Animal Production from Tree-Pasture Association Systems in Brazil

João C. Saibro
Universidade Federal do Rio Grande do Sul, Brazil

ANIMAL PRODUCTION FROM TREE-PASTURE ASSOCIATION SYSTEMS IN BRAZIL

J.C. Saibro
Departamento de Plantas Forrageiras e Agrometeorologia, Universidade Federal do Rio Grande do Sul, P.O. Box 776, 90012-970 Porto Alegre, RS, Brasil

Abstract

Agroforestry systems (AFS) in general and silvipastoral systems (SPS) in particular, have been studied intensively in Brazil since the 1980's. The majority of the research work has been conducted in the wet tropical Amazon region, in the semi-arid conditions of the Northeast, and under subtropical soil and climatic conditions in the Southeast or in the South. Research emphasis has been placed on interactions between the main components of AFS: tree, pasture, soil and microclimatic elements. Evaluation of animal performance in SPS generally has not been the main objective of experiments. A recent survey of research on SPS using *Eucalyptus spp.* in Brazil , showed that only 6.5% of the references in such articles pertained to the productive performance of sheep and beef cattle under grazing (Couto et al.,1998). In the Tropics, the native rain forest is the most important arboreal substrate, because it has to be preserved for environmental and biodiversity maintenance. Accordingly, research has focused on identification of either native or exotic timber tree/palm tree species to be used in SPS. At the present time, SPS using species of *Pinus*, rubber tree, mango tree, brazilian chestnut tree and coconut tree are common in this region. *Brachiaria brizantha* cv. Marandu, *B. humidicola, Paspalum atratum* BRA-009610, *Desmodium ovalifolium* CIAT-350 , *Pueraria phaseoloides* BRA-0612 and *Centrosema macrocarpum* CIAT-5065 are some of the shade tolerant forage species showing promise for SPS in the Amazon region. In the *Caatinga* ecosystem, in the Northeast, research has shown that browsing of native shrubs associated with the utilization of *Leucaena leucocephala* protein bank and/or buffelgrass pasture allows substantial increases of liveweight gain or milk production by sheep, goats and dairy cows. In the Southeast region, in Minas Gerais and São Paulo states, SPS consist mainly in the association of *Eucalyptus spp* and *Panicum maximum*. Studies involving two-year-old eucalypt plantations showed that sheep or beef calves grazing *P. maximum* cv. Colonião allowed from 52 to 93% reduction of forest establishment and maintenance costs, as a result of selling animal products and reduction of grass competition by grazing. In the South, the most important exotic arboreal materials are *Eucalyptus, Pinus* and *Acacia* species, while *Mimosa scabrella* and *Araucaria angustifolia* are potential useful native trees. Species of *Trifolium* and annual ryegrass (*Lolium multiflorum*) mixtures have been used as cool-season pastures while *P. maximum* cultivars and *B. brizantha* cv. Marandu are used as warm-season pasture grasses. Beef calf liveweight gains on SPS consistently outyielded those obtained by grazing the native pasture in full sunlight, at two locations in Rio Grande do Sul state.

Although there is a reasonable amount of information on the establishment and management of SPS within each ecoclimatic brazilian region, the level of adoption of this new technology at the farm level is still considered very low. The benefits and possible eventual adverse consequences of the tree x pasture association on animal production, along with a discussion of the future prospects of research and potential adoption of SPS in Brazil are addressed in this paper.

Keywords: Agroforestry system, silvopastoral system, pastures, native forests, plantations

Introduction

The Brazilian territory covers more than 8.5 million km^2 , occupying around 47% of the continent of South America. Within its geographic limits, conditions vary from a humid, hot tropical climate in the Equatorial Amazon region (4^o N – 8^o S), in which plant growth can occur throughout the year, to a temperate climate in high elevations in the South (24^o – 33^o S). In Central Brazil and the Northeast, humid and dry semi-arid climates dominate respectively in which there are well defined dry or rainy seasons and that restrict plant growth. In general, Brazilian soils are oxisols and ultisols (Sanchez, 1976), which are characterized as well drained, leached, and acid, with low phosphorus and low organic matter content.

