uruguay was established on top of the NP, through fertilization and introduction of cultivated species, mainly for the autumn and winter-spring seasons where they obtain 1.0 - 1.5 t $ha^{-1}$ of legume forage DM. Nitrogen fertilization is also being used and the forage quality from those pastures promotes ADG around 0.600 kg $an^{-1}$ under conservative fixed SR. In association with the NP, the system finishes a competitive steer before 28 month of age. Most of the pastures are devoted to finishing steers for the international market, and the LWG are in the border of 450 - 500 kg $ha^{-1}$ (Risso and Berretta, 1996). For the sheep and lamb production program, Montossi et al. (1998) have developed high quality pastures and managed the flock according to market demands, where LWG of 500 - 600 kg $ha^{-1}$ are in place, with a productivity of 8.0 kg LWG $ha^{-1}$ $d^{-1}$ for the fat lamb pastures. The summer water stress limits the yield increase in pasture productivity for the season. But promotes pasture productivity in the rice irrigated areas, where winter and summer pastures produce 0.800 kg of ADG $an^{-1}$ and an average of 800 kg LWG $ha^{-1}$, year round grazing and no feed supplements (Mas, 1996). Similar productivity is being obtained in Chile (Soto, 1993), and in the upland areas with more emphasis on the autumn and winter-spring season, with 1.00 kg ADG $an^{-1}$ with finishing steers, and above 1.0 t LWG $ha^{-1}$ (Goic and Siebald, 1987). In Argentina, the Pampaean region and in the agriculture belt the  crop-pasture rotation systems devoted to finishing steers are producing 0.700 - 1.00 kg ADG $an^{-1}$ under lenient grazing and LWG $ha^{-1}$ close to 1.0 t of LWG $ha^{-1}$, also under grazing plus some feed supplements (Rosso, 1993).

It is recognized that heavy grazing develops a leafy sward, there are new tissues actively growing in the pasture profile, but the grazing animals attain bellow levels of optimum intake, weight less and dispute for the available forage mass. On the more leniently grazed pasture treatments, they have more forage mass to select from, and it is easier to compromise forage accumulation rate with the animals carried, and higher sustainable ADG $an^{-1}$ is obtained. The ADG $an^{-1}$ and LWG $ha^{-1}$ were related to the forage DMO levels in a **curvilinear** fashion with $R^2$= 0.94 and $R^2$ = 0.99, respectively (Maraschin et al., 1993; Moraes and Maraschin, 1993); Maraschin et al., 1997*a*), and delineate the shape of the curve of LWG $ha^{-1}$, indicating the overriding importance of the ADG $an^{-1}$ for expressing the animal potential of the pasture. For two summer seasons the DMO that optimised the ADG $an^{-1}$ were within the range of 11.7 % to 12.5 % LW $d^{-1}$ (Maraschin et al., 1993; Moraes and Maraschin, 1993) and defined the area of land needed to produce enough forage feed to well nourish the grazing animals (Moore, 1980). For the association of winter and summer cultivated pastures, maximum ADG $an^{-1}$ were attained with DMO of 12.4 % and 12.5 % LW $d^{-1}$, corresponding to DM residues of 2100 and 2900 kg DM $ha^{-1}$, respectively (Moraes and Maraschin, 1993). These values are well above those registered for temperate pastures in the literature, and might help to guide new pasture studies directed toward superior animal responses.

The changes brought by experimental results suitable to central Brazil, and the "Cerrados"area were presented by Macedo (1997). The persistency of cultivated pastures were dependent on initial soil fertility status and lenient grazing management. Lenient grazing is important, but not enough for the pasture sustainability. The decline in soil fertility status was the starting point to pasture degradation (Macedo, 2000). The first symptom observed was the reduction in carrying capacity under equivalent forage on offer levels; the pasture regrowth do not acquire previous status after resting; and the reduction in forage mass and quality reduces ADG $an^{-1}$. Bare spots become visible in the pastures, the weeds invade and the native species return to the site. So, judicious monitoring of carrying capacity would indicate the beginning of the degradation process. When detected early costs 100.00 U\$ $ha^{-}1$ to recover the area, while later detection raise them to 200.00 U\$ $ha^{-1}$. The reduction in SR helps to maintain animal performance but do not overcome the trend in pasture degradation, similar to what occurs in the grasslands of Argentina (Deregibus, 1988). The ADG $an^{-1}$ is the indicator that forage quality was affected and productivity is going downward. However, there is a close trend between pasture DM accumulation rate and ADG $an^{-1}$, as observed by Macedo, 1997; Maraschin et al., 1997 *a* and *b*).

The scenario of the cultivated pastures for the tropics of South America is demonstrated by several fold increase in ADG $an^{-1}$ and LWG $ha^{-1}$ allowed by the results of Lascano (2000) in Colombia; Serrão and Simão Neto (1975) in the Amazon region: Lobato et al. ( 1986) for eastern Brazil and by Macedo (1997) when the NP was replaced by fertilised cultivated pastures in west-central Brazil. Another alternative that is acquiring importance is the integration of crops and grassland agriculture within a complete system of land use and farm productivity. The annual crops will generate financial resources for improving the soil fertility level, thus reducing costs of pasture establishment. Consistent results are showing new pastures with increased pasture potential for the region, where fertilised *Panicum* pastures are producing 740 kg $ha^{-1}y^{-1}$, while the *Brachiaria sp* reach a ceiling yield at 600 kg $ha^{-1}y^{-1}$. These differences come from the higher ADG $an^{-1}$ and higher number of steers carried by the *Panicum* pastures, compared to the *Brachiaria sp* pastures (Euclides et al., 2001). Based on these results a beef production program was established with the target of 100 kg of carcass $ha^{-1}y^{-1}$(Macedo, 2000). Depending on the year, dry-lot feeding is also used because the animals must leave the farm before they complete 24 months of age. For enterprises adopting low levels of technology, *Brachiaria sp* is the option, while for those enterprises adopting the existing high level of technology, the *Panicum* pastures shall be recommended.

