Revista Brasileira de Zootecnia

ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., v.39, p.151-168, 2010 (supl. especial)

Brazilian scientific progress in pasture research during the first decade of XXI century

Valéria Pacheco Batista Euclides[1], Cacilda Borges do Valle[1], Manuel Cláudio Motta Macedo[1], Roberto Giolo de Almeida[2], Denise Baptaglin Montagner[3], Rodrigo Amorim Barbosa[2]

[1] Embrapa Gado de Corte. Bolsista CNPq.
[2] Embrapa Gado de Corte.
[3] Departamento de Zootecnia, UFGD.

ABSTRACT - This paper aims to discuss the scientific progress obtained in the past ten years in genetics and plant breeding, soil fertility and plant nutrition and the importance of target sward conditions for planning, controlling and recommending management grazing of tropical grasses. In addition, progress in crop-livestock integration systems and management alternatives for mitigation of greenhouse gas emission by beef cattle production systems, two very important areas related to sustainable production systems, will also be discussed.

Key Words: crop and pasture association**,** grazing management, methane emission, tropical forage

Progresso científico em pastagem na primeira década do século XXI

RESUMO - O objetivo neste trabalho é discutir os progressos científicos obtidos nos últimos dez anos em genética e melhoramento de plantas, fertilidade do solo e nutrição de plantas, além da importância dos objetivos concernentes a condições de pasto para planejamento, controle e recomendações de manejo de pastejo de gramíneas tropicais. Além disso, também serão discutidos o progresso nos sistemas de integração lavoura-pecuária e as alternativas de gestão para a mitigação das emissões de gases de efeito estufa em sistemas de produção de gado de corte, duas áreas muito importantes associadas a sistemas de produção sustentável.

Palavras-chave: associação de cultura e pastagem, emissão de metano, forragem tropical, manejo de pastejo

Introduction

In Brazil, beef and dairy cattle production systems are based mostly on pasture production, which is the main source of animal feed. About 90% of the nutrients required by the ruminants are obtained directly through grazing. Along the period from 1995 through 2006 the Brazilian cattle herd grew from 153.1 million to 171.6 million heads, while land surface covered with pastures decreased from 177.7 million to 162.9 million ha (IBGE, 2006). These numbers clearly demonstrate the importance of pasture for national livestock support but most importantly, express the effort in research, developed along these years, by several research institutions in the country resulting in a significant improvement in the efficiency of pasture utilization. However, according to Da Silva (2004), in spite of these efforts, increments in output from the production systems were lower than expected. Furthermore, there is a consensus that the main reason for that is that the majority of research studies has been carried out without taking into account the multidisciplinary characteristics of animal production under grazing (Carvalho, 1997; Da Silva & Pedreira, 1997; Hodgson & Da Silva 1999; Wade & Carvalho, 1999). In fact, most of the published research comes from trials in plots under cutting due to difficulties in carrying out experimentation with pastures under grazing at most research institutions and universities. Thus, these types of recommendations can hardly be directly extrapolated to productions systems.

Maraschim (2000) wrote an extensive review on the forage research implemented in Brazil during the twentieth century and emphasized that the majority of the pasture work used variables that did not consider what happens with forage under grazing. He pointed out several limitations in pasture research then such as lack of application of the principles of physiology and ecophysiology in pasture management; inadequate use of sampling techniques; lack of incorporation of new evaluation methodologies; little

Corresponding author: val@cnpgc.embrapa.br

attention paid in choosing experimental animals; little understanding of ingestive behavior and diet selection for the animal; and few studies on soil:plant relationship under grazing, consequently resulting in faulty recommendation for pasture fertilization. In addition to the critical points raised by Maraschin (2000), Nascimento Jr. et al. (2004) contested the need for developing and releasing new cultivars by breeding and or/selection before learning how to manage what was already available.

This paper aims to discuss the scientific progress obtained in the past ten years in genetics and plant breeding, soil fertility and plant nutrition, and grazing management, as a result of the evaluation of beef and milk production systems in Brazil and contrast those to important criticism made by some authors. In addition, progress in crop-livestock integration systems and management alternatives for mitigation of greenhouse gas emission by beef cattle production systems, two very important areas related to sustainable production systems, will also be discussed.

Breeding of tropical forages

Brazil has about 100 million hectares of cultivated pastures and 8 grass and 7 legume genera with a total of 20 species are registered for seed production at the Ministry of Agriculture, Livestock and Supply (www.agricultura.gov.br/sementes e mudas-cultivares registradas). However, if the forage seed market in Brazil is analyzed the conclusion is unmistakably of a lack of diversity since 45% of the area and 60% of the seed production is of *Brachiaria brizantha* cv. Marandu and 90% of the seed exported is of four *Brachiaria* cultivars (www.estatexport.com.br). There is public demand for sustainable production systems with less impact on the environment conflicting with this lack of biodiversity which exposes the ecosystems and the production systems to hazardous circumstances considering climate change and selection pressure imposed on pests and/or diseases. Nascimento Jr. et al. (2004) contested this need for developing and releasing new cultivars by breeding and or/ selection. According to them, and citing Lupinacci (2003): ‘there are several forage plants available and except in rare situations, there are forage options for all the different ecosystems in Brazil as well as for any type of intensification in animal production’. This is clearly an academic view since the market and animal production enterprises indicate otherwise. Besides, traditional cultivars are succumbing to diseases, such as *Panicum maximum* cv. Tanzânia-1 attacked by a fungus, *Bipolaris maydis* (Charchar et al., 2003); and there are alarming reports of death and decay of extensive areas of *Brachiaria brizantha* cv. Marandu pastures due to water logging and root rots (Barbosa et al., 2006); furthermore, none of the available cultivars is resistant to the sugar cane spittlebug *Mahanarva* spp. (Souza et al., 2000), to cite some examples of need of new or improved forages to replace older releases. Moreover, only *Brachiaria humidicola* common and cv. Llanero (known as ‘dictyoneura’) are the options for pasture in poorly drained soils and both have nutritional value, seed dormancy and production limitations that can be improved through breeding. Thus, selection from the natural diversity and specially breeding with its infinite capacity to create novelty are important if Brazil is to continue to lead the tropical world in animal production on pastures. Both, new varieties and their proper management contribute equally to continuous sustainable production systems.

In Brazil, breeding and selection of tropical forages began in the mid-1980’s focusing mostly on *Panicum maximum*, *Brachiaria* sp., *Andropogon*, *Stylosanthes*, *Arachis* and *Leucaena*. Due to limitations concerning germplasm availability, teams trained on the basic aspects of forage breeding, and efficient screening techniques to evaluate the complex merit criteria, only a few genera and species are being bred. Forage breeding programs require commitment and multidisciplinary teams but recently released cultivars in Brazil, selected either from germplasm collections as well as from bred progenies are expected to fulfill expectations of increased productivity with sustainable production.

Progress in the last decade includes the release of cultivars and significant advances in knowledge and methodologies for the main forage species. *B. brizantha* cv. Xaraés (Valle et al., 2004), and the first protected cultivar, BRS Piatã (Euclides et al., 2008, 2009) were released by Embrapa and Unipasto in 2003 and 2007 respectively. A new cultivar of *B. humidicola* (cv. BRS Tupi) was registered (2004) and protected (2009) to be released very shortly, adding to the only two cultivars recommended for waterlogged soils (Gontijo Neto et al., 2005; Andrade et al., 2010). These cultivars can promote pasture diversification with increased leaf dry matter production of better nutritive value. Other cultivars released by Embrapa in the last decade include estilosantes Campo Grande (Embrapa, 2007), the first legume cultivar to effectively impact beef production in pastures and *P. maximum* cv. Massai (Embrapa, 2001); two cultivars were released by a commercial company in São Paulo: cv. Aries and cv. Atlas (http://www.agronomia.com.br/conteudo/artigos/artigos_gramineas_tropicais_panicum.htmhttp://www.agronomia.com.br/conteudo/produtos/produtos_sementes_gramineas_capim_atlas.htm); and a legume for animal supplementation and soil amendment released by Embrapa and Unipasto: *Cajanus cajan* BRS Mandarin (Godoy, 2005).

Breeding tropical forages this past decade has focused on increased production but also towards tolerance or resistance to biotic and abiotic stresses such as aluminum levels, waterlogging and drought tolerance, resistance to diseases and pests. Screening techniques still need perfecting to translate into more efficient selection. Three cycles of selection on *Brachiaria* interspecific hybrids in Colombia resulted in significant increase in spittlebug tolerance (Miles et al., 2006). Cytogenetics of *Brachiaria* has been reviewed and its importance to breeding documented (Valle & Pagliarini, 2009). In general, interspecific hybrids have shown varying amounts of abnormalities explaining the low seed yields and the importance of including cytogenetics in the choice of progenitors for crosses as well as candidates for cultivar development (Mendes-Bonato et al., 2002; Felismino et al., 2008). Also, a new basic chromosome number has been described for the genus (x = 6) found in *B. dictyoneura* (Risso-Pascotto et al., 2006) and in *B. humidicola* (Boldrini et al., 2009).

The search for molecular markers for the traits of importance listed above and for apomixis has been underway, both on CIAT's and Embrapa's programs. A putative marker for apomixis was described (Zorzatto et al., 2010) using a hybrid population of *B. humidicola*, and that should substitute, with greater speed and efficiency, the laborious and time-consuming ovary extraction, clearing and microscope examination for identification of mode of reproduction. Use of microsatellite markers for the characterization of diversity on the *Brachiaria* germplasm was also pursued for the five most important species (Jungmann et al., 2009a,b) and can be used to select genitors for the breeding program. Microsatellite markers were also developed for *P. maximum* (Sousa et al., 2009) to study diversity in the germplasm, to verify the population structure, allowing the development of a strategy for germplasm conservation and breeding in *P. maximum*. RAPD markers used in *Stylosanthes* to determine crossing rate in *S. capitata* and *S. guianensis* (Chiari et al., 2007) established that the first has a mixed mode of reproduction while the second is essentially autogamous. Microsatellites were also developed for *Stylosanthes* (Santos et al., 2009a, b, c) and can be used to select genitors and study inheritance of traits of interest. There is an international project underway, involving Australia, Brazil, New Zealand and Argentina, to produce the first transgenic material of *Brachiaria* and *Paspalum*, considering lower lignin levels and better nutritional value in an effort to reduce methane emissions from cattle (Spangenberg, personal communication).

Breeding of *Brachiaria* spp. involves both inter and intraspecific hybridization. Progress in the breeding of this important grass for pastures include the identification of two spittlebug resistant interspecific hybrids between *B. ruziziensis* and *B. brizantha* which are now under agronomic evaluation (VCU Trials) as the first phase for cultivar development. Grazing trials will be sown as soon as enough seed is available this year. Intraspecific breeding was finally accomplished in 2005 in Campo Grande for the improvement of nutritional value of *B. humidicola* while maintaining the adaptation to periodically water-logged soils (Valle et al., 2008, 2009). The best 50 hybrids have been evaluated under cutting since 2008 and were ranked based on an index of genetic values for leaf dry matter production, leaf percentage, total dry matter production and regrowth (Valle et al., 2009). Top apomictic hybrids are candidates for cultivar development and top sexual will be used in further cycles of recombination. Breeding is at the hexaploid level and cannot include the two commercial cultivars (common and Llanero) since those are nonaploids. Breeding of *B. decumbens* was limited to its use as a pollen parent onto *B. ruziziensis*. Chromosome duplication of sexually reproducing accessions was recently accomplished (Simioni & Valle, 2009) and field crossing with cv. Basilisk was successfully carried out in 2009. The first spaced-plant progeny test of *B. decumbens* hybrids was established this year in the field, and the objective will be to breed for spittlebug resistance and improved forage quality in further cycles of recombination.