Under these environmental conditions, the Brazilian territory was originally largely covered by forests. However, the deforestation process has almost completely eliminated the Atlantic Forest and the Araucária Forest, and the Amazonian or Rain Forest is presently under attack. Yet large areas comprised of Cerrados, Campos, Caatingas and other vegetation-complex formations still exist such as the Pantanal in Central Brazil and the Mangues, at the eastern sea shores, all of which are affected by strong negative anthropic action (Pauwells, 1999).

At present, commercial Eucalyptus, Pinus and Acacia plantations represent around 80% of the total area of cultivated exotic forest species and it is estimated that the entire production from forest lands contributes some US$ 12-18 billion to the Brazilian national economy. On the other hand, within the nation there are 154 million cattle, 14.1 million sheep, and 6.6 million goats, in addition to 8.5 million head of various other species (buffaloes, horses, donkeys, etc.). About 73% of Brazil's bovines are concentrated in the Center-West, Southeast and South geographic regions while 94% of it's caprines and 46% of it's ovines are in the Northeast. In 1996, the beef cattle industry contributed around US$ 6,0 billion to the national gross product (IBGE, 1997).

There is a great potential for integrated production of forest and pasture based livestock products on large areas scattered throughout the country's agroecological regions, as already shown by some reports (Couto et al., 1994, Couto et al., 1998; Silva, 1998). Besides, the viability of silvopastoral systems under similar soil and climatic conditions has been demonstrated elsewhere, both under tropical and temperate conditions (MacDicken and Vergara, 1990; Reynolds, 1995). However, there is a need for determining locally, for each component of the system, the management steps that would sustainably maximize, the physical productivity, environmental integrity, profitability and social welfare of such systems..

Although there is a fairly large amount of research work on agroforestry in progress in Brazil, there is also a remarkable deficiency of information on the performance of animals grazing under these systems.

Agroforestry Systems Research in Brazil

Integrated land use in native forestry ecosystems is one of the oldest and most traditional types of agriculture in Brazil. The technique of shifting cultivation, from area to area, first practiced by the Indian communities was later adopted by the early settlers and it is still one of the most important approaches to land use in some parts of the nation, especially in the Amazon region. As a consequence of this activity and also due to indiscriminate timber exploitation for

several centuries, the Atlantic Forest and the Araucária Forest were almost entirely destroyed. During the last four decades, the Rain Forest has been the target of an intensive deforestation process, resulting from expansion of the pasture based beef industry and widening of the so called agricultural frontier (Serrão et al.,1993).This degradation process has generated strong worries and concern all over the world, particularly by environmental agencies, because many people feel it is important to stop destruction of this fantastic renewable natural resource, which is considered to be a global heritage.

In this context, due to intensive introduction of exotic forestry species that began in the early part of the last century, silvicultural research increased dramatically over a period of several decades, but research activities on agroforestry systems has only shown significant growth since the 1980's. A reasonable amount of information was produced in some regions of the country (Graça, 1992 ; Montoya and Medrado, 1994 a,b,c) but the majority of these results reflect responses from the tree x soil x crops or pastures, with relatively little information generated relative to the performance of domestic ruminants grazing the understory available forage. Ribaski (1992) reported the performance of beef replacement heifers grazing buffelgrass (*Cenchrus ciliaris*), *Panicum maximum* and *Urochloa mosambicensis* as understory pastures in an 8 year old Eucalyptus plantation on a "Caatinga" area, in Pernambuco state, in the Northeast region. In this study, heifers had an ADG of 0.600 kg and 56 kg/ha LWG over three months. Information on soil, pasture and tree conditions were also reported. This status of Brazilian research makes a strong contrast with countries such as New Zealand, where pasture productivity and animal performance in pastoral agroforestry systems have been evaluated for long periods of time, sometimes over 20 years (Hawke, 1997). This shows the need to give higher priority to local agroforestry systems studies, particularly the evaluation of animal performance, as an efficient way of better understanding the complex interactions present in these multistrata systems.

Pastoral Agroforestry Systems in Brazil

This subject will be dealt with based on a bibliographic review of studies, published during the last 20 years, and it is not intended to fully cover this topic. A regional approach will be used in order to offer a better perspective as far as present Brazilian research activities on agroforestry systems is concerned, particularly the evaluation of animal performance.