It seems that moderate levels of technology adoption tend to predominate in central Brazil, where most of the recommendations are to increase the number of stocker calves. For the central Brazil, Corsi and Santos (1995) report 26.0 - 41.0 t DM for the two most cultivated *Panicum* cultivars in the area, which qualifies them for high pasture potential since the ADG $an^{-1}$ are not better than 0.600 kg $an^{-1}$, suggesting a longer period of time to finish a slaughter steer. New experimental results with *Brachiaria* cultivars showed different rates of leaf growth rate for the wet and the dry seasons (Euclides et al., 2001). Some ecotypes displayed higher leaf DM yield in the dry season while others performed better for the wet season, and were recommended to be tested for animal gains. They have already showed high pasture potential. The hopes rely on the animal potential of those new cultivars.

Very contributing to learn and understand what happens in the pasture profile is to promote grazing based on the green leaf lamina dry matter (GLLDM), evaluating the pasture dynamics and enjoying the shaping up of the silhouette of a steer gaining weight and being finished on pasture under grazing. At low levels of GLLDM the animals graze more frequently, promote tiller density as well as invasion of other plant species, and adversely affects root mass, plant diameter, internode length, tiller weight, rate of accumulation of GLLDM and total

GLLDM yield. It seems that heavy grazing does not help the pasture. It is already known that pasture plants require carbohydrates for regrowth. The stored carbohydrates would be used for respiration and root maintenance within a short period after defoliation. Under continuous stocking grazing these short periods are endless, so the energy used for regrowth is expected to come from current photosynthesis (Richards,1993). The maintenance of higher GLLDM levels promoted the interception and use of a greater proportion of the incident radiation and use for tissue production, and hence, higher rate of photosynthesis, yielding more carbohydrates for regrowth. The weight changes of the morphological components reflect the contribution of a greater proportion of the canopy to the photosynthetic process, suggesting an increased supply of photosynthates to all plant parts, indicating a sustainable response to more lenient forms of pasture defoliation. An interesting aspect is the way the animal treats the pasture according to the forage that is available for grazing. At high GLLDM on offer they remove less lamina tissue, and more leaf mass would be present in the more leniently grazed pasture treatments. With this embodied selective grazing one can expect high rate of intake and approach the maximum ADG $an^{-1}$, and express the overriding importance of animal potential for pasture evaluation, contributing to the yield of upgraded animal products. With clearly defined levels of pasture management being applied on Mott dwarf elephantgrass, the relationship between DMO and ADG was also curvilinear (R2 = 0.97). The sustainable optimum ADG of 1.043 kg $an^{-1}$ at a DMO of 10.5 % LW $d^{-1}$ of GLLDM yielding 1188 kg LWG $ha^{-1}$ can finish a slaughter steer within 210 days of grazing, under continuous stocking (Maraschin et al., 1997*b*). These curvilinear responses assure that ADG $an^{-1}$ is paramount to LWG $ha^{-1}$ in determining pasture yield.

According to Minson (1983) the ideal pasture for cattle grazing is the one that allows for a bite size of 0.300 g of OM. Such bite size would be attainable with an available green forage mass of 1000 - 1500 kg $ha^{-1}$ of that forage being consumed by the animal under unrestricted grazing. And this unrestricted means also strong opportunities for selective grazing. Based on the acquired knowledge in conducting grazing experiments to evaluate DMO and animal and pasture responses, there is a suggestion to consider, at least, 1500 - 2000 kg $ha^{-1}$ live green leaf lamina DM as the forage mass from which the grazing animals will get their diet (Ribeiro Filho et al., 1997). I believe this DMO will make and compromise for the unrestricted opportunities for DM consumption under grazing. As stated by Illius and Hodgson (1996), the foraging behavior and diet selection play a pivotal role in grazing systems, not only by linking primary and secondary production, but also because it is the selectivity of herbivores which mediates and localizes their impact on the population ecology of plant species in the pasture.

## Pasture Sustainability

In any system of soil utilization the use of livestock during short periods do not yield enough elements to develop evaluation criteria for the contributions from pastures, since the biology of the system demands much more time to establish and to stabilize in relation to the defined schedule of crops and pastures in the rotation. The first requirement for a sustainable pasture system is that mineral nutrients be conserved or replenished. Productive systems require nutrients in a readily absorbed form by plant roots. The root system developed by pasture plants helps in the conservation of this nutrient status with very small losses. Dung and urine plus dead plant material are the sources of nutrients in the recycling stream and are discussed by Boddey et al. (1996). The estimates of pasture DM consumption goes up to 30 % of primary production, and 80 to 90 % of this is excreted. The animal selects the richest parts of plants, and the remaining elements are recycled in the litter which decomposes gradually. Deposition rates of litter from

*Brachiaria decumbens* and *A. gayanus* in the “Cerrados” goes up to 6,0 - 10,0 t DM $ha^{-1}y^{-1}$, while there are estimates of 15,0 to 17,0 t DM $ha^{-1}$ $y^{-1}$ in *B. humidicola* in the humid regions of eastern Brazil. This rate of deposition of nutrient poor organic matter may be the cause of lack of sustainability of these pastures. These nutrients are conserved but are immobilized and not available for plant growth. Where maintenance fertilisation of P and K is practiced pastures of *Brachiaria* have persisted for 8 and 16 years with no signs of decline in productivity (Lascan0, 2000: Serrão and Simão Neto, 1975). There are strong suggestions that P immobilization in insoluble inorganic forms may be partially responsible for the decline, but N deficiency caused by the deposition of large quantities of plant litter of very high C:N ratio is cited as the main cause (Macedo, 1997). Modest annual applications of P and K can maintain good pasture stands, but N fertilizer lasts only few weeks. Then the appropriate solution would be to introduce N-fixing legume into the sward to reduce the C:N ratio in the litter. The exiting news are that the tropical legumes no longer allow for doubts, are well documented, and do exist. Although management of the tropical legumes might be a problem in maintaining adequate balance, there is enough knowledge to assure legume persistency under grazing. Every review on this subject has showed that hogh grazing pressures, through the mistakes imposed by the fixed SR paradigm, and the long rest periods due to the mixed up advantages of rotational grazing have contributed for the reduced proportion of legumes throughout the tropics.