P. maximum is the most productive forage grass planted by seeds in the tropics. Its high quality and production secures intensive beef production and finishing of animals on pasture. There are 18 cultivars registered in the official site of the Ministry of Agriculture, Livestock and Supply (www.agricultura.gov.br sementes e mudas-cultivares registradas) however, only two of those, cvs. Tanzania and Mombaça, respond for about 90% of the seed of this species commercialized in Brazil. These, like *Brachiaria*, are apomictic thus also form monocrops. Cultivar Massai, a natural hybrid between *P. maximum* and *P. infestum*, was released in 2000 (Embrapa, 2001) and compared to cvs. Tanzania and Mombaça, it has lower growth habit and greater volume of leaves (Brâncio et al., 2002), thus it is easier to manage, provides better soil cover and can be used as pasture for sheep. Its digestibility and consumption, however, is lower (Euclides et al., 1999) thus resulting in lower individual and per area gains but it utilizes soil P more efficiently and it is also very resistant to spittlebugs.

P. maximum is being bred at Embrapa Beef Cattle for multipurpose use such as biomass production, for shade tolerance aiming at pasture-forest production systems, resistance to waterlogging to be used in poorly drained areas and resistance to *Bipolaris maydis*, a leaf fungus (Jank et al., 2008). In the last decade, hybrids and accessions were tested under two shade levels and interesting genotypes identified. All plants showed increased height and decreased tillering as shading increased from full sun to 54 to 81% shade. Root production was decreased under high shading in favor of aerial biomass production. There was high heritability for number of tillers and high genetic variability thus promising genotypes can be identified for testing under field conditions. Evaluations for biomass production at Embrapa Cerrados tested 24 genotypes of *P. maximum* and reported average dry matter contents of 65% (Fernandes et al., 2009). The results obtained demonstrated that there are accessions with better performance than the commercial cultivars (except cv. Milênio), when the crop was managed for maximum biomass accumulation and dry matter content. Thus *P. maximum* is truly a choice to use as a dual purpose crop – energy and animal production as long as the management is adjusted for each purpose.

Breeding of *Stylosanthes* in the past ten years has produced breeding populations and indicated important strategies for gain with selection, on the short, medium and long term (Resende et al., 2008). The breeding objectives for this legume include anthracnose resistance, seed production and overall dry matter production. Recurrent selection was recommended for both *S. guianensis* since controlled crosses can be performed and for *S. capitata*, since its mixed mode of reproductions allows for open pollinated families to be evaluated. One cultivar, *Stylosanthes* Campo Grande, was released in 2000 (Embrapa, 2007). This cultivar is a physical mixture of two species, *S. capitata* and *S. macrocephala*. Ten and five accessions, respectively, were used to make this multiline so as to confer horizontal resistance to the fungal disease, anthracnose (Grof; Fernandes, 2000). Breeding for this cultivar also involved improvement of seed production, so that reseeding assures maintenance of this legume in mixed pasture.

Arachis pintoi is another very important native legume species for which much basic knowledge has been accumulated over the past decade. Five cultivars are registered in the site of the Ministry of Agriculture, Livestock and Supply (www.agricultura.gov.br sementes e mudas, cultivares registradas) however, only the one cultivar registered by Embrapa (cv. BRS Mandobi) is to be planted by seeds compared to others in the market that use vegetative propagation only. Its breeding is being carried out at Embrapa Acre and interesting genotypes were also tested in acid soils, in Campo Grande with superior genotypes already identified for use in mixed pastures (Assis et al., 2008).

Soil fertility and plant nutrition

Important advances were achieved in this area over the last decade, mainly in methods of fertilization and required doses of fertilizer for pasture establishment. These results are widely used in the Southwest and Mid-West regions of Brazil. According to Souza and Lobato (2004), more than 90% of the soils are dystrophic in the Mid-West region, which means that soil base saturation is less than 50%. The majority of soils are acid and soil aluminum saturation is also high, in many cases above 50%. Soil CTC ranges from 4.0 e 12.0 $cmol_c / dm^3$ in the majority of Oxisols and Ultisols. Thus, soils under pastures can be considered of low and intermediate fertility.

Another import characteristic of soils under pasture in Brazil verified by Souza & Lobato (2004) and Macedo (2005) is that phosphorus is the most limiting nutrient related to pasture establishment and pasture sustainability. Once P is replaced, nitrogen drives pasture production. These observations can be extrapolated to the Southwest, Mid-West and North, where more than 70% of the herds and cultivated pasture of Brazil are concentrated.

A comparative analysis of different recommendations for pasture fertilization was conducted by Macedo (2004). Since then, no significant changes have occurred, and conclusions of Macedo (2004) are still valid, especially for pasture establishment. There were no great differences among recommendations done by Cantarutti et al. (1999) and Vilela et al. (2004), with exception of the one done by Werner et al. (1996). Recommendations based on results of fertilization for pasture establishment are many as compared to those for pasture fertilizer maintenance. In this case, there is a lack of research.

Classes of adaptation to soil fertility and acidity were done, and forages were classified in accordance to degrees of adaptation and fertilizer needs. This criterion is valid to identify classes of soil base saturation and needs of soil levels of P and K for many tropical forages. Classification suggested for tropical grasses and legumes are:

Group 1- Forages well adapted to acid and low fertility soils - *Andropogon gayanus, Brachiaria decumbens, Brachiaria humidicola, Brachiaria ruziziensis, Paspalum atratum, Stylosanthes guianensis cvs.* Mineirão and Bandeirante, *Stylosanthes macrocephala* cv Pioneiro, *Stylosanthes capitata + macrocephala* cv Campo Grande, *Calopogonium mucunoides*;

Group 2 - Forages with intermediate adaptation to acid and low fertility soils - *Brachiaria brizantha:* cvs Marandu, Xaraés, Piatã, *Setaria anceps*, *Panicum maximum* cvs. Vencedor and Centenário, *Arachis pintoi*;

Group 3 - Forages not well adapted to acid and low fertility soils - *Panicum maximum* cvs Colonião, Tobiatã, Tanzânia, Mombaça, Massai, *Pennisetum purpureum*, *Cynodon, Leucaena leucocephala e Neonotonia wightii*.

Table 1 summarizes ranges of soil critical levels for pasture establishment with tropical forages, critical levels in leaves for plant establishment and maintenance, and critical values in leaves required for daily animal diets.

The large range found for soil and plant tissue critical levels of P reflects the differences in behavior of different tropical forages in their adaptation to soils with different fertility and textures. As an example, values of soil P, as extracted by Mehlich-1, may vary from 3 to a 21 mg dm^3. This means that values go from clayed to sandy soils and from high to low adaptability depending upon forage species.

Table 1 - Critical levels of nutrients in soils for forage establishment and in plant tissue for establishment and maintenance of forage pastures and critical values required in plants for animal diets

Nutrient	Soil	Plant tissue (g or mg /kg MS)	
	mg or $cmol_c/dm^3$	Plant	Animal
N	-	10.0	18.0
P[1]	3.0 - 21.0	0.8 - 1.8	1.8
K	25.0 - 50.0	7.4 - 9.5	7.0
Ca	1.0 - 1.5	2.1 - 6.0	4.3
Mg	0.5	> 1.5	1.0
S	10.0 - 12.0	1.4 - 16	1.7
Na	-	-	0.6
Zn[2]	1.0	15.0	20.0
Cu[2]	1.0	3.0	4.0

[1] Extrator Mehlich-1.
[2] Values in mg/dm^3 for soil and mg/kg for plant.
Adapted from Macedo (2004, 2005) and Monteiro (2005).

P fertilizer recommendations for pasture maintenance was a major improvement brought about by research focusing on animal production and sustainability. Macedo (2004) established that the following criteria should be observed: a) soil P levels, in the arable layer, must be at least 80% of those required for plant establishment, according to each forage species and soil type; and b) dosage of P_2O_5 required must be adjusted for desired animal liveweight gains in terms of kg ha^{-1}. Souza et al (2004) added the degree of species adaptability to soil fertility to this criterion (Table 2).

Grazing management

At the end of the 1990's, the concepts related to the ecophysiology of tropical grasses and grazing ecology received greater attention from researchers and were incorporated in the experimental protocols for pasture evaluation. The significant changes and advances that occurred regarding the understanding of important factors and processes that determine adequate use of tropical grass in pastures can be found in the review paper by Da Silva & Nascimento Jr. (2007). This change in paradigm has generated a large database which has guided strategies for pasture utilization.

Based on the published results some grazing management recommendations were produced. Generally, the concept of the critical leaf area index (LAI), condition in which the sward intercepts 95% of the incident light, is valid and may be applied for tropical grasses (Carnevalli et al., 2006; Barbosa et al., 2007; Pedreira et al., 2007; Souza Jr., 2007). That is thus the best moment to interrupt the growth process (Figure 1), which ensures high utilization of forage produced and avoid deterioration of sward structure by excessive accumulation of stem and dead material (Tables 3 and 4).

Also, those authors have observed a large correlation between canopy height and its light interception (LI), indicating that sward height could be used as a reliable field guide for monitoring and controlling regrowth and grazing process. So, *P. maximum* cvs. Mombaça (Carnevalli et al.,

Table 2 - Estimated dosages of P_2O_5 recommended as annual application to guarantee animal productivity and degree of adaptability of different tropical forages to soil acidity and soil fertility in finishing animals

Species	Productivity (kg LW ha^{-1}. year)					
	200	350	500	650	800	950
	kg/ha/year P_2O_5					
Highly adapted	10	20	25	35	*	*
Intermediate	*	25	40	50	60	70
Poorly adapted	*	*	50	65	80	95

* Cells without recommendation values indicate that forages species of the respective group do not match with the target yields.

Table 3 - Features of a *Panicum maximum* cv. Mombaça pasture grazed at either 95 and 100 % canopy light interception (LI) and post-grazing residue of 30 and 50 cm, from January 2001 to February 2002

	Sward 95 % LI		Sward 100 % LI	
Post-grazing height (cm)	30 cm	50 cm	30 cm	50 cm
Pre-grazing height (cm)	90	115	90	115
Number of grazing cycle	7.0	8.3	6.0	5.8
Herbage accumulation (t ha^{-1})	26.9	18.5	24.9	20.8
Pre-grazing				
Tiller population (tiller m^{-2})	400	430	360	400
Forage mass (t ha^{-1})	4.6	6.1	7.4	8.3
Leaf blade (%)	70.9	57.7	60.3	57.5
Stem (%)	14.7	18.9	26.4	22.1
Crude protein (%)	14.8	12.7	13.6	13.2
IVOMD (%)	63.3	59.7	60.3	60.1
Post-grazing				
Tiller population (Tiller m^{-2})	350	340	290	320
Forage mass (t ha^{-1})	1.8	3.1	4.0	4.9
Herbage volumetric density (kg $cm^{-1}.ha^{-1}$)	75.0	84.5	76.8	86.3
Leaf blade (%)	46.3	44.6	34.2	33.0
Stem (%)	19.9	26.2	31.6	34.0
Rest period (days)				
Spring	22	23	40	35
Summer	24	25	37	31
Autumn-winter	95	140	115	186

Adapted from Bueno (2003) and Carnevalli et al. (2006).