The North

This is the largest Brazilian geographic region, occupying 45% of the nation's land area. It contains about 4 million km^2 of Amazon Forest, the largest and most complex plant ecosystem in the rainy tropics of the world. The predatory extraction of natural resources is the main economic activity of the shifting cultivation process. Of particular importance is the extraction of timber, latex (rubber) and native plant fruits, such as the Brazilian cashew nut (*Bertholletia excelsa*), all of which is accomplished by shifting cultivation from area to area. The dairy industry has no significant importance but the beef industry consists of 18.3 million cattle and 0.5 million buffaloes (IBGE, 1997). The average stocking rate on native pastures in the Cerrados and Savanna regions of Amapá, Roraima and Pará states is 0.2-0.5 head/ha , but as high as 1.0 head/ha on *Brachiaria humidicola* pastures, showing average yields of 30 and 50 kg/ha/year LWG, on native and cultivated pastures, respectively (Souza Filho and Dutra, 2000). These figures indicate very poor animal performance, lacking efficiency and sustainability of both

systems using pastures at full sun. Further discussion on development of agroforestry systems and animal production in the Brazilian Amazon is presented by Veiga and Serrão (1990), Veiga (1990) and Simão Neto and Dias-Filho (1995). In general, a lack of information on animal performance in silvopastoral systems is evident in these papers.

On the other hand, research recently conducted in Rondônia state, aimed at generating useful information relative to the establishment of silvopastoral systems in the region, showed that the forage grasses *Brachiaria brizantha* cv. Marandu, *B. humidicola* and *Paspalum atratum* BRA-9610 evaluated under rubber tree (*Hevea brasiliensis*) shade, showed more promise than seven other grass species (Costa et al., 1999). Under eucalyptus shade, the forage legumes *Desmodium ovalifolium* CIAT-350, *Pueraria phaseoloides* CIAT-9900 and BRA-0612 e *Centrosema macrocarpum* CIAT-5065 were among the best tested. In this trial, forage peanut (*Arachis pintoi*) cv. Amarillo did not perform as well under shade (Costa et al., 2000), as it normally does in full sun. According to data from the Acre state, forage DM yields above 30 t/ha were obtained by the access BRA-031143, in the establishment year (Wendling et al., 1999), while the accesses BRA-031534 and BRA-031828 yielded 16.0 and 15.3 t/ha during the rainy season and 4.5 and 3.7 t/ha in the dry season, respectively (Carneiro et al., 2000). When *Arachis pintoi* was subjected to shading levels of 0, 30, 50 and 70% its DM yield, though reduced by increased shade, was considered adequate even at the highest shading level (Andrade and Valentim, 1999). The authors concluded that this legume showed good adaptation, yield and persistence and therefore could be used as soil cover in agroforestry systems or as a forage species in silvopastoral systems. Animal physiological parameters and performance were evaluated under shade in Rondônia state. Wool-less sheep Santa Inês x Morada Nova breeds were grazed on *Brachiaria brizantha* cv. Marandu, *Andropogon gayanus* cv. Planaltina and *Pueraria phaseoloides* pastures at three shading levels (0%, 30%, and 45%) by rubber tree. Sheep heart beat and respiration rhythm under shade were significantly lower ($P<0.05$) compared to those of animals in full sun. In the dry season, the highest ADG and G/ha were obtained by sheep at the 45% shade level, but ADG in the rainy season was not affected (Table 1), in spite of shade reducing ($P<0.05$) the available forage (Magalhães et al., 1996). The authors concluded that wool-less sheep showed good adaptation to the harsh summer climatic conditions of the wet tropics and that shade considerably reduced the depressive effects of thermal stress. Similar results, reported by Magalhães et al.(1999), were obtained with steer buffaloes grazing *B. brizantha* pasture under shade. In the dry season, the best ADG and LWG/ha were obtained under dense shade; however, in the wet season shading levels did not affect either animal performance or forage yield (Table 2). According to the authors, the latter study indicates that *B. brizantha* cv. Marandu shows satisfactory shade tolerance in the wet tropical environment.