The tropical legumes compete poorly with the aggressive tropical grasses for soil N and once established in the sward they usually obtain high proportion (> 80 %) of their N from the legume/rhizobium symbiosis (Cadisch et al., 1993). In a study with *S. guyanensis* cv "Bandeirantes" they observed approximately 81 % of its N from biological N fixation, and since the animal grazes more from the grasses than the legume, the total contribution to the sward was between 67 and 117 kg N $ha^{-1}$, due to the amount of litter from the legume. It seems that the great impact on the N cycle resides in the increase in N returned to the soil via litter. To maintain pasture productivity, the average net mineralisation rates would need to be 150 and 127 kg N $ha^{-1}y^{-1}$ for the pure grass and the mixture, respectively. In the long term this shall resolve the problem of N immobilization, and the lack of N for plant growth. However, the legume must persist in the pasture. Although some *Stylosanthes sp.* have problems of seed supply, apparently *S. guyanensis* cv Mineirão does not have any problem and can be a reliable alternative for N supply to the tropical pasture ecosystem for the "Cerrados "area as is also expected from the multilineal **S. capitata X S. macrocephala,** cv "Campo Grande" (Euclides and Macedo (1999), Pers. Communication), still in tests at "CNPGC/EMBRAPA". There are no doubts that the biological nitrogen fixation introduces an extra source of protein to the animal diet, but more important to the ecosystem is the litter quality and hence N recycling for the long term productivity of the tropical pastures.

For the tropical savannas of the "Cerrados" area of Brazil, a minimum of 3.0 ppm of P in top 20 cm soil layer is required to establish and maintain cultivated pastures. And fertilizer rates of 35 - 70 kg $ha^{-1}$ of P are needed, depending on the grass or legume to be sown. A better understanding of the process can be achieved when the nutritional status shows, at least, 1.2 g of P $kg^{-1}$ DM in the last expanded leaf to sustain a productivity of 350 - 450 kg LWG $ha^{-1}$ (Macedo, 1997). A very important aspect is also to maintain a high proportion of last expanded leaves in the pastures for grazing. Maintenance of nitrogen fertilization benefits pasture production (Euclides et el., 2001; Fisher et al., 1993), which can be increased by the contribution of the 50 kg $ha^{-1}$ of biological nitrogen fixation from the tropical legumes (Boddey et al, 1996). From many grazing experiments under fixed SR, Macedo (1997) observed higher ADG $an^{-1}$ when pastures of *Panicum* maintained 2.5 t DM $ha^{-1}$ while in *Brachiaria* pastures 3.0 t DM $ha^{-1}$were maintained.

These values are very close to the recommendations of Almeida et al. (1997); Moraes and Maraschin, 1993) for intensively managed pastures. It is becoming notorious that ADG $an^{-1}$ is the pasture parameter that more accurately indicates effective applied pasture management for productive tropical grasslands. This approach helps in determining the animal potential of the pastures; in the characterization of the animal production there from to attend market demands (Mccall and Sheath, 1993), and incorporating the bountiful benefits of leniently grazed pastures increasing $CO^2$ sequestration, and consequent reductions of methane emissions, pasture degradation, and environmental damage. The solution is at hand, since it is very easy to reduce presently used SR, to the levels of forage DMO that optimize individual animal performance.

## References


**Acuña, H.P.** (1993). Evaluación de pasturas en pequeñas parcelas bajo pastoreo. In: J.P. Puignau (ed.) Dialogo XXXVIII. *Metodologia de Evaluacion de Pasturas*. IICA. Montevideo. Uruguay. p.35-44.

**Allen, V.G**. (1991). Terminology for grazing lands and grazing animals. *The Forage and Grazing Terminology Committee.* VPI. Blacksburg, VA. USA. Pocahontas Press, Inc. 38 p.

Almeida, E.X., Maraschin G.E., Harthmann O.E.L. and Ribeiro Filho H.M.N. (1997). Dinâmica d pastagem de capim elefante anão cv. Mott e sua relação com o rendimento animal. *Anais XXXIV Reunião Anual da Sociedade Brasileira de Zootecnia.* Juiz de Fora, MG. p.271-273.

**Araujo Filho, J.A., Mesquita R.C.M. and Leite E.R.** (1994). Avaliação de pastagem nativa. In: J.P. Puignau (ed). *Utilización y Manejo de Pastizales*. Dialogo XL. IICA-Procisur. Montevideo, Uruguay. p.61-70

**Ayarza, M.A, Rao I.M., Thomas R.J., Fisher M.J., Lascano C.E. and Herrera P.** (1993). Standing root biomass and root distribution in *Brachiaria decumbens-Arachis pintoi* pastures under grazing. *Proceedings of the. XVII International Grassland Congress.* NZ-Australia. p. 1921.

**Barcellos J.M., Severo H.C., Acevedo A.S. and Macedo W.** (1980). Influência da adubação e sistema de pastejo na produção da pastagem natural. In: Pastagens; adubação e fertilidade do solo. UEPAE/Bagé, RS. Miscelanea, 2. 123 p.

**Barcellos, A.O.** (1996).Sistemas extensivos e semi-intensivos de produção: pecuária bovina de corte nos Cerrados. In: R.C. Pereira e L.C.B. Nasser (ed). *Proceedings 1st International Symposium on Tropical Savannas.* Brasilia, DF. p. 130-136.