Table 4 - Features of *Brachiaria brizantha* cvs. Marandu and Xaraés pastures grazed at either 95 and 100 % canopy light interception and post-grazing residue of 10 and 15 cm, from January 2001 to February 2002

	Marandu[1]				Xaraés[2]	
	95% LI		100% LI		95% LI	100% LI
Post-grazing height (cm)	10	15	10	15	15	15
Pre-grazing height (cm)	25		34		30	42
Number of grazing cycle	5.2	7.7	4.7	5.0	6.0	4.0
Herbage accumulation (t ha^{-1})	13.6	16.0	19.9	14.0	17.4	22.8
Pre-grazing						
Herbage density (kg $cm^{-1}.ha^{-1}$)	255	308	240	233	83	126
Forage mass (t ha^{-1})					2.2	4.8
Leaf blade (%)	54.4	45.5	47.3	47.0	88.5	81.6
Stem (%)	37.9	41.5	41.1	38.2	7.9	13.9
Crude protein (%)	9.3	9.3	8.5	8.5	13.8	12.2
IVOMD (%)	59.7	66.6	59.7	66.6	69.8	69.5
Post-grazing						
Forage mass (t ha^{-1})	2.7	2.7	3.7	3.7	3.3	4.1
Leaf blade (%)	12.2	18.8	8.3	9.6	16.9	38.1
Stem (%)	76.8	62.1	49.2	75.5	38.1	45.9
Rest period (days)						
Summer	60	30	59	61		
Autumn-winter	234	215	210	214		
Spring	37	30	45	44		

[1] Adapted from Souza Jr. (2007) and Sarmento (2007), period from October 2004 to December 2005.
[2] Adapted from Pedreira et al. (2007) and Nave (2007), period from Setember 2005 to February 2006.

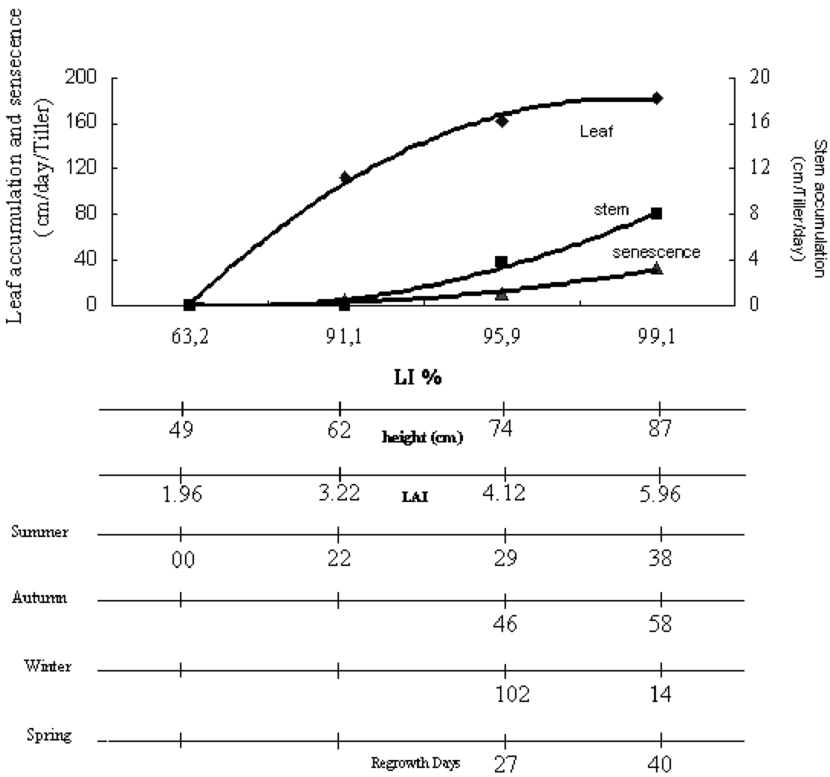

Figure 1 - Leaf blade, stem and dead material accumulations, sward light interception (LI), sward height, leaf area index (LAI) and regrowth days on *Panicum maximum* cv. Tanzânia, according to seasons of the years (Adapted from Barbosa et al., 2007).

2006; Montagner, 2007), and Tanzania (Mello & Pedreira, 2004; Barbosa et al, 2007), *B. brizantha* cvs. Marandu (Souza Jr., 2006) and Xaraés (Pedreira et al., 2009), reached 95% LI with the follows heights 90, 70, 25 e 30 cm, respectively (Figure 1; Tables 3 and 4). Given seasonal and regional variations and the potential impact of fertilizer use, there were substantial variations in grazing intervals to achieve these targets (Figure 1; Table 3 and 4).

According to Da Silva (2004), the definition of a proper post-grazing residue, consistent with satisfactory levels of animal performance and herbage utilization, and aiming at maintaining target sward conditions would certainly favor optimal use and nutritive value of produced herbage. So, Difante et al. (2010), also based on pre-grazing condition of 95% LI, or 70 cm height, evaluated Tanzânia pastures subjected to two grazing intensities (25 and 50 cm post-grazing residues), and found greater average daily gains, lower stocking rate and grazing efficiency when the sward was grazed to 50 cm when compared to that grazed down to 25 cm (Table 5). Evidence from experiments indicated that the appropriate post-grazing height intervals for Tanzânia and Mombaça are, respectively, from 25 to 50 cm (Barbosa et al., 2007; Difante et al. 2009); and from 30 to 50 cm (Bueno, 2003; Carnevalli et al., 2006; Montagner, 2007). Pastures of *B. brizantha* cvs Marandu (Souza Jr., 2007; Sarmento, 2007) and Xaraés (Pedreira et al., 2007; Nave, 2007) were evaluated using the same protocol. Based on plant characteristics (Table 4), these should be grazed down to a post-grazing height of 15 cm.

The need to understand aspects of plant-animal interface and animal response to defoliation practices must be recognized (Da Silva & Carvalho, 2005; Carvalho et al., 2009). However, this type of research still needs considerable amount of efforts. A summary of the results for tropical forage accumulated so far will be presented.

Palhano et al. (2006; 2007a) studied the short-term rate of herbage intake of dairy heifers grazing Mombaça pastures, and found that bite mass decreased and bite rate increased with decreasing pre-grazing sward heights. Despite the greater bite mass in taller swards, time per bite decreased, resulting in increasing intake rate up to 100 cm sward height (Table 6). Furthermore, as pre-grazing sward heights decreased, the number of feeding stations increased and the number of steps between feeding stations decreased, showing the importance of controlling sward structure (Table 6).

Table 5 - Features of a *Panicum maximum* cv. Tanzânia pasture with two grazing intensities, from December 2004 to May 2005

	Post-grazing residue (cm)	
	25	50
Number of grazing cycle	3	5
Grazing intervals (days)	50	33
Herbage mass (t ha^{-1})	7.1	8.3
Herbage accumulation (kg ha^{1}.day, DM)	164.9	90.6
Leaf blade (%)	61.7	59.6
Stem (%)	13.4	15.9
Herbage intake (kg of DM per 100 kg of liveweight)	2.0	2.2
Herbage removed (%)	68.0	45.6
Grazing efficiency (%)	90.4	49.8
IVOMD (%)	68.5	67.9
Average daily gain (g)	665	800
Stocking rate (steers ha^{-1})	6.1	4.9
Productivity (kg ha^{1} of liveweight)	600	560

Adapted from Difante et al. (2009a,b, 2010).

Table 6 - Features of *Panicum maximum* cv. Mombaça pastures grazed by dairy heifers, according to pre-grazing sward heights, from February 2002 to April 2002

	Pre-grazing height				
	60	80	100	120	140
Post grazing heights (cm)	43	60	96	105	114
Herbage mass (t ha^{-1})	7.6	9.1	11.0	13.1	17.2
Leaf blade mass (t ha^{-1})	1.4	2.9	4.1	5.3	7.7
Herbage volumetric density (kg cm^{-1}.ha)	126	114	110	109	122
Leaf blade volumetric density (kg cm^{-1}.ha)	21	36	43	43	54
Crude protein (%)	19.2	16.1	11.7	12.2	10.1
Bite mass (mg $bite^{-1}$)	2.1	3.2	4.2	5.2	6.1
Bite rate (bites min^{-1})	31.6	27.9	24.1	20.4	16.6
Time per bite (sec $bite^{-1}$)	24.5	32.9	40.9	48.9	56.9
Feeding station (number min^{-1})	5.5	3.3	2.1	1.6	1.9
Steps between feeding stations (numbers)	1.7	2.0	2.3	2.6	3.0
Herbage intake (kg per 100 kg of liveweight)	2.1	2.3	2.5	2.5	2.4

Adapted from Palhano et al. (2006, 2007).

Modifications in sward structure and ingestive behavior of cattle during the grazing down process in Marandu pasture was studied by Trindade (2007). Treatments corresponded to combinations between two grazing intensities (post-grazing residues of 10 and 15 cm) and two grazing intervals (equivalent to the period of time necessary for swards to reach 95% and 100% LI). During the grazing process, the 100% LI treatments resulted in heavier bites, but lower intake rate and proportion of leaves in the herbage consumed compared to the 95% LI pastures. Pastures 95/10 and 95/15 were associated with largest grazing activity and highest intake rate, suggesting higher daily intake. However, 95/15 was the pasture that resulted in the largest proportion of leaves in the herbage consumed, and in the lowest values of frequency and intensity of defoliation of leaves. This pattern of defoliation resulted in a high residual leaf area after grazing, favoring regrowth and quick returns of swards to grazing. The grazing strategy that allowed more efficient harvest of herbage was that where grazing was initiated with 95% LI and finished with 15 cm post-grazing height.

Difante et al. (2009a), also, observed as grazing progressed and herbage was removed from Tanzânia pastures, that the herbage available was reduced and the presence of leaves diminished in the medium and lower strata, making animals increase their grazing time. The bite rate on swards grazed to 25 cm residue varied linearly with occupation days at a rate of 0.64 bite per minute, which represents 371 additional bites for each additional occupation day. However on swards grazed to 50 cm residue, the bite rate did not vary during the occupation period, indicating that the higher post-grazing residue did not severely interfere with sward structure in order to cause variations in bite rate.

According to Carvalho et al. (2009) the way that the animal grazes during the occupation period is a function of the sward structure defined for pre and post-grazing. Based on several research results they concluded that the reduction of the sward height, more than 40% of initial height, the forage removal rate decreases, due to increasing the stem and dead material on the grazing horizon by limiting the bite depth.

The knowledge of structural variables and morphogenesis of plants has also been an important tool to manage continuously stocked pastures. A series of experiments was designed to evaluate functional relationships between plant and animal responses to the defoliation strategies characterized by tight control of sward conditions (Table 7). Cultivars of *Cynodon* Tifton and Coastcross were grazed by sheep to maintain sward heights from 5 to 20 cm and cultivars of *Brachiaria brizantha* Marandu e Xaraés were grazed by cattle to maintain sward heights from 10 to 45 cm. In those sets of experiments, the forage mass contained low proportions of leaf blade, which normally occurs on continuously stocked pastures, consequently the leaf:stem and the leaf:no-leaf (stem and dead material) ratios were low, and the largest ratios were observed for pastures maintained lower, regardless of the cultivar, place or soil fertilization (Table 7). However, a tiller dynamic pattern of compensation involving tiller size and population density was observed (Sbrissia et al., 2001; 2003; Sbrissia & Da Silva, 2008), consequently there was a relative stability of forage production among sward heights. Nutritive value of hand plucked herbage showed high crude protein and *in vitro* organic matter digestibility percentages (Table 7), indicating that differences in intake and animal performance were due to the sward structure (Table 7), affecting the ingestive behavior and consequently constraining forage intake by the grazing animals. Those results indicate the potential for developing grazing management strategies based on sward height targets for cultivars of *Cynodon* and *B. brizantha*, as postulated by Hodgson & Da Silva (2002).