At present, there are around 25 million hectares of degraded pastures and deforestation in the Brazilian Amazon from 1997 to 1998, the size of the affected areas grew up from 13,227 km^2 to 17,383 km^2 , leveling in 1999 (INPE, 2000). Reduction of this huge area by converting to more sustainable land use systems in order to reduce the degradation of native regional forest resources, is the biggest challenge faced by agroforestry research in the Amazon.. Certainly, silvopastoral systems will be able to help in the recovery of these areas and development of more sustainable conditions, thus increasing biodiversity, reducing the degradation pressure on the remaining forest and establishing greater social and economic stability in the region.

The Northeast

This region encompasses nine states of the Brazilian federation, totaling around 1.5 million km^2 , and includes 18 % of the nation's land area. The regional animal herd consists of 22.8 million bovines, 6.7 million sheep and 6.2 million goats, which represent 15%, 45% and 94% of Brazil's livestock, respectively. These data clearly indicate the importance of meat and milk from small domestic ruminants for the small landowner-dominated economy and in the feeding of the rural population in the Northeast. In the so called "Sertão" there is a region showing a semi arid climate, with rainfall under 750 mm/year, average yearly temperatures above 25^o C and long dry spells (Pauwells, 1999), with predominance of litosol, podzolic and red-yellow latosol soils (Sanchez,1976). This is the domain of "Caatinga", a vegetation ecosystem structured with small trees and shrubs belonging mainly to the *Leguminoseae* and *Euphorbiaceae* families. This is the largest and most important native, renewable forage resource at the regional level, covering around 900,000 ha, and used mainly for pastoral purposes. According to criteria used by Nair (1993), the "Caating" would be considered a sub-system of silvopastoral systems. The ecosystem "Caatinga" has been extensively studied, particularly since the 1960's, with research activities dealing mainly with the management of its woody (thinning) and herbaceous components, use of fertilizers, mixed grazing and sometimes, associated with introduced forage species such as buffelgrass and leucaena (*Leucaena leucocephala),* as reported by Araújo Filho, Souza and Carvalho (1995). Research conducted by EMBRAPA/CPATSA in Pernambuco state, led to the development of a forage system for raising beef cattle, known as the CBL (Caatinga+buffelgrass+leucaena) system. The main objective is to stimulate the utilization of the "Caatinga" native plants during two to four months of the rainy season. With this system, buffelgrass pastures are grazed during eight to ten months and leucaena is used as a protein bank, either grazed daily for short periods of time, or used as leucaena hay during the dry season (Guimarães Filho and Soares, 1992). This system has potential for use on over 40 million hectares of the semi arid region and its use may increase production by over 1000% in some cases as compared to the local, traditional production systems used to produce weaned calves or fattening steers. Further details on establishment, management and utilization of the CBL system are reported and discussed by Guimarães, Soares and Riché (1995).

The advancement of scientific and technological knowledge regarding the management and approaches to utilizing the"Caatinga" ecosystem made it possible to run economic analyses, in order to determine the most profitable management system. With sheep, it was possible to identify one method of the "Caatinga" improvement (thinning+bermudagrass+phosphate fertilizer), as the best economic alternative. Though this is apparently the most expensive compared to three other simpler and cheaper methods (Souza Neto, Araújo Filho and Souza, 1999), this procedure offers the farmer the opportunity to make sound investment decisions, making the adoption of technology easier.

At present, the semi arid ecosystem suffers a brutal degradation process, due to overgrazing by domestic ruminants and excessive extraction of wood for fuel and charcoal production. Consequently these are the main factors responsible for heavy biodiversity losses, increased soil erosion and rapid expansion of the size of areas undergoing desertification (Araújo Filho, Souza and Carvalho, 1995). Mainly due to the frequent and unusually long dry spells, this ecosystem lacks sufficient moisture to support large forest plantations , so it may be difficult to develop true silvopastoral schemes. In this region, this integrated land use system is probably better suited to ecological conditions on the hill slopes or in river valleys and on residual areas of the Atlantic Forest closer to the Atlantic Ocean where rainfall is much higher.