**Barcellos, J.M., Echeverria L.C.R., Pimentel D.M., Soares W.V. and Valle L.S.** (1978). Produccion de ganado de carne en suelos de baja fertilidad en el Brasil: Estudio de dos sistemas simulados de produccion en Mato Grosso do Sul. In: L.E., Tergas y P.A.Sánchez (ed) *Produccion de Pastos en Suelos Acidos de los Tropicos*. CIAT. Cali. Colombia. 1. p 321-329.

**Barthram, G.T.** (1981). Sward structure and the depth of the grazed horizon. *Grass and Forage Science.* **36**: 130-131.

**Beranger, C**. (1989). Increasing production efficiency in plant animal systems. *Proceedings of the XV International Grassland Congress.* Nice, France. p. 98-103.

**Berreta, E.J., Risso D.F., Levratto J.C. and Zamit W.** (1998). Mejoramiento de campo natural de basalto fertilizado con nitrogeno y fosforo. In: Berretta, E.J. (ed). *Seminario de Actualizacion en Tecnologias para Basalto.* Tacuarembó, INIA. Uruguay. p. 63-74.

**Bertol, I., Gomes K.E., Denardin R.B.N., Machado L.A.M. and Maraschin G.E.** (1998). Soil physics properties and their relation todifferent levels of forage supply on a natural pasture. *Pesquisa Agropecuária Brasileira*. **33**: 779-786.

**Blanco, J.A.C.** (1994). Utilización y Manejo de los pastizales en las sabanas del Beni, Bolívia. In: **Puignau, J.P.** (ed.) *Utilización y Manejo de Pastizales*. Dialogo XL IICA. Montevideo, Uruguay, p.191-196

**Boddley, R.M, Alves B.J.R. and Urquiaga S.** (1996). Nitrogen cycling and sustainability of improved pastures in the brazilian "Cerrados". In: R.C. Pereira and L.C.B. Nasser (ed). *Proceedings 1st International Symposium on Tropical Savannas*. Brasilia, DF. p.31-38.

**Boin, C**. (1986). Produção animal em pastos adubados. *Simposio sobre Calagem e Adubação de Pastagens.* Nova Odessa. SP. p. 383-420.

**Briske, D.D.** (1991). Developmental Morphology and Physiology of Grasses. In: Heitsmidt and Stuth, J.W. *Grazing Management*. An Ecological Perspective. Timber Press. Portland. OR. USA. p. 85-108.

**Briske, D.D and Heitshmidt RK**. (1991). An Ecological Perspective. In: Heitshmidt, R.K and Stuth, J.W. *Grazing Management*. An Ecological Perspective. Timber Press. Portland, OR. USA. p. 11-26.

**Brummer, E.C. and Bouton J.H.** (1991). Plant traits associated with grazing-tolerant alfalfa. *Agron. J.,* **86**: 996-1000.

**Cadish, G., Carvalho E.F., Suhet A.R., Vilela L., Soares W., Spain J.M., Urquiaga S., Giller K.E. and Boddey R.M.** (1993). Importance of legume nitrogen fization in sustainability of pastures in the Cerrados of Brazil. *Proceedings of the XVII International Grassland Congress.* NZ-Australia. p. 1915-1916.

**Cauhepe, M.A.** (1994). Ecologia y producción animal enla Pampa Inundable, Argentina.. In: Puignau, J.P. (ed).*Utilizacion y Manejo de Pastizales*. Dialogo XL. IICA, Montevideo, Uruguay. p. 5-30.

**Coates, D.B., Ash A.J. and McLean R.W.** (1993). Diet selection, diet quality, dry matter intake and growth rate of cattle grazing tropical grass-legume. *Proceedings of the XVII International Grassland Congress*. NZ. Australia. p.720-723.

**Corazza, E.J., Silva J.E., Resck D.V.S. and Gomes A.C.** (1999). Comportamento de diferentes sistemas de manejo como fonte ou depósito de carbono em relação à vegetação de Cerrado. *R. Bras. de Ciencia do Solo,* **23**: 425-432.

**Cox, M.L.** (1966). Animal Agriculture in Latin America.- Present status and possibilities for expansion. *Proceedings of the 15th Annual. Meeting on the Role of Animal Agriculture in Meeting World Food Needs*. Natl. Academy of Sciences. p.179-191.

**Deregibus, V.A.** (1988). Importancia de los pastizales naturales en la Republica Argentina: Situación presente y futura. *Revista Argentina de Producción Animal*. **8**: 67-78.

**Deregibus, V.A.** (2000). Animal Production on Argentina's Humid Grazinglands: Problematics and Possibilities. In: Lemaire,G., Hodgson, J., Moraes, A., Carvalho, P and Nabinger, C. (ed) *Grassland Ecophysiology and Grazing Ecology.* CABI Publishing, UK.

**Dougherty, C.T., Bradley N.W., Lauriault L.M., Arias J.E., Cornelius P.L.** (1992). Allowance-intake relations of cattle grazing vegtative tall fescue. *Grass and Forage Science*.**47**: 211-219.

**Euclides, V.P., Valle C.B., Macedo M.C.M. and Oliveira M.P.** (2001). Evaluation of *Brachiaria brizantha* ecotypes under grazing in small plots.*Proceedings of the XIX International Grassland Congress.* Piracicaba, SP. Brazil.

**Euclides, V.P.B., Macedo M.C.M. and Oliveira M.P.** (2001). Animal production in tropical pastures renovated by subsoiling and fertilization in the cerrados of Brazil. *Proceedings of the XIX International Grassland Congress.* Piracicaba, SP. Brazil.