These set of responses led Da Silva (2004) to conclude that the optimal sward height to balance pasture and animal requirements under continuous stocking management was about 15 com for *Cynodon* cultivars and 30 cm for *B. brizantha* cv. Marandu. The results obtained in Campo Grande (Table 7) confirm this sward height for both cultivars, Marandu and Xaraés. Detailed strategies for the implementation of the flexible management and suggestions to overcome challenges over the year can be found in Da Silva (2004).

CLIS - Crop and Livestock Integration Systems a new approach to sustainability

Pasture degradation is by far the most important problem of livestock production in Brazil. Over 100 millions ha of cultivated pasture are under exploitation in the country nowadays, but about 60% are estimated to be in varying degrees of degradation (Macedo, 2009). Degradation is commonly associated with decrease of animal production, poor soil fertility, lack of soil conservation, weed invasion, presence of pests and diseases, environmental problems and decline in sustainability. Common procedures for direct recuperation of pastures, such as animal management practices, fertilizer application and new cultivars are already available, but tradition, costs and final prices of products have discouraged some farmers.

More recently, an efficient alternative, but consisting of a more complex agricultural system, has been used in order to recuperate pastures: these are a series of crop and livestock integration systems (CLIS). Costs of fertilizer, soil preparation, seeds, etc used to recuperate pastures and improve soil fertility can be compensated when CLIS is utilized. A complementary benefit is observed because fertilization of annual crops improve soil fertility levels and, on the other side, the deep rooted tropical grasses improve soil physical proprieties, alleviating soil compaction, soil density and water infiltration rate. Many studies done with CLIS, in the Cerrado region of Brazil, have shown improvement in animal and crop production as demonstrated by higher stocking rates, liveweight gain, and grain yields, moving towards new thresholds of production and environment conditions thus in the direction of sustainability. Also, higher profits, raise in employment, use of by products and efficient use of machinery and labor, are also other advantages related to CLIS.

Crop and livestock systems are defined as productions systems of grain, fiber, meat, milk, wool and others, which are cultivated in the same area, in simultaneous planting, or sequentially, in a rotational way. The objectives are of maximizing the biological cycles of animals, plants and their residues, improve use of the residual effects of fertilizers, attempt to minimize use of pesticides, herbicides, etc., to improve efficiency of machinery, equipment and labor, providing more employment, raising income, and social conditions in the rural area, with the perspective of environment protection and sustainability.

Associated technologies such as minimum tillage (direct seeding), along with crop and pasture rotation, have boosted CLIS even more. Minimum tillage has been implemented in more than 60% of soil preparation in Brazil (Macedo, 2009).

Tabela 7 - Sward height, herbage mass (kg ha^{-1}), tiller population density (tiller m^{-2}), leaf area index (LAI), herbage accumulation rate (kg ha^{-1} day), leaf blade percentage, leaf:stem (LSR) and leaf:noleaf (LNLR) rations, volumetric density (VD; kg ha^{-1} cm) crude protein (CP) and in vitro organic matter digestibility (Dig), herbage intake (HI; kg DM per 100 kg LW), average daily gain (ADG) for tropical grasses under continuously stocked

Pasture	Site	Fertilizer kg ha^{-1}	Sward height (cm)	Masst ha^{-1}	TPD	LAI	TAF	LB	Sward structure LSR	Sward structure LNLR	VD	Nutritive value CP (%)	Nutritive value Dig. (%)	HI	ADGkg
Cynodon spp.	Piracicaba	280 N	5	2.3	14,295	1.6	84.6	20.5	0.46	0.21	356	20.6	80.4		0.023b
Coastcross[1]			10	3.5	12,217	2.2	82.4	20.9	0.47	0.21	285	17.7	77.3		0.026b
			15	4.3	11,414	2.2	76.9	18.9	0.42	0.18	259	17.4	74.1		0.033b
			20	6.1	11,722	3.3	74.6	16.8	0.41	0.17	245	16.1	77.4		0.041b
Cynodon spp.	Piracicaba	280 N	5	4.3	13,520	1.9	66.3	19.4	0.37	0.19	424	21.3	85.2		0.005b
Tifton 85[2]			10	5.0	12,436	2.6	69.5	19.2	0.41	0.19	356	18.0	80.7		0.024b
			15	6.4	10,299	3.5	68.3	16.5	0.37	0.17	329	15.9	76.2		0.032b
			20	7.6	83,90	4.0	86.5	15.4	0.33	0.15	317	15.6	78.0		0.040b
B. brizantha	Piracicaba	300 N	10	5.5	1,069	1.9a	72.0	21.9	0.77	0.23	506	13.7	67.1	1.30	0.190
Marandu[3]		50 K_2O	20	10.0	978	5.6a	79.1	22.2	0.81	0.22	475	12.7	66.2	1.80	0.510
			30	13.8	865	6.6a	73.8	20.3	0.73	0.21	424	12.4	63.1	1.80	0.750
			40	17.3	692	6.9a	68.8	21.5	0.76	0.22	398	11.3	62.4	2.00	0.930
B. brizantha	Campo Grande	200	15	3.2	1,020	2.0a	64.0	28.8	2.2	0.41	220	12.7	59.9	2.07	0.615
Marandu[4]		0-20-20	30	6.1	853	3.2a	59.3	20.9	1.2	0.26	212	11.0	58.0	3.04	0.628
		100 N	45	7.8	722	4.3a	50.0	17.6	0.8	0.21	185	10.2	57.3	2.72	0.675
B. brizantha	Campo Grande	200	15	2.6	644	1.7a	59.9	32.6	1.9	0.48	175	11.5	61.7	1.88	0.724
Xaraés[5]		0-20-20	30	5.9	581	3.1a	64.5	25.0	1.2	0.33	210	9.9	58.8	2.55	0.717
		100 N	45	7.7	485	3.5a	72.1	20.9	0.9	0.26	170	9.4	56.8	2.34	0.580
B. brizantha	Piracicaba	200 N	15	2.6		1.6a	95.0	44.0	2.4	0.85	169				
Xaraés[6]		200 K_2O	30	5.6		2.5a	101.0	35.0	1.3	0.55	177				
			45	8.3		3.4a	93.0	28.0	0.9	0.39	181				

[a] LAI estimated by LAI-2000 canopy analyzer equipment.
[b] Sheep.
[1] Experimental period August 1998 to April 1999 (Carnevalli et al., 2001a; Sbrissia et al., 2001).
[2] Experimental period August 1998 to March 1999 (Fagundes et al., 1999; Carnevalli et al., 2001a,b; Sbrissia et al., 2003).
[3] Experimental period December 2001 to December 2002 (Andrade, 2003; Sarmento, 2003; Sbrissia, 2004; Molan, 2004; Sbrissia & Da Silva, 2008).
[4] Experimental period January 2007 to December 2008 (Paula, 2010).
[5] Experimental period January 2007 to December 2008 (Carloto, 2010).
[6] Experimental period December 2008 to May 2009 (Pequeno, 2010).

Adoption of this system in large scale, covering many regions, with different climate and soil, is highly dependent of crops that produce high amounts of residues and straw for better soil coverage. CLIS can be used with many crops, such as: soybeans, corn, pearl millet, sorghum, cotton, sunflower, etc. and especially perennial tropical grasses as *Brachiaria spp*, intercropped or not. Thus, CLIS became one important alternative to pasture recuperation and improvement for sustainability not just of annual crops but also one of the most important practices nowadays for animal production systems in Brazil. Forages in CLIS produce straw and soil cover for minimum tillage systems, improve soil chemical, physical and biological properties, lead to better use of equipments, improve farmers income, and multiply jobs in rural areas (Macedo, 2009).

One of the advantages to CLIS adoption is the possibility of simultaneous seeding of crops and pasture at the same time and same operation, regardless of planting period: late spring-mid summer or late summer- mid autumn. Recommendations were provided by many authors and institutions in the last 10 years.

Simultaneous planting of corn and tropical forages is an old and common practice among farmers. However, well defined and organized systems as a process or as a technological package have been reported: 'Barreirão' system (Kluthcouski et al., 1991) had rice and *Brachiaria* as companion crop, and a defined soil preparation in the system; whereas the Santa Fé system (Cobucci et al., 2001), incorporated minimum tillage (no soil preparation), added a selective herbicide application in order to suppress the competition from *Brachiaria* and *Panicum* species with corn, when simultaneously seeded. Variations can be found in many other related articles with the same or similar objectives, reported by Jakelaitis et al. (2004, 2005a,b), Severino (2005), Freitas (2005) and Ceccon et al. (2008).

Ceccon & Staut (2007), for instance, suggested a very interesting variation of simultaneous planting to establish CLIS with corn and *Brachiaria spp*, dealing with different row arrangements and using the same planting equipment. Emphasis of this method is to provide enough straw and adequate residue cover for minimum tillage in the following summer. In this proposition, pasture establishment is not perceived as a typical long term crop or as an ideal CLIS. In spite of this restriction it has been an important alternative for CLIS adoption, and animal production in the period of autumn and winter season.

Simultaneous planting systems as presented before have encouraged farmers to seed annual crops, such as corn, plus forage and to obtain practically the same grain yields as corn planted alone. These results by Kluthcouski & Aidar (2003) and Zimmer et al. (2010) are presented in Table 8.

Papers by Costa & Macedo (2001), Cobucci et al. (2007), Muniz (2007), Martha Jr. et al. (2008) and Macedo (2009) have shown the economical advantages of CLIS in relation to the traditional systems. The majority of them demonstrated greater investment rates, and better net present value related to CLIS.

Another example is presented in Table 9, as described by Cobucci et al. (2007). A complete test of CLIS was carried out in 120 ha, subdivided in paddocks of 40 ha, beginning in the summer of 2005. Initially soybean was planted in one area, and corn + *brachiaria*, simultaneously in other two areas. The main objective was to have productive pasture during autumn-winter, between May and September and to finish the animals for slaughter.

A new tendency is to incorporate a new component into CLIS: trees. Results obtained at Embrapa Dairy Cattle by Carvalho et al. (1997), with the objective of selecting different tropical forages adapted to levels of shade, proposed strategies for agro forestry systems. Studies with row arrangements for trees, species of trees, tropical forages adapted to shadow and enough space to cultivate annual crops are already possible as described by Macedo (2009).

Table 8 - Corn grain yield (kg ha^{-1}), forage dry matter (kg ha^{-1}), and number of forage plants at establishment (nº m^{-2}), treatments of corn alone and intercropped with six different tropical forages, 145 days after planting. Nicossulfuron herbicide to suppress forage grow was applied in the corn intercropped. Campo Grande, MS, from November, 2008 to April, 2009

Treatment	Corn grain	Forage dry matter	Forages nº plants
Corn + *P. maximum* cv Mombaça	6,237a	3,082a	17.0b
Corn + *P. maximum* cv Massai	6,480a	1,345b	24.5a
Corn + *B. ruziziensis* cv Kennedy	6,480a	906b	16.1b
Corn + *B. brizantha* cv. Marandu	6,341a	1,082b	17.2b
Corn + *B. brizantha* cv. Xaraés	6,446a	893b	17.4ab
Corn + *B. brizantha* cv BRS Piatã	6,142a	658b	17.7ab
Corn alone	5,803a	-	-

Letters followed by the same letter in the column are not statistically significant at 5% of probability by Waller-Duncan test.
Source: Zimmer et al. (2010), unpublished data.

Mitigation of greenhouse gas emission

Discussions encompassing greenhouse effects (GEE) and its consequences became global and have been occupying international agendas not only of scientific forums but also of those related to governmental concerns since the end of the 1990s. The reason for that was firstly information about significant increment in the concentration of such gases in the atmosphere, mainly, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (NO_2). Such discussions were amplified since those emissions were credited to human activities and were responsible for global climatic changes. However, after the first wave of discussions in which the focus involved several sectors of economy, the main emphasis was redirected to evaluating and implementing alternatives related to mitigation and to sequestration.