The Central-West

This is the second largest region of the country, covering a surface of about 1.6 million km^2. In the northern part of Mato Grosso state, in a zone of close contact with the south Amazon, it has a wet equatorial climate, with average yearly temperatures above 25 ^{o} C and rainfall over 2000 mm, well distributed throughout the year. In the rest of Mato Grosso, and in the states of Mato Grosso do Sul and Goiás a typical tropical climate dominates, which is characterized by high temperatures ($20^{o} - 25^{o}$C) and rainfall totaling between 1500 and 1000 mm per year, but concentrated in one rainy season from October to April. In this area soils are predominantly latosols (46%), podzolics (15%) and sandy (15%). Under these general soil and climatic conditions the ecosystem Cerrados, (sometimes also called bioma) occurs. The Cerrados has a total area equivalent to ¼ of the Brazilian territory, including parts of the Minas Gerais and São Paulo states.

In the early 1960's, more intense occupation of the Central-West region began in which, the slash-and-burn process was used to "open" the Cerrado vegetation, thus allowing the planting of rice and pastures. Four decades later, around 60 million hectares were cleared in connection with development of a the new agricultural frontier. On this land soybeans, corn, sugarcane, rice and pastures for dairy and beef cattle were planted. In 1996, the dairy and beef industries in this area generated about US$ 2.4 and 0.8 billion, respectively (IBGE, 1997). The beef cattle herd in this region is the largest in the country, comprised of 50.6 million head, representing 1/3 of the nation's bovine herd. According to Zimmer and Euclides Filho (1997), the Central-West region has an area of 43 million hectares covered by cultivated pastures, around 50% of which are estimated to have some degree of degradation. The main forage species established for cultivated pastures are perennial grasses within the *Brachiaria , Panicum* and *Andropogon* genera while legume species of *Stylosanthes, Calopogonium mucunoides* and *Leucaena leucocephala* are used mainly for direct grazing or as a protein bank. The great majority of scientific research aimed at evaluating pastures and animal production in this region has been conducted by EMBRAPA units, particularly at the Beef Cattle National Research Center located in Campo Grande, Mato Grosso do Sul state. The animal performance on these pastures, may change according to the degree of pasture degradation, which reduces forage availability, and level of soil fertility. When double amounts of limestone, phosphate and potassium were applied on *P. maximum, B. brizantha* and *B. decumbens* pastures, average animal production reached 565 kg/ha/year LW compared to 395 kg/ha/year LW when single doses were used. In addition, animal productivity linearly decreased from the first to the third evaluation year, from 670 and 435 to 445 and 325 kg/ha/year, at high and low soil fertility levels, respectively (Euclides et al., 1997). Results reported by Barcellos et al., (1997) on *B. brizantha* cv. Marandu subjected to three methods of pasture improvement using fertilizers, showed that animal gain per area, on average, reached 620 kg/ha/year, compared to a degraded pasture which produced 365 kg/ha/year. These results clearly indicate the strong dependence of pastures on fertilizers in order to obtain satisfactory animal production, due to the extremely low fertility of the Cerrado soils.

At present, the establishment and use of forest plantations is of little importance in the Central-West region. However, early experimental evidences shows a good adaptation and growth of *Pinus oocarpa* and *Eucalyptus grandis* in the Cerrados region of the Goiás state (Melo et al.,1992). Besides, the Cerrado has very rich, native arboreal flora with many species showing much potential as timber producers. According to Ribeiro et al.(1992), more than 20 woody species, among them 13 *Leguminosae* species, exhibit characteristics that may make them attractive for use in agroforestry systems in the Cerrados ecosystem.