**Falesi, I.C. and Veiga J.B.** (1986). O solo da Amazonia e as pastagens culltivadas. In: Peixoto, A.M., Moura, J.C. e Faria, V.P. (ed). *Pastagens na Amazonia.* FEALQ. Piracicaba, SP. p.1-26.
Fisher, M.J., Lascano C.E., Thomas R.J., Ayarza M.A., Rao I.M., RIippstein G. and Thornley Y. **J.H.M.** (1993). An integrated approach to soil-plant-animal interactions on grazed legume-based pastures on tropical acid soils. *Proceedings of the XVII International Grassland Congress.* Rockhampton, Brisbane, Australia-NZ. Pp.1903-1904.
**Fisher, M. J. and Trujillo W**. (1999). Fijación de carbono por pastos tropicales en las sabanas de suelos acidos neotropicales. *Proceedings*. CATIE, Turrialba, Costa Rica.
**Gibb, M.J. and Treacher T.T.** (1976). The effect of herbage allowance on herbage intake and performance of lambs grazing perennial ryegrass and red clover swards. *J. Agric. Sci.* Camb. 86:355-365.
**Goic, L.M. and Siebald E.S.** (1987). Sistemas de Producción zona sur. In: Goic, L.M. and Aedo, N.M. (ed). Sistemas de Producción de Carne Bovina a Traves de Chile. Boletin Técnico. n$^{o}$ 101. Santiago, Chile. p 85-105.
**Gomes, K.E., Maraschin G.E., Mielniczuk J. and Riboldi J.** (1998). Efeito de ofertas de forragem, diferimentos e adubações sobre a dinâmica de uma pastagem natural. IV. Características químicas do solo. *Anais da XXXVReunião Anual da Sociedade Brasileira de Zootecnia.* Botucatu, SP. p.116-118.
**Gomez, P.O. and Jahn E.** (1993). Opportunities and constraints for production of marketable products from temperate grassland systems with minimal financial inputs. In: Baker, M.J. (ed). *Grasslands for our World.* SIR Publishing. Wellington, NZ. 563-567.
**Grof, B., Fernandes C.D., Santos A.V. dos. and Almeida C.B.** (1997). Selection of *Stylosanthes guianensis* for the Cerrados of Brazil. *Proceedings of the XVIII International Grassland Congress.* Winipeg, Manitoba. Canada. ID # 565. p. 4-33.
**Hadley, M.** (1993). Grasslands for sustainable ecosystems. *Proceddings of the XVII International Grassland Congress.* NZ-Australia. p.21-28.
**Hepp, C.K., Thiermann H.E. and Ramirez C.L.** (1988). Praderas en la zona austral, XI Región. In: I.N. Ruiz (ed) *Praderas de Chile.* INIA. Santiago, Chile. p. 561-586.
**Humphreys, L.R.** (1997). Grassland demprovement and environmental protection. In: **The** *Evolving Science of Grassland Improvement*. Cambridge Univ. Press. UK.
**Illius, A.W. and Hodgson J.** (1996). Progress in Understanding the Ecology and Management of Grazing Systems. In: Hodgson J and Illius A.W. (ed). *The Ecology and Management of Grazing Systems*. CAB International. UK. p 429-457.
**Jones, C.E.** (1996). Pastoral value and production from native pastures. *New Zealand Journal of Agricultural Research.* **39**: 449-456.
**Karia, C.T. and Andrade R.P.** (1996). Avaliação preliminar de espécies forrageiras no Centro de Pesquisa Agropecuária dos Cerrados: Perspectivas futuras. In: R.C. Pereira e L.C.B. Nasser. (ed). *Proceedings 1$^{st}$ International Symposium on Tropical Savannas.* Brasilia, DF. p. 471-475.
**Lascano, C.** (2000). Selective grazing on grass-legume mixtures in tropical pastures. In: Lemaire, G., Hodgson, J., Moraes, A., Carvalho, P., Nabinger, C. (ed). *Grassland Ecophysiology and Grazing Ecology.* CABI Publishing, UK.
**Leite, E.R., Araujo Filho J.A. and Mesquita R.C.M.** (1994). Ecossistema semi-arido. In: Puignau, J.P. (ed). *Utilizacion y Manejo de Pastizales*. Dialogo XL. IICA. Montevideo, Uruguay. p. 49-60.
**Lemaire, G. and Agnusdei M.** (2000). Leaf tissue turn-over and efficiency of herbage utilisation. In: Lemaire, G., Hodgson, J., Moraes, A. Carvalho, P. Nabinger, C. (ed). *Grassland Ecophysiology and Grazing Ecology*. CABI Publishing. UK.