In Brazil, agriculture sectors contribute with approximately 22% of GEEs produced by human activities. However, if these emissions were added to those from land use change and from new areas incorporated to agriculture use, such a percentage would rise to 80% (Brasil, 2009). In this situation Brazil ranks as the fifth greater country in the GEEs emission scale, which is a great challenge to be faced.

Brazilian animal production, mainly, beef cattle production, occupies an important position in global scenario as the larger commercial herd and also the most important player as an exporter. This position created tension in beef cattle international markets and varying barriers began to be imposed. Previously, such barriers used to be tax rates related but nowadays they encompass environmental and social issues, which are related to deforestation, inefficiency of beef cattle production systems and GEEs emissions (Steinfeld et al., 2006). In this sense, scientific progress in tropical and subtropical forages might have important effects on mitigation of GEEs, by improving nutritive value and other processes related to beef cattle production systems. Such a potential is strengthened by projections made by Barioni et al. (2007), on methane emissions by beef cattle under Brazilian production conditions, during the period from 2007 through 2025. Such prediction indicates important improvement in beef production, showing increments of 7.4% in herd size and 29.3% in number of slaughtered animals, representing an overall increase of 25.4% in beef production and only 2.9% in methane emission per unity of beef produced.

On the other hand, projections made by E. Assad and H. S. Pinto cited by Deconto (2008) indicated that an increase of 3ºC (average increase predicted by IPPC for 2100) might cause a loss of 25% in the carrying capacity of the pastures, which is equivalent to an increase in production costs of 20% to 45% . Furthermore, they pointed out that such an area lost would occur mainly due to the increment of 30 to 50 days in the dry period on areas which are today with cultivated pastures.

Such projections reinforce the need for strengthening studies on forages focusing on adaptation to global climatic changes, looking for quality and rates of degradation in the rumen e GEEs production associated to feed supplementation under grazing, pasture management, pasture recovery and with crop- pasture-forest integrated production systems.

As far as reduction of GEE emissions through forage breeding, Abberton et al. (2007) presented the following suggestions: a) reduction of enteric CH_4 emissions by ruminants by modifying forage plants composition, increasing soluble carbohydrates and digestibility in grasses, and increasing the amount of compounds which difficult protein degradation in the rumen, as tannins in legumes; b) reduction of N_2O emissions in pastures by using more efficient plants in using N, which in turn will increase primary production and, as a consequence, animal productivity, resulting in less emission per unity of animal product; and c) forage breeding focusing on increase in productivity of root system emphasizing morphology, composition and recycling.

Several studies with different variation of crop-pasture-forest integrated systems indicate that the forest component provides various benefits which in turn improve land use

Table 9 - Soybean, carcass, and co plus pasture yields, economical rates of CLIS during 2005-2006, Santa Luzia Farm, São Raimundo das Mangabeiras, MA

	Ha	Period months	Yield kg ha^{-1}	Income R\$ ha^{-1}	Cost R\$ ha^{-1}	Net profit R\$ ha^{-1}	Net profit area (R\$)	%
Soybean	40	4	3420	1368.20	1150.10	218.10	8724.00	8.9
Carcass	80	5	128	1983.33	1755.09	233.33	18666.40	19.0
Corn + *Brachiaria*	80	4	8580	2288.00	1400.00	888.00	71040.00	72.2
						Total	98430.40	100
						Total/ha/ano	R\$ 820,25	

Prices: Carcass = R\$ 48.10/ 15 kg; Soybean= R\$ 24.00 /60 kg; Corn grain= R\$ 16.00/ 60 kg.
R\$ 1.00 = US\$ 1.71 Source: Adapted from Cobucci et al. (2007).

efficiency (Carvalho et al., 2001; Macedo, 2009). Therefore, the possibilities of increasing use of these systems under global climatic changes scenarios are enhanced by their capability to produce positive impacts on microclimatic variables and also to increase carbon sequestration.

Integrated systems with 250 to 350 eucalyptus trees/ha, which will be ready for cutting after eight to twelve years, produce 25 m^3 ha^{-1}.year of wood (Ofugi et al., 2008). This represents an annual carbon sequestration of approximately 5t ha^{-1} C or 18 t ha^{-1} of CO_2eq., which means a neutralization of GEE emissions of 12 adult bovines. However, there are few studies evaluating C balance in such systems in Brazil. On the other hand, biomass produced by forages, mainly those with high productivity like *Pennisetum* might be used to produce second generation ethanol and to obtain carbon credits.

Due to the difficulty in obtain estimates of GEEs emissions in beef cattle production systems there are only a small number of studies carried out on feedlot (Nascimento 2007; Oliveira et al., 2007; Possenti et al., 2008) and under grazing with beef catlle (Demarchi et al., 2003) and also with dairy cattle (Primavesi et al., 2004; Pedreira et al., 2009). These studies were very important mainly because they resulted in information to counteract values from IPPC (1996) related to enteric methane and so they contributed for setting up more realistic estimates for Brazilian production systems.

Under Brazilian conditions the main source of methane emission is from enteric fermentation of bovines since the emissions from decomposition of feces on pastures are very small. These sources represents 62.5 and 1.6% of emissions of methane produced by human activities, respectively (Brasil, 2009). Studies with ruminants have demonstrated that methane emissions depend on quality of the ingested feed as well as the quality of the diet. Normally, diets with high digestibility are more consumed and produce less methane emission per unity of feed ingested than diets of low quality (Oliveira et al., 2007).

Therefore, the development of strategies for increasing the nutritive value of the diet should be prioritized on forage research programs. Several studies have been carried out in Brazil using forages with high content of tannin for bovine diets, mainly using sorghum and legumes (Vitti et al., 2005; Possenti et al., 2008), or additives as ionofores, probiotics, oils and fat (Franco & Ribeiro, 2009). The results of such strategies have proved efficient in reducing methane emissions as well as improvement in the standard of rumen fermentation and in animal energetic efficiency.

As far as nitrous oxide is concerned, in Brazil, bovine dejects are responsible for 39.4% of the human emissions of GEE (Brasil, 2009) and the lost of N by urine is greater than one observed in feces (Ferreira, 1995). The emissions of this oxide are influenced by the distribution of the dejects, by management of N fertilization and by soil characteristics (Lima, 2006). It should be pointed out that the pattern of dejects distribution across the pastures imposes extra difficulty for obtaining precise estimates.

There are several studies on pasture ecosystems in different biomes of Brazil such as the Amazon, Cerrado and Mata Atlântica, which consider the amount of carbon in the soil under cultivation as compared to soil under native vegetation. Such studies indicate that in general, soil under pasture can accumulate C in comparable or even in superior levels to those under native vegetation and they also show that degraded pasture induce loss of C accumulated (Cerri et al., 2006; Jantalia et al., 2006). Fisher et al. (2007), in a extensive review involving studies on Savannah regions of Brazil and Colombia carried out from 1998 through 2004, observed that the rates of litter deposition were underestimated and as a consequence there was overestimation of production and underestimation GEEs mitigation.

In 2009, as a result of COP-15 held in Copenhagen, Brazil stood out by presenting voluntary proposals of NAMAS (Nationally Appropriate Mitigation Actions) related to agriculture with some important goals to be achieved by 2020: reduction of 83 to 104 Mt of CO_2 eq. using pasture recuperation, from 18 to 22 Mt CO_2 eq. using integrated systems, from 16 to 20 Mt of CO_2 eq. using biological nitrogen fixation (Brasil, 2010). These goals demonstrate the need for improving the efficiency of Brazilian bovine production systems aiming at GEE mitigation and here, there is an important role to be played by Brazilian forage research. According to Cerri et al. (2010) these goals are attainable with the technologies already available, however, there is a need for governmental incentive and investment to stimuate the correct use of them by production systems.

Methodological standardization should be developed in order to study different soil-atmosphere systems (Costa et al., 2006) and with the animal components (Primavesi et al., 2004; Berndt et al., 2009) aligned with the orientation given by IPCC (1996, 2006).

This scientific-technological knowledge is strategic for Brazil since it will contribute for a better understanding about adequate management of animal production systems in order to minimize impacts and derive environmental, economic and social benefits. In addition, it would enlighten the Brazilian society about the true benefits and drawbacks of animal production and strengthen the country's position for international negotiations as well as provide arguments to neutralize potential embargos.

Conclusions

There is a wealth of questions still to be answered in the development of improved technologies and methods to work with breeding tropical forages. Teamwork and multidisciplinary projects are essential to tackle this challenge of working with non-domesticated crops but each advance is a major contribution to the scientific knowledge about these important forages for the tropical animal production.

There is still lack information in pasture fertilization when maintenance is focused. Experiments with grazing animals, in periods of three to four years duration, are recommended. In spite of the cost and the time involved, this type of researchey should be stimulated, involving interdisciplinary teams to measure biological, economical and environmental aspects.

It is unquestionable that progress has been obtained in the generation of knowledge on morphology and morphogenesis of tropical grasses for planning, controlling and recommending grazing management. However, research on animal responses to defoliation practices is an area that still needs considerable long time effort.

CLIS, along minimum tillage and pasture recuperation, are at the present moment the most important alternatives to mitigate deforestation and pasture degradation. Carbon sequestration is also more efficient in these systems. CLIS plus trees research must be improved in the future.

More research is needed for evaluating C and N balances in main animal productions systems. This should be done in each biome in order to guide national inventories as well as public policies for the sector. There is also a need to strengthen efforts oriented to know better not only the size of the herd but also the stratification by categories and species of forage and their distribution.

References

ABBERTON, M.T.; MACDUFF, J.H.; MARSHALL, A.H. et al. [2007]. **The genetic improvement of forage grasses and legumes to reduce greenhouse gas emissions**.. Disponível em: <http://www.fao.org/ag/AGP/agpc/doc/climatechange/papers/abberton_%20geneticimprovement.pdf> Acesso em: 12/04/2010.

ANDRADE, F.M.E. **Produção de forragem e valor alimentício do capim-Marandu submetido a regimes de lotação contínua por bovinos de corte**. 2003. 125f. Dissertação (Mestrado em Agronomia) – Escola Superior de Agricultura Luiz de Queiroz/Universidade de São Paulo, Piracicaba.

ANDRADE, C.M.S.; VALENTIM, J.F.; VALLE, C.B. Produção animal em cultivares de *Brachiaria humidicola* sob pastejo na região amazônica. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 47., 2010, Salvador. **Anais...** Salvador: SBZ, 2010. (CD-ROM).

ASSIS, G.M.L.; VALENTIM, J.F.; CARNEIRO JR., J.M. et al. Seleção de genótipos de amendoim forrageiro para cobertura do solo e produção de biomassa aérea no período de estabelecimento utilizando metodologia de modelos mistos. Revista Brasileira de Zootecnia, v.7, p.1905-1911, 2008.

BARBOSA, R.A. **Morte de pastos de braquiárias**. Campo Grande: Embrapa Gado de Corte, 2006. 206p.

BARBOSA, R.A; NASCIMENTO JR., D.; EUCLIDES, V.P.B. et al. Capim-tanzânia submetidos a combinações entre intensidades e freqüência de pastejo. **Pesquisa Agropecuária Brasileira** v.42, p.329-340, 2007.

BARIONI, L.G.; LIMA, M.A.; ZEN, S. et al. A baseline projection of methane emissions by the brazilian beef sector: preliminary results. In: GREENHAUSE GASES AND ANIMAL AGRICULTURE CONFERENCE, 2007, Christchurch. **Proceedings...** Christchurch, New Zealand, 2007. p.32-33.