The Southeast

The Southeast encompasses around one million km^2, representing 11% of the total Brazilian land area . In a large part within the region, the climate within this region is subtropical, with strong influence of altitude due to the presence of the Atlantic Forest at higher elevations. On the eastern side, the landscape is dominated by land that previously was covered by the Mar and by the Mantiqueira mountain ridges. On the western side, the physiognomy is dominated by the Cerrados. Dairy and beef are the most important pastoral enterprises, each supplying the largest portion of the Brazilian internal market, 70 million people (43% of the country's population) living in large cities such as São Paulo, Rio de Janeiro and Belo Horizonte. At present, the largest areas under forestry are in this region, totaling around 3 million hectares of eucalyptus and 5 million hectares of Pinus plantations. Research on agroforestry systems in the Southeast has been intensified at the Federal University of Viçosa, in Minas Gerais state since the 1980's and the issue of identifying superior genotypes for use of trees with pastures has been addressed at the EMBRAPA/CNPGL, in Coronel Pacheco, Minas Gerais. The search for shade tolerant forage grass species has mainly involved genotypes within the *Brachiaria, Melinis, Andropogon, Panicum* and *Setaria* genera (Castro, 1999). Fast growing arboreal legume species that can be grown in association with perennial grass pastures in southeast Minas Gerais include *Acacia angustissima, Racosperma auriculiformis, R. mangium, Albizia lebbek* and *Gliricidia sepium* (Carvalho, 1998; Carvalho et al., 1999). Native woody species ,recommended to be grown with pastures include "angico-vermelho" (*Anadenanthera macrocarpa), "*angico-branco*" (A. colubrina*) , "jacarandá-branco" (*Platypodium elegans*) and "vinhático" (*Plathymenia foliolosa*). A comprehensive and detailed study involving *Eucalyptus citriodora* in association with *Panicum maximum* was conducted at Dionisio county, Minas Gerais state by Couto et al.(1994). In this study, in which the performance of beef calves and sheep, soil compaction, chemical composition and soil cover were documented, and a financial analysis made, one year old beef calves, weighing 180 kg LW each, and sheep with 33 kg LW each were used. Treatments were several stocking rates, which consisted of 9 or 6 calves alone or in association with ten sheep, in addition to ten sheep alone, and a check plot without grazing, where forage harvesting was done by hand.. Animal performance data is shown in Table 3.

Calf ADG between 0.4 and 0.5 kg was considered satisfactory, taking into account that according to local information, this gain is twice the level necessary to make a profit with beef cattle in Minas Gerais state. The main conclusions of this study were: a) grazing by cattle and/or sheep did not reduce tree plant height or stem diameter (dbh); b) eucalyptus tree survival was not affected by the grazing animals; c) grazing reduced the amount of understory vegetation, thus helping to prevent forest fires; d) soil compaction in the top 15 cm of soil increased when stocking rate was increased; e) animal products from this pastoral agroforestry system allowed a reduction of eucalyptus stand establishment costs by 52% to 93%; and f) cattle and sheep can be introduced into young eucalyptus plantations (4 to 6 months old) without significantly damaging the trees. Due to its comprehensive scope, this important experimental work can be considered, within limits, as a model of pastoral agroforestry research. It generated relevant information on the performance of each individual system component and also allowed a simple but sound economic analysis to help producers make proper management decisions. At present, a great deal of research work on pastoral agroforestry schemes is under way in this region, often supported by grants from private companies from the forestry sector and coordinated by the Sociedade de Investigações Florestais (SIF) = Forestry Research Society, located at the Department of Forestry

Engineering, Federal University of Viçosa, Minas Gerais. Additional information on the Atlantic Forest ecosystem as well as on agroforestry systems using eucalyptus in Brazil can be found in excellent reviews by Pereira, Boddey and Rezende (1995) and by Couto et al. (1998), respectively.

There is great potential for the development of pastoral agroforestry systems in the Southeast, mainly due to suitable environmental conditions but also to the fact that both eucalyptus or pinus plantations and beef cattle production are already well established rural activities.

The South

This region contains the states of Paraná, Santa Catarina and Rio Grande do Sul , covering an area of 577.000 km^2 at the country's most meridional corner, bordering Uruguay, Argentina and Paraguay. Since almost all of this area is located south of Tropic of Capricorn, the region has a subtropical climate with a yearly average temperature lower than 20^o C and rainfall well distributed throughout the year. At zones with 500 to 1200 m elevation above sea level, severe frosts and, occasionally, snow fall can occur during winter. In its northern part, the original vegetation of this region was mostly the Araucária Forest and the Atlantic Forest at the Meridional Plateau ; the southern part is dominated by the Campos formation, an extensive pastoral ecosystem covering the southern half of Rio Grande do Sul state, which spreads into Uruguay and northeast Argentina (Pauwells, 1999). Dairy and beef cattle herds total 14.1 million head, basically kept on native pastures. Livestock produce US$ 600 million per year while permanent cash crops (erva-mate plantations, apple orchards, grape vineyards, etc.) produce about US$ 320 million and the forestry industry generates around US$ 400 million per year. The main forestry species planted in the region are loblolly pine (*Pinus elliottii , P. taeda*) , *Eucalyptus spp. ,* and black wattle (*Acacia mearnsii*), while the Brazilian pine tree (