**Lemaire, G. and Gastal F.N.** (1997). uptake and distribution in plant canopies. In: Lemaire, G. (ed*). Diagnosis of the Nitrogen Status in Crops.* Springer, Germany. p.3-44.
**Lobato, E., Kornelius E. and Sanzonowicz C.** (1986). Adubação fosfatada em pastagens. ***Simposio sobre Calagem e Adubação de Pastagens***. Nova Odessa, SP. p.145-174.
**McCall, D.G. and Sheath G.W.** (1993). Development of intensive grassland systems - from science to practice. In: Baker, M.J. (ed). *Grasslands for our world*. SIR Publishing, Wellington, NZ. p. 468-476.
**Macedo, M.C.M.** (1995). Pastagens no Ecossitema Cerrados. Pequisa para o Desenvolvimento Sustentável. *Anais do Simpósio sobre Pastagens nos Ecossistemas Brasileiros.* XXXII Reun. Anual da Sociedade Brasileira de Zootecnia. Brasilia, DF. p.28-62.
**Macedo, M.C.M.** (2000). Sistemas de produção animal em pasto na savanas tropicais da America: limitações à sustentabilidade. In: Reunion LatinoAmericana de Produccion Animal, 16; Congresso Uruguayo de Produccion Animal, 3; 2000. Montevideo. Anales. Argentina. ALPA Delmercosur.Com. CD-ROM. Conferencias.
**Macedo, M.C.M.** (1997). Sustainability of pasture production in the savannas of tropical America. *Proceedings of the. XVIII International Grassland Congress.* Saskatoon, Saskatchewan, Canada. p.391-399.
**Maraschin, G.E., Moraes A. de, Silva L.F.A. da, and Riboldi J.** (1993). Cultivated pasture, forage on offer and animal response. *Proceedings of the XVII International Grassland Congress.* NZ-Australia. p. 2014-2015.
**Maraschin, G.E. and Jacques A.V.A.** (1993). Grassland opportunities in the subtropical region of South America. *Proceedings of the XVII Internationl Grassland Congress*. NZ-Australia. 1977-1981.
**Maraschin, G.E., Almeida E.X de, and Harthmann O.E.** (1997). Pasture dynamics of Mott dwarf elephantgrass as related to animal performance. *Proceedings of the XVIII International Grassland Congress.* Saskatoon. Saskatchawan, Canada. Session 29. # 286. (*b*)
**Maraschin, G.E., Mella S.C., Irulegui G.S. and Riboldi J.** (1983). Performance of a subtropical legume-grass pasture under different grazing managment systems. *Proceedings of the XIV International Grassland Congress*. Lexington, KY. USA. p.459-461.
**Maraschin, G.E., Moojen E.L., Escosteguy C.M.D., Correa F.L., Apezteguia E.S., Boldrini I.I. and Riboldi J.** (1997a). Native pasture, forage on offer and animal response. *Proceedings of the XVIII International Grassland Congress.* Saskatoon,m Saskatchwan, Canada.
**Mas, C.** (1995). Consideraciones sobre la implantacion de pasturas en rastrojos de arroz. In: Risso, D.F., Berretta, E.J. Morón A. (ed). *Produccion y Manejo de Pasturas*. INIA, Tacuarembó. Uruguay. p.183-191.
**Mcivor, J.G.** (1993). Distribution and abundance of plant species in pastures and rangelands. *Proceedings of the XVII International Grassland Congress*. NZ-Australia. p. 285-289.
**Minson, D.J.** (1983). Forage Quality: Assessing the Plant-Animal Complex. In: Smith, J.A. and Hays. V.W. (ed) (1981). *Proceedings of the XIV International Grassland Congress.* Lexington, KY. USA. p.23-29.
**Montossi, F., San Julian R., Risso D.F., Berretta E.J., Rios M., Frugoni J.C. Zamit W. and Levratto J.** (1998). Alternativas tecnologicas para la intensificacion de la produccion de carne ovina en sistemas ganaderos del basalto. In: BERRETTA, E.J.(ed). *Seminario de Actualizacion en Tecnologias para Basalto*. INIA, Tacuarembó, Uruguay. p.243-256.
**Moore, J.** (1980) Forage Quality. In: Hoveland, C.S. (ed) *Crop Quality Storage, and Utilization.* ASA. CSSA. Madison, WI. USA. p.61-91.

**Moraes, A. de, and Maraschin G.E.** (1993). Animal production and dynamics of pangolagrass, ryegrass and white clover pasture as influenced by grazing pressure. *Proceedings of the XVII International Grassland Congress*. NZ-Australia. P. 2015-2016.

**Nabinger, C., Maraschin G.E. and Moraes A.** (2000). Pasture related problems in beef cattle production in southern Brazil. In: Lemaire, G. Hodgson, J. Moraes, A., Carvalho, P., Nabinger, C.(ed). *Grassland Ecophysiology and Grazing Ecology*. CABI Publishing. UK.

Noordwijk, M. van, Cerri C., Woomer P.L., Nugroho K. and Bernoux M. (1997) Soil carbon dynamics in the humid tropical forest zone. *Geoderma* **79**: 187-225.

**Nores G.A. and Estrada R.D.** (1978). Evaluacion economica de sistemas de produccion de carne de res en los llanos orientales de Colombia. In: L.E. Tergas y P.A. Sánchez (ed).*Produccion de Pastos en Suelos Acidos de los Tropicos*.CIAT. Cali. Colombia. p. 347-362.

**Norman, M.J.T.** (1970). Relationships between liveweight gain of grazing steers and availability of Townsville lucerne. In: M.J.T. Norman (ed). *Proceedings of the XI International Grassland Congress.* Surfers Paradise, Queensland, Australia. p.829-832..

**Oesterheld, M., Sala O.E. and McNaughton S.J.** (1992). Effect of animal husbandry on herbivore-carrying capacity at a regional scale. *Nature*. **356**: 234-236.

**Orr, D.M. and Paton C.J.** (1993). Seca stylo (*Stylosanthes scabra, cv. Seca*) populations increase faster under light grazing. *Proceedings of the XVII International Grassland Congress.* NZ-Australia. p.1906-1907.

**Ovalle, C.M. and Squella F.N.** (1988). Terrenos de pastoreo com praderas anuales en la área de influencia climatica mediterranea In: I.N. Ruiz (ed). *Praderas de Chile*. INIA. Santiago, Chile. p. 369-410.

**Paladines, O. and Leal J.A.** (1978). Manejo y productividad de las praderas en los llanos orientales de Colombia. In: L.E.Tergas y P.A. Sánchez (ed). *Produccion de Pastos en Suelos Acidos de los Tropicos.* CIAT. Cali. Colombia. p.331-346.

**Pereira, J.M., Boddey R.M. and Rezende C.P.** (1995). Pastagens no Ecossistema Mata Atlantica. Pesquisa para o Desenvolvimento Sustentável. *Anais do Simpósio sobre Pastagens nos Ecossistemas Brasileiros.* XXXII Reun. Anual da Sociedade Brasileira de Zootecnia. Brasilia, DF. p.94-146.

**Pizzarro, E.A. and Toledo J.M.** (1986). La evaluación de pasturas con animales, consideraciones para los ensayos regionales (ERD). CIAT, Calli. Colombia. p.1-12.

**Picio, R.M., Benitez C.A., Fernandes J.G. and Pallares O.R.** (1994). Aumentos de la produtividad com técnicas de manejo del campo natural en la provincia de Corrientes. In: J.P. Puignau (ed). *Utilizacion y Manejo de Pastizales*. Dialogo XL. IICA, Montevideo, Uruguay. p.185-190.