BERNDT, A.; ANDRADE, F.M.E.; SANTOS, P.M. et al. Avaliação de cápsulas com gás traçador SF_6 utilizadas na determinação de emissão de metano entérico em bovinos. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 46., 2009, Maringá. **Anais...** Maringá: UEM; SBZ, 2009. p.1-3.

BOLDRINI, K.R.; PAGLIARINI, M.S.; VALLE, C.B. Meiotic behavior of a nonaploid accession endorses x = 6 for *Brachiaria humidicola*. **Genetics and Molecular Research**, v.8, p.1444-1450, 2009.

BRANCIO, P.A.; NASCIMENTO JR., D.; EUCLIDES, V.P.B. et al. Avaliação de três cultivares de *Panicum maximum* Jacq. sob pastejo. 1- Composição química e digestibilidade da forragem. **Revista Brasileira de Zootecnia**, v.31, p.1605-1613, 2002.

BRASIL [2009]. **Ministério da Ciência e Tecnologia. Inventário brasileiro das emissões e remoções antrópicas de gases de efeito estufa: informações gerais e valores preliminares**. Disponível em: <http://ecen.com/eee75/eee75p/inventario_emissoes_brasil.pdf>. Acessado em: 12/04/ 2010.

BRASIL [2010]. Ministério das Relações Exteriores. Disponível em: <http://www.mre.gov.br/portugues/imprensa/nota_detalhe3.asp?ID_RELEASE=7811> Acesso em: 12/4/2010.

BUENO, A.A.O. **Características estruturais do dossel forrageiro, valor nutritivo e produção de forragem em pastos de capim-mombaça subetidos a regimes de lotação intermitente**. 2003. 124f. Dissertação (Mestrado em Agronomia) – Escola Superior de Agricultura Luiz de Queiroz/Universidade de São Paulo, Piracicaba.

CANTARUTTI, R.B.; MARTINS, C.E.; CARVALHO, M.M. et al. Pastagens. In: RIBEIRO, A.C.; GUIMARÃES, P.T.G.; ALVAREZ, V.H. (Eds.) **Comissão de fertilidade do solo do Estado de Minas Gerais**: Recomendação para uso de corretivos e fertilizantes em Minas Gerais - 5ª Aproximação. Viçosa, MG: UFV, 1999. p.332-341.

CARLOTO, M.N. **Produção animal, morfogênese e acúmulo de forragem do capim-xaraés submetidos a intensidades de pastejo sob lotação continua**. 2010. 68f. Dissertação (Mestrado em Ciência Animal) – Universidade Federal de Mato Grosso do Sul, Campo Grande.

CARNEVALLI, R.A.; DA SILVA, S.C.; CARVALHO, C.A.B. et al. Desenpenho de ovinos e respostas de pastagens de Coastcross submetidas a regimes de desfolha sob lotação contínua. **Pesquisa Agropecuária Brasileira**, v.36, p.919-927, 2001a.

CARNEVALLI, R.A.; DA SILVA, S.C.; FAGUNDES, J.L. et al. Desenpenho de ovinos e respostas de pastagens de Tifton 85 (Cynodon spp.) sob lotação contínua. **Scientia Agrícola**, v.58, p.7-15, 2001b.

CARNEVALLI, R.A.; DA SILVA, S.C.; BUENO, A.A.O. et al. Herbage production and grazing losses in *Panicum maximum* cv. Mombaça under four grazing managements. **Tropical Grasslands**, v.40, p.165-176, 2006.

CARVALHO, M.M.; SILVA, J.L.O.; CAMPOS JR., B.A. Produção de matéria seca e composição mineral da forragem de seis gramíneas tropicais estabelecidas em um sub-bosque de angicovermelho. **Revista Brasileira de Zootecnia**. v.26, p.213-218, 1997.

CARVALHO, M.M.; ALVIM, M.J.; CARNEIRO, J.C. **Sistemas agroflorestais pecuários**: opções de sustentabilidade para áreas tropicais e subtropicais. Brasília: FAO, 2001. 414p.

CARVALHO, P.C.F. A estrutura da pastagem e o comportamento ingestivo de ruminantes em pastejo. In: SIMPÓSIO SOBRE AVALIAÇÃO DE PASTAGENS COM ANIMAIS, 1997, Maringá. **Anais...** Maringá: UEM, 1997. p.25-52.

CARVALHO, P.C.F.; KOZLOSKI, G.V.; RIBEIRO, H.M.N.F. et al. Avanços metodológicos na determinação do consumo de ruminantes em pastejo. **Revista Brasileira de Zootecnia**, v.36, p.151-170, 2007 (supl. especial).

CARVALHO, P.C.F.; TRINDADE, J.K; MEZZALIRA, J.C. et al. Do bocado ao pastoreio de precisão: Compreendendo a interfase planta:animal para explorar a multifuncionalidade das pastagens. **Revista Brasileira de Zootecnia**, v.38, p.109-122, 2009 (supl. especial).

CECCON, G.; SACOMAN, A.; MATOSO, A.O. et al. **Consórcio de milho safrinha com *B. ruziziensis*, em lavouras comerciais de agricultores**. Dourados: Embrapa Agropecuária Oeste, 2008. 28p. (Boletim de Pesquisa, 48).

CECCON, G.; STAUT, L.A. Milho safrinha: rumo a estabilidade In: SEMINÁRIO NACIONAL DE MILHO SAFRINHA, 9., 2007, Dourados. **Anais...** Dourados: Embrapa Agropecuária Oeste, 2007. p.86-92.

CERRI, C.E.P.; FEIGL, B.J.; PICCOLO, M.C. et al. Seqüestro de carbono em áreas de pastagens. In: SIMPÓSIO SOBRE MANEJO ESTRATÉGICO DA PASTAGEM, 3., 2006, Viçosa, MG. **Anais...** Viçosa, MG: UFV, 2006. p.73-80.

CERRI, C.C.; BERNOUX, M.; MAIA, S.M.F. et al. Greenhouse gas mitigation options in Brazil for land-use change, livestock and agriculture. **Scientia Agricola**, v.67, p.102-116, 2010.

CHARCHAR, M.J.D.; ANJOS, J.R.N.; FERNANDES, F.D. et al. *Panicum maximum* cv. Tanzânia, nova hospedeira de *Bipolaris maydis*. **Fitopatologia Brasileira**, v.28, p.385, 2003 (supl.).

CHIARI, L.; RESENDE, R.M.S.; MATIDA, E.T. et al. Estimativa da taxa de cruzamento em *Stylosanthes capitata* usando marcadores RAPD. In: CONGRESSO BRASILEIRO DE MELHORAMENTO DE PLANTAS, 4., 2007, São Lourenço. **Anais...** São Lourenço: Melhoramento de Plantas e Agronegócio, 2007. (CD-ROM).

COSTA, F.S.; GOMES, J.; BAYER, C. et al. Métodos para avaliação das emissões de gases de efeito estufa no sistema solo-atmosfera. **Ciência Rural**, v.36, p.693-700, 2006.

COSTA, F.P.; MACEDO, M.C.M. Economic evaluation of agropastoral systems: some alternatives for Central Brazil. In: WORKSHOP ON AGROPASTORAL SYSTEM IN SOUTH AMERICA, 2001, Tsukuba. **Proceedings...** Tsukuba: JIRCAS, 2001. p.57-62. (Working Report, 19).

COBUCCI, T.; KLUTHCOUSKI J.; AIDAR, H. Sistema Santa Fé: produção de forragem na entressafra. In: WORKSHOP INTERNACIONAL PROGRAMA DE INTEGRAÇÃO AGRICULTURA E PECUÁRIA PARA O DESENVOLVIMENTO SUSTENTÁVEL DAS SAVANAS TROPICAIS SULAMERICANAS, 2001, Santo Antonio de Goiás. **Anais...** Santo Antonio de Goiás: Embrapa Arroz e Feijão, 2001. p.125-135. (Documentos, 123)

COBUCCI, T.; WRUCH, F.J.; KLUTHCOUSKI, J. et al. Opções de integração lavoura-pecuária e alguns de seus aspectos econômicos. **Informe Agropecuário: Integração Lavoura-Pecuária**, v.28, p.25-42, 2007.

DA SILVA, S.C. Fundamentos para manejo do pastejo de plantas forrageiras dos gêneros Brachiaria e Panicum In: SIMPÓSIO SOBRE MANEJO ESTRATÉGICO DA PASTAGEM, 2., 2004, Viçosa, MG. **Anais...** Viçosa, MG: UFV, 2002. p.347-385.

DA SILVA, S.C.; CARVALHO, P.C.F. Foraging behaviour and herbage intake in the favourable tropics/subtropics. In: McGILLOWAY, D.A. (Ed.) **Grassland**: a global resource. Wageningen: Wageningen Academic Publishers, 2005. p.81-95.

DA SILVA, S.C.; NASCIMENTO JR., D. Avanços na pesquisa com plantas forrageiras tropicais em pastagens: características morfofisiológicas e manejo do pastejo. **Revista Brasileira de Zootecnia**, v.36, p.121-138, 2007 (supl. especial).

DA SILVA, S.C.; PEDREIRA, C.G.S. Fatores condicionantes e predisponentes da produção animal a pasto. In: SIMPÓSIO SOBRE O ECOSSISTEMA DE PASTAGENS, 3., 1997, Jaboticabal. **Anais...** Jaboticabal: UNESP, 1997. p.1-62.

DECONTO, J.G. **Aquecimento global e a nova geografia da produção agrícola no Brasil**. São Paulo: Embrapa/Unicamp, 2008. 84p.

DEMARCHI, J.J.A.A.; MANELLA, M.Q.; LOURENÇO, A.J. et al. Preliminary results on methane emission by Nelore cattle in Brazil grazing *Brachiaria brizantha* cv. Marandu. In: INTERNATIONAL METHANE & NITROUS OXIDE MITIGATION CONFERENCE, 3., 2003, Beijing, China. **Proceedings...** Beijing: China Coal Information Institute, 2003. p.80-82.

DIFANTE, G.S.; EUCLIDES, V.P.B.; NASCIMENTO JR., D. et al. Desempenho e conversão alimentar de novilhos de corte em capim-tanzânia submetido a duas intensidades de pastejo sob lotação rotativa. **Revista Brasileira de Zootecnia**, v.39, p.33-41, 2010.

DIFANTE, G.S.; EUCLIDES, V.P.B.; NASCIMENTO JR., D. et al. Ingestive behaviour, herbage intake and grazing efficiency of beef cattle steers on tanzânia guineagrass subjected to rotational stocking managements. **Revista Brasileira de Zootecnia**, v.38, p.1001-1008, 2009a.

DIFANTE, G.S.; NASCIMENTO JR., D.; EUCLIDES, V.P.B. et al. Sward structure and nutritive value of tanzânia guineagrass subjected to rotational stocking managements. **Revista Brasileira de Zootecnia**, v.38, p.9-19, 2009b.

EMPRESA BRASILEIRA DE PESQUISA E AGROPECUÁRIA - EMBRAPA. [2001]. **Capim-massai (*Panicum maximum* cv. Massai)**: alternativa para diversificação de pastagens. Disponível em: <http://www.cnpgc.embrapa.br/publicacoes/cot/COT69.html> Acesso em: 5/5/2010.

EMPRESA BRASILEIRA DE PESQUISA E AGROPECUÁRIA - EMBRAPA. [2007]. **Cultivo e uso do estilosantes-campo-grande**. Disponível em: <http://www.cnpgc.embrapa.br/publicacoes/cot/pdf/Cot105.pdf> Acesso em: 5/5/2010

EUCLIDES, V.P.B.; MACEDO, M.C.M.; VALLE, C.B. et al. Produção de forragem e características da estrutura do dossel de cultivares de *Brachiaria brizantha* sob pastejo. **Pesquisa Agropecuária Brasileira**, v.43, p.1805-1812, 2008.