**Richards, J.H.** (1993). Physiology of plant recovery from defoliation. In: Baker, M.J. (ed). *Grasslands for our World.* SIR Publishing. Wellington, NZ. p. 46-55.

**Riveros, F.** (1993). Grasslands for our world. *Proceedings of the XVII International Grassland Congress.* NZ-Australia. p.15-20.

**Risso, D.F. and Berretta E.** (1995). Mejoramiento de campos en suelos sobre cristalino. In: Risso, D.F., Berretta, E.J. Moron, A. (ed). *Produccion y Manejo de Pasturas*. INIA Tacuarembó. ROU. p.193-211.

**Roberts, C.R.** (1978). Algunas causas comunes del fracasso de praderas de leguminosas y gramineas tropicales en fincas comerciales y posibles soluciones. In: L.E. Tergas y P.A. Sánchez (ed).*Produccion de Pastos en Suelos Acidos de los Tropicos*. CIAT. Cali. Colombia. p. 427-446.

**Rosso. O.R.** (1993). Manejo de la invernada. Chacra & Campo Moderno. Suplemento Especial. INTA, Balcarce. Argentina. 39 p.

**Seligman, N.G.** (1993). .Modelling as a tool for grassland science progress. *Proceedings of the. XVII International Grassland Congress.* NZ-Australia. p. 743-748.
**Serrão, E.A.S and Simão Neto M.** (1975). The adaptation of tropical forages in the Amazon region. *Proc. of the Symposium Tropical Forages in Livestock Production Systems*. ASA Spec. Publication number 24. p. 31-52.
**Siebald, E.S.** (1994). Mejoramiento mediante fertilización de las praderas naturalizadas de la zona templada húmeda de Chile. In: J.P. Puignau (ed). *Uilización y Manejo de Pastizales*. Dialogo XL. IICA, Montevideo, Uruguay. p. 181-184.
**Scholl, J. M., Lobato J.F.P. and Barreto I.L.** (1976). Improvement of pasture by direct seeding intonative grass in southern Brazil with oats, and with nitrogen supplied by fertilizer or arrowleaf clover. *Turrialba*. **26:** 144-149.
**Smith, C.A.** (1970). The feeding value of tropical grass pastures evaluated by cattle weight gains. In: M.J.T Norman (ed). *Proceedings of the XI International Grassland Congress*. Surfers Paradise, Queensland, Australia. p. 839-841.
**Soto, P.O.** (1988). Praderas de la precordillera Andina en la zona centro-sur. In: I.N. Ruiz (ed). *Praderas de Chile*. INIA. Santiago, Chile. p. 523-538.
**Stuth, J.W., Fuhlendorf S.D. and Quirk M.F.** (1997). Grazing Systems Ecvology: a Phylosophical Framework. *Proceedings of the XVIII International Grassland Congress.* Saskatoon, Saskatchwan. Canada.
**Stuth, J.W., Kirby D.R. and Chmielewski R.E.** (1981). Effect of herbage allowance on the efficiency of defoliation by the grazing animal. *Grass and Forage Science*. **36**: 9-15. 1981.
**Stuth, J.W. and Maraschin G.E.** (2000). Sustainable management of pasture and rangelands. In: Lemaire, G., Hodgson, J. Moraes, A., Carvalho, P. Nabinger, C. (ed). *Grassland Ecophysiology and Grazing Ecology*. CABI Publishing. UK.
**Tergas, L.E. and Sanchez P.A.** (1978). *Produccion de Pastos en Suelos Acidos de los Tropicos*. CIAT. Cali. Colombia.
**Thomas, D. and Rocha C.Mc.** (1986). Manejo de pasturas y evaluación de la producción animal. In: Lascano C., Pizzarro, E. (ed). *Evaluación de pasturas con animales*. RIEPT, CIAT. Cali. Colombia. p. 43-60.
**Toledo, C.S.** (1993). The Chaco savanna lands of South America with particular reference to the processes of degradation in their pastoral and forestry resources. *Proceedings of the XVII International Grassland Congress.* NZ-Australia. p. 241-246.
**Torres, A.B., Avendaño J.R., Ovalle C.M. and Paladines O.M.** (1994). La carga animal com ovinos en el espinal de la zona mediterránea subhumida IV. Consumo y selectividad. In: J.P. Puignau (ed) *Utilizacion y Manejo de Pastizales*. Dialogo XL. IICA. Montevideo, Uruguay. p. 243-250.
**Zimmer, A.H.** (1997). Brazilian beef cattle production. In: J.A. Gomide (ed). *Proceedings of the International Symposium on Animal Production Under Grazing.* VIÇOSA, MG. Brazil. p.1-30.

**Table 1 -** Productivity of natural grasslands in important regions of South America*

| COUNTRY/ REGION | GRASSLAND TYPE | RAINFALL mm | DM $ha^{-1}$ $y^{-1}$, t | A U $ha^{-1}$ | WEANING RATE, % | LWG $ha^{-1}$ |
|---|---|---|---|---|---|---|
| Argentina | | | | | | |
| Temperate | Native Pasture | 700 -1000 | 1.0 - 6.0 | 0.2 - 0.8 | 60 - 70 | 50 - 130 |
| Subtropical | Native Pasture | 1000 -1500 | 2.0 - 5.0 | 0.3 - 0.8 | 45 -50 | 30-50 |
| | "Chaco" | 400 - 600 | 0.8 | 0.07 | - | - |
| Brazil | | | | | | |
| South | Native Pasture | 1200 - 1800 | 2.0 - 6.0 | 0.3 - 0.8 | 50 - 60 | 30 - 50 |
| SE | Savannas | 900 - 3000 | 0.8 - 2.0 | 0.4 - 0.8 | 50 - 60 | 30 - 50 |
| "Cerrados" | Savannas | 800 - 1800 | 1.5 - 3.0 | 0.2 - 0.8 | 50 - 60 | 20 - 35 |
| North | Tropical W/D | 2000 - 3000 | - | - | - | - |
| NE | "Caatinga" | 300 - 500 | 1.0 - 4.0 | - | - | 20 - 40 |
| Chile | | | | | | |
| -Temperate | Native Pasture | 400 - 2300 | 1.0 - 3.0 | 0.1 - 0.5 | 60 - 70 | 20 - 50 |
| -Dryland | Native Pasture | - | 0.3 - 0.5 | - | - | - |
| Colombia | -Native Pasture | ->2000 | 2.0 - 3.0 | 0.2 - 0.5 | 45 - 55 | 20 - 30 |
| Paraguay | Savannas | 800 - 1000 | 0.8 - 4.0 | 0.03-0.5 | 50 - 60 | 30 - 50 |
| Uruguay | Native Pasture | 1000 - 1300 | 2.5 - 5.0 | 0.7 - 1.0 | 70 - 75 | 80 - 100 |
| Bolivia | Savanas W/D | 1800 | 0.8 - 2.0 | 0.07-0.2 | - | - |

*Various sources

**Table 2 -** Livestock production from Grasslands of the Eastern Llanos of Colombia

| Pasture Type | Kg Gain.An$^{-1}$.y$^{-1}$ | Kg LWG Ha$^{-1}$.y$^{-1}$ |
|---|---|---|
| Natural Savanna | 28 | 6 |
| Natural Savanna Burned | 70 - 100 | 19 - 25 |
| Melinis minutiflora | 130 | 145 |
| Brachiaria decumbens | 85 - 115 | 200 |
| S. guyanensis + Grasses + P | 205 | 180 |

Adapted from Paladines, (1978)

**Table 3 -** Pasture attributes and Photosynthetically Active Radiation use efficiency on a Native Pasture of Rio Grande do Sul, Brazil, under levels of dry matter forage on offer. Five years mean. (PAR = 21 600 000 MJ $ha^{-1}$)

| PASTURE ATTRIBUTES | D M ON OFFER % L W $day^{-1}$ | | | |
|---|---|---|---|---|
| | 4.0 | 8.0 | 12.0 | 16.0 |
| Dry Matter $ha^{-1}$ $d^{-1}$, kg $ha^{-1}$ | 11.88 | 15.52 | 16.28 | 15.44 |
| Dry Matter Production, kg $ha^{-1}$ | 2075 | 3488 | 3723 | 3393 |
| Primary Production, MJ $ha^{-1}$* | 40,877 | 68,714 | 73,343 | 66,842 |
| PAR / Primary Production, % Efficiency | 0.20 | 0.34 | 0.36 | 0.33 |
| ADG $an^{-1}$, kg | 0.150 | 0.350 | 0.450 | 0.480 |
| Animal.days $ha^{-1}$, n | 572 | 351 | 286 | 276 |
| LWG $ha^{-1}$, kg LW | 80 | 120 | 140 | 135 |
| Secondary Production, MJ $ha^{-1}$ | 1.880 | 2.880 | 3.290 | 3.173 |
| PAR / Secondary Production, % Efficiency | 0.009 | 0.015 | 0.017 | 0.013 |

*Aerial DM only.
(Adapt. from Briske and Heitschmidt (1991)).

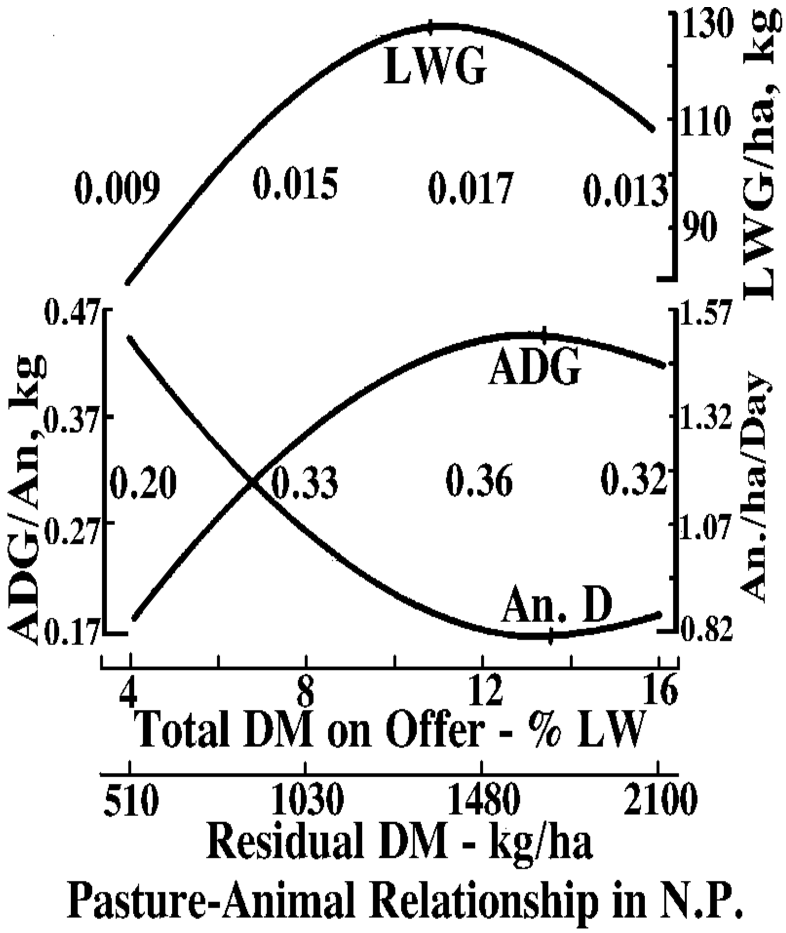


**Figure 1 -** Relationship between forage dry matter on offer and animal related responses forthe native pasture of Rio Grande do Sul.