EUCLIDES, V.P.B.; MACEDO, M.C.M.; VALLE, C.B. et al. Qualidade nutricional da forragem e produção animal em pastagens de *Brachiaria brizantha*. **Pesquisa Agropecuária Brasileira**, v.44, p.15-23, 2009.

EUCLIDES, V.P.B.; THIAGO, L.R.L.S.; MACEDO, M.C.M. et al. Consumo voluntário de forragem de três cultivares de *Panicum maximum* sob pastejo. **Revista Brasileira de Zootecnia**, v.28, p.1177-1185, 1999.

FAGUNDES, J.L.; DA SILVA, S.C.; PEDREIRA, C.G.S. et al. Intensidades de pastejo e a composição morfológica de pastos de *Cynodon spp*. **Scientia Agrícola**, v.56, p.1-14, 1999.

FELISMINO, M.; PAGLIARINI, M.; VALLE, C.B. A differential phenotypic expression of a divergent spindle mutation in interspecific *Brachiaria* hybrids. **Cell Biology International**, v.32, p.1459-1463, 2008.

FERNANDES, F.D.; CARVALHO, M.A.; RAMOS, A.K.B. et al. Evaluating *Panicum maximum* as an energy crop: biomass productivity In: SIMPÓSIO INTERNACIONAL SOBRE MELHORAMENTO DE FORRAGEIRAS, 2009, Campo Grande. **Anais...** Campo Grande: Embrapa Gado de Corte, 2009. (CD-ROM).

FERREIRA, E.; ROCHA, G.C.; BRAZ, S.P. et al. Modelos estatísticos para o estudo da distribuição de excretas de bovinos em pastagens tropicais e sua importância na sustentabilidade desses sistemas. **Livestock Research for Rural Development**, v.16, 2004. Disponível em: <http://www.lrrd.org/lrrd16/9/ferr16066.htm> Acesso em: 20/4/2010.

FRANCO, G.L.; RIBEIRO, S.S. Redução da emissão dos gases de efeito estufa pelos ruminantes. In: ENCONTRO SOBRE ZOOTECNIA DE MATO GROSSO DO SUL, 6., 2009, Campo Grande. **Anais...** Campo Grande: UFMS, 2009. p.1-20. (CD-ROM).

FREITAS, F.C.L.; FERREIRA, F.A.; FERREIRA, L.R. et al. Cultivo consorciado de milho para silagem com *Brachiaria brizantha* no sistema de plantio convencional. **Planta Daninha**, v.23, p.635-644, 2005.

FISHER, M.J.; BRAZ, S.P.; SANTOS, R.S.M. et al. Another dimension to grazing systems: soil carbon. **Tropical Grasslands**, v.41, p.65-83, 2007.

GIACOMINI, A.A.; DA SILVA, S.C.; SARMENTO, D.O.L. et al. Growth of marandu palisadegrass subjected to strategies of intermittent stocking. **Scientia Agrícola**, v.66, p.733-741, 2009.

GODOY, R.; BATISTA, L.A.R.; SANTOS, P.M. et al. Avaliação agronômica de linhagens selecionadas de guandu (*Cajanus cajan* (L.) Millsp). **Revista Brasileira de Zootecnia**, v.34, p.7-19, 2005.

GONTIJO NETO, M.M.; EUCLIDES, V.P.B.; MACEDO, M.C.M. et al. Avaliação de cultivares de *Brachiaria humidicola* sob pastejo na época seca. In: REUNIÃO ANUAL DA SOCIEDADE BRAZILEIRA DE ZOOTECNIA, 42., 2005, Goiânia. **Anais...** Goiânia: SBZ, 2005. (CD-ROM).

HODGSON, J.; DA SILVA, S.C. Optioms in tropical pasture management. In: REUNIÃO ANNUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 39., 2002, Recife. **Anais...** Recife: SBZ, 2002. p.180-202.

HODGSON, J.; DA SILVA, S.C. Sustainability of grazing systems: goals, concepts and methods. In: LEMAIRE, G.; HODGSON, J.; MORAES, A. et al. (Eds.) **Grassland ecophysiology and grazing ecology**. Wallingford: CAB International, 2000. p.1-13.

IPCC [2006] Emissions from livestock and manure management. In: **IPCC Guidelines for National Greenhouse Gas Inventories**. Paris: 2006. p. 10.1-10.84.

JAKELAITIS, A.; SILVA, A.A.; FERREIRA, L.R. et al. Manejo de plantas daninhas no consórcio de milho com capim-braquiaria (*Brachiaria decumbens*). **Planta Daninha**, v.22, p.553-560, 2004.

JAKELAITIS, A.; SILVA, A.A.; FERREIRA, L.R. et al. Efeito de herbicidas no consorcio de milho com *Brachiaria brizantha*. **Planta Daninha**. v.23, p.69-78, 2005a.

JAKELAITIS, A.; SILVA, A.F.; SILVA, A.A. et al. Influencia de herbicidas e de sistemas de semeadura em *Brachiaria brizantha* consorciada com milho. **Planta Daninha**, v.23, p.59-67, 2005b.

JANK, L.; RESENDE, R.M.S.; VALLE, C.B. et al. Melhoramento genético de *Panicum maximum*. In: RESENDE R.M.S.; VALLE, C.B.; JANK, L. (Eds) **Melhoramento de forrageiras tropicais**. Campo Grande: Embrapa Gado de Corte, 2008. p.55-87.

JANTALIA, C.P.; TERRÉ, R.M.; MACEDO, R.O. et al. Acumulação de carbono no solo em pastagens de *Brachiaria*. In: ALVES, B.J.R. (Ed.). **Manejo de sistemas agrícolas**: impactos no seqüestro de C e nas emissões de gases de efeito estufa. Porto Alegre: Genesis, 2006. p.157-170.

JUNGMANN, L.; SOUSA, A.C.B.; PAIVA, J. et al. Isolation and characterization of microsatellite markers for *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf. **Conservation Genetics**, v.10, p.1873-1876, 2009a.

JUNGMANN, L.; VIGNA, B.B.Z.; PAIVA, J. et al. Development of microsatellite markers for *Brachiaria humidicola* (Rendle) Schweick. **Conservation Genetics Resources**, v.1, p.475-479, 2009b.

KLUTHCOUSKI, J.; PACHECO, A.R.; TEIXEIRA, S.M. et. al. **Renovação de pastagens de Cerrado com Arroz 1- Sistema Barreirão**. Goiânia: Embrapa-CNPAF, 1991. 20p. (Documentos, 33).

KLUTHCOUSKI J.; AIDAR, H. Implantação, condução e resultados obtidos com o Sistema Santa Fé. In: **Integração Lavoura e Pecuária**. Santo Antonio de Goiás: Embrapa Arroz e Feijão, 2003. p.407-441.

LIMA, M.A. Emissão de metano e óxido nitroso na produção animal em pastagens. In: SIMPÓSIO SOBRE MANEJO DA PASTAGEM, 23., 2006, Piracicaba. **Anais...** Piracicaba: FEALQ, 2006. p.249-269.

LUPINACCI, A.V. Lançamento de cultivares de plantas forrageiras: uma visão crítica In: SIMPÓSIO SOBRE O MANEJO DA PASTAGEM, 20., 2003, Piracicaba. **Anais...** Piracicaba: FEALQ, 2003. p.83-104.

MACEDO, M.C.M. Analise comparativa de recomendações de adubação em pastagens. In: SIMPÓSIO SOBRE MANEJO DA PASTAGEM, 21., 2004, Piracicaba. **Anais...** Piracicaba: FEALQ, 2004. p.317-355.

MACEDO, M.C.M. Pastagens no ecossistema cerrados: evolução das pesquisas para o desenvolvimento sustentáveis. In: REUNIÃO ANUAL DA SOCIEDADE BRASILAIRA DE ZOOTECNIA, 42., 2005, Goiânia. **Anais...** Goiânia: SBZ, 2005. p.56-84.

MACEDO, M.C.M. Integração lavoura e pecuária: o estado da arte e inovações tecnológicas. **Revista Brasileira de Zootecnia**, v.38, p.133-146, 2009 (supl. especial).

MARASCHIN, G.E. Relembrando o passado, entendendo o presente e planejando o futuro. Uma herança em forrageiras e um legado em pastagens. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 37., 2000, Viçosa, MG. **Anais...** Viçosa, MG: SBZ, 2000. p.113-179.

MARTHA JR., G.B.; VILELA, L.; SOUSA, D.M.G. Economia de fertilizantes na integração lavoura-pecuária no Cerrado. **Revista de Política Agrícola**, v.27, n.4, p.14-19, 2008.

MELLO, A.C.L.; PEDREIRA, C.G.S. Respostas morfológicas do capim-tanzânia (*Panicum maximum* jacq. cv. tanzânia-1) irrigado à intensidade de desfolha sob lotação rotacionada. **Revista Brasileira de Zootecnia**, v.33, p.282-289, 2004.

MENDES-BONATO, A.B.; PAGLIARINI, M.S.; FORLI, F. et al. Chromosome numbers and microsporogenesis in *Brachiaria brizantha* (Gramineae). **Euphytica**, v.125, p.419-424, 2002.

MILES, J.W.; CARDONA, C.; SOTELO, G. Recurrent selection in a synthetic *Brachiariagrass* population improves resistance to three spittlebug species. **Crop Science**, v.46, p.1088-1093, 2006.

MOLAN, L.K. **Estrutura do dossel, interceptação luminosa e acúmulo de forragem em pastos de capim-marandu submetidos a alturas de pastejo por meio de lotação contínua**. 2004. 159f. Dissertação (Mestrado em Agronomia) – Escola Superior de Agricultura Luiz de Queiroz/Universidade de São Paulo, Piracicaba.

MONTAGNER, D.B. **Morfogênese e acúmulo de forragem em capim-mombaça submetido a intensidades de pastejo rotativo**. 2007. 60f. Tese (Doutorado em Zootecnia) – Universidade Federal de Viçosa, Viçosa, MG.

MONTEIRO, F.A. Amostragem de solo e de planta para fins de analise química: métodos e interpretação de resultados. In: SIMPÓSIO SOBRE MANEJO DA PASTAGEM, 22., 2005, Piracicaba. **Anais...** Piracicaba: FEALQ, 2005. p.151-179.

MUNIZ, L.C. **Avaliação bio-economica em sistema de integração lavoura-pecuária**. 2007. 91f. Dissertação (Mestrado em Agronegócio – Desenvolvimento Sustentável) - Escola de Agronomia e Engenharia de Alimentos, Universidade Federal de Goiás, Goiânia.

NASCIMENTO, C.F.M. **Emissão de metano por bovinos Nelore ingerindo Brachiaria brizantha em diferentes estádios de maturação**. 2007. 65f. Dissertação (Mestrado, em Nutrição e Produção Animal) - Faculdade de Medicina Veterinária e Zootecnia/USP, Pirassununga.

NASCIMENTO JR., D.; DA SILVA, S.C.; ADESE, B. Perspectivas futuras do uso de gramíneas em pastejo. In: REUNIÃO ANNUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 41., 2004, Campo Grande. **Anais...** Campo Grande: SBZ, 2004. p.130-141.

NAVE, R.L.G. **Produtividade, valor nutritivo e característica físicas da forragem do capim-xaraés [Brachiaria brizantha (Hochst ex A. RICH.) STAPF.] em resposta a estratégias de pastejo sob lotação intermitente**. 2007. 94f. Dissertação (Mestrado em Agronomia) – Escola Superior de Agricultura Luiz de Queiroz/Universidade de São Paulo, Piracicaba.

OFUGI, C.; MAGALHÃES, L.L.; MELIDO, R.C.N. et al. Integração lavoura-pecuária (ILPF), sistemas agroflorestais (SAFs). In: TRECENTI, R. (Ed.). **Integração lavoura-pecuária-silvicultura**. Brasília: MAPA/SDC, 2008. p.20-25.

OLIVEIRA. S.G.; BERCHIELLI, T.T.; PEDREIRA, M.S. et al. Effect of tannin levels in sorghum silage and concentrate supplementation on apparent digestibility and methane emission in beef cattle. **Animal Feed Science and Technology**, v.135, p.236-248, 2007.

PALHANO, A.L.; CARVALHO, P.C.F.; DITTRICH, J.R. et al. Estrutura da pastagens e padrões de defolhação em capim-mombaça em diferentes alturas do dossel forrageiro.. **Revista Brasileira de Zootecnia**, v.35, p.2253-2259, 2006.

PALHANO, A.L.; CARVALHO, P.C.F.; DITTRICH, J.R. et al. Características do processo de ingestãode forragem por novilhas holandesas em pastagem de capim-mombaça. **Revista Brasileira de Zootecnia**, v.36, p.1014-1021, 2007.

PAULA, C.C.L. **Produção animal, morfogênese e acúmulo de forragem do capim-marandu submetidos a intensidades de pastejo sob lotação continua**. 2010. 2007. 74f. Dissertação (Mestrado em Ciência Animal) – Universidade Federal de Mato Grosso do Sul, Campo Grande.

PEDREIRA, B.C.; PEDREIRA, C.G.S.; DA SILVA, S.C. Estrutura do dossel e acúmulo de forragem de *Brachiaria brizantha* cultivar Xaraés em resposta a estratégias de pastejo. **Pesquisa Agropecuária Brasileira** v.42, p.281-287, 2007.

PEDREIRA, M.S.; PRIMAVESI, O.; LIMA, M.A. et al. Ruminal methane emission by dairy cattle in Southeast Brazil. **Scientia Agricola**, v.66, p.742-750, 2009.

PEQUENO, D.N.L. **Intensidade de pastejo como condicionante da estrutura do dossel e da assimilação de carbono de pastos de capim xaraés [*Brachiaria brizantha* (A. Rich) Stapf. cv. Xaraés] sob lotação contínua**. 2010. 75f. Dissertação (Mestrado em Agronomia) – Escola Superior de Agricultura Luiz de Queiroz/Universidade de São Paulo, Piracicaba.

POSSENTI, R.A.; FRANZOLIN, R.; SCHAMMAS, E.A. et al. Efeitos de dietas contendo *Leucaena leucocephala* e *Saccharomyces cerevisiae* sobre a fermentação ruminal e a emissão de gás metano em bovinos. **Revista Brasileira de Zootecnia**, v.37, n.8, p.1509-1516, 2008.

PRIMAVESI, O.; FRIGHETTO, R.T.S.; PEDREIRA, M.S. et al. Metano entérico de bovinos leiteiros em condições tropicais brasileiras. **Pesquisa Agropecuária Brasileira**, v.39, n.3, p.277-283, 2004a.

RISSO-PASCOTTO, C.; PAGLIARINI, M.S.; VALLE, C.B. A new basic chromosome number for the genus *Brachiaria* (Poaceae: Panicoideae: Paniceae). **Genetic Research Crop Evolution**, v.53, p.7-10, 2006.

SANTOS, M.O.; KARIA, C.T.; RESENDE, R.M.S. et al. Isolation and characterization of microsatellite loci in the tropical forage legume *Stylosanthes guianensis* (Aubl.) Sw. **Conservation Genetics Resources**, v.1, p.43-46, 2009a.

SANTOS, M.O.; SASSAKI, R.P.; CHIARI, L. et al. Isolation and Characterization of microsatellite loci in tropical forage *Stylosanthes capitata* Vogel. **Molecular Ecology Notes**, v.9, p.192-194, 2009b.

SANTOS, M.O.; SASSAKI, R.P.; FERREIRA, T.H.S. et al. Polymorphic microsatellite loci for *Stylosanthes macrocephala* Ferr. et Costa, a tropical forage legume. **Conservation Genetics Resources**, v.1, p.481-485, 2009c.

SARMENTO, D.O.L. **Comportamento ingestivo de bovinos em pastos de capim marandu submetidos a regimes de lotação contínua**. 2003. 76f. Dissertação (Mestrado em Agronomia) – Escola Superior de Agricultura Luiz de Queiroz/ Universidade de São Paulo, Piracicaba.

SARMENTO, D.O.L. **Produção, composição morfológica e valor nutritivo da forragem em pastos de Brachiaria brizantha (Hochst ex A. Rich) Stapf. cv. Marandu submetidos a estratégias de pastejo rotativo por bovinos**. 2007. 144f. Tese (Doudorado em Agronomia) – Escola Superior de Agricultura Luiz de Queiroz/Universidade de São Paulo, Piracicaba.

SBRISSIA, A.F. **Morfogênese, dinâmica do perfilhamento e do acúmulo de forragem em pastos de capim-marandu sob lotação contínua**. 2004. 171p. Tese (Doutorado em Agronomia) – Escola Superior de Agricultura Luiz de Queiroz/ Universidade de São Paulo, Piracicaba.

SBRISSIA, A.F.; DA SILVA, S.C. Compensação tamanho/densidade populacional de perfilhos em pastos de capim-marandu. **Revista Brasileira de Zootecnia**, v.37, p.35-47, 2008.

SBRISSIA, A.F.; DA SILVA, S.C.; CARVALHO, C.A.B. et al. Tiller siza/population density compensation in Coastcross grazed swards. **Scientia Agrícola**, v.58, p.655-665, 2001.

SBRISSIA, A.F.; DA SILVA, S.C.; MATHEW, C. et al. Tiller size/ population density compensation in grazed Tifton 85 bermudagrass swards. **Pesquisa Agropecuária Brasileira**, v.38, p.1459-1468, 2003.

SEVERINO, F.J.; CARVALHO, S.J.P.; CRISTOFFOLETI, P.J. Interferências mútuas entre a cultura do milho, espécies forrageiras e plantas daninhas em um sistema de consorcio. I-Implicações sobre a cultura do milho. **Planta Daninha**, v.23, p.589-596, 2005.

SOUZA, O.C.; ZIMMER, A.H.; VALLE, L.C.S. et al. **Diagnóstico de morte de pastagens de *Brachiaria brizantha* nas regiões de Araguaína, TO, e Redenção, PA**. Campo Grande: Embrapa Gado de Corte, 2000. p. 1-11. (Documentos, 96).

SOUSA, A.C.B.; CAMPOS, T.; SFORÇA, D.A. et al. Microsatellite markers in *Panicum maximum* Jacq. (Poaceae): a study for the genetic diversity, germplasm conservation and breeding. In: SIMPÓSIO INTERNACIONAL SOBRE MELHORAMENTO DE FORRAGEIRAS, 2009, Campo Grande. **Anais...** Campo Grande: Embrapa Gado de Corte, 2009. (CD-ROM).

SOUZA JR., S.J. **Estrutura do dossel, interceptação de luz e acúmulo de forragem em pastos de capim-marandu submetidos a estratégias de pastejo rotativo por bovinos de corte**. 2007. 122f. Dissertação (Mestrado em Agronomia) – Escola Superior de Agricultura Luiz de Queiroz/Universidade de São Paulo, Piracicaba.

RESENDE, R.M.S.; RESENDE, M.D.V.; JANK, L. et al. Melhoramento genético de leguminosas forrageiras. In: RESENDE, R.M.S.; VALLE, C.B.; JANK, L. (Orgs.) **Melhoramento de forrageiras tropicais**. Campo Grande: Embrapa Gado de Corte, 2008. p.117-159.

SIMIONI, C.; VALLE, C.B. Chromosome duplication in *Brachiaria* (A.Rich.) Stapf allows intraspecific crosses. **Crop Breeding and Applied Biotechnology**, v.9, p.328-334, 2009.

SOUSA, D.M.G.; LOBATO, E. **Correção da acidez do solo**. In: Cerrado: Correção do solo e adubação. Planaltina: Embrapa Cerrados, 2002. p.81-96.

SOUSA, D.M.G.; LOBATO, E. Correção da acidez do solo. In: **Cerrado**: Correção do solo e adubação. Planaltina: Embrapa Cerrados, 2002. p. 81-96

STEINFELD, H.; GERBER, P.; WASSENAAR, T. et al. **Livestock's long shadow**: environmental issues and options. Rome: FAO, 2006. 375p.

TRINDADE, J.K.; DA SILVA, S.C.; SOUZA JR., S.J. et al. Composição morfológica da forragem consumida por bovinos de corte durante o rebaixamento do capim-marandu submetido a estratégias de pastejo rotativo. **Pesquisa Agropecuária Brasileira**, v.42, p.883-890, 2007.

VALLE, C.B.; EUCLIDES, V.P.B.; PEREIRA, J.M. et al. **O capim-xaraés (*Brachiaria brizantha* cv. Xaraés) na diversificação das pastagens de braquiária**. Campo Grande: Embrapa Gado de Corte, 2004. 36p. (Documentos, 149).

VALLE, C.B.; PAGLIARINI, M.S. Biology, cytogenetics, and breeding of *Brachiaria*. In: SINGH, R.J. (Ed.) **Genetic resources, chromosome engineering, and crop improvement**. Boca Raton: CRC Press, 2009. v.5, p.103-151.

VALLE, C.B.; RESENDE, R.M.S.; CHIARI, L. et al. Agronomic evaluation of *Brachiaria humidicola* hybrids. In: SIMPÓSIO INTERNACIONAL SOBRE MELHORAMENTO DE FORRAGEIRAS, 2009, Campo Grande. **Anais...** Campo Grande: Embrapa Gado de Corte, 2009. (CD-ROM).

VALLE, C.B.; SIMIONI, C.; RESENDE, R.M.S. et al. Melhoramento genético de *Brachiaria*. In: RESENDE, R.M.S.; VALLE, C.B.; JANK, L. (Eds.) **Melhoramento de forrageiras tropicais**. Campo Grande: Embrapa Gado de Corte, 2008. p.13-53.

VILELA, L.; SOARES, W.V.; SOUSA, D.M.G. et al. Calagem e adubação para pastagens. In: SOUSA, D.M.G.; LOBATO, E. (Eds.) **Cerrado**: Correção do solo e adubação. Planaltina: Embrapa Cerrados, 2004. p.367-382.

VITTI, D.M.S.S.; ABDALLA, A.L.; BUENO, I.C.S. et al. Do all tannins have similar nutritional effects? A comparison of three Brazilian fodder legumes. **Animal Feed Science and Technology**, v.119, p.345-361, 2005.

WADE, M.H.; CARVALHO, P.C.F. Defoliation patterns and herbage intake on pastures. In: LEMAIRE, G.; HODGSON, J. MORAES, A. et al. (Eds.) **Grassland ecophysiology and grazing ecology**. Wallingford: CAB International, 2000. p.233-248.

WERNER, J.C.; PAULINO, V.T.; CANTARELLA, H. et al. Forrageiras. In: RAIJ, B.; CANTARELLA, H.; QUAGGIO, J.A. et al. (Eds.) **Recomendações de Adubação e Calagem para o Estado de São Paulo**. Campinas: Instituto Agronômico, 1996. 285p. (Boletim, 100).

ZORZATTO, C.; CHIARI, L.; BITENCOURT, G.A. et al. Identification of a molecular marker linked to apomixis in *Brachiaria humidicola* (Poaceae). **Plant Breeding**, 2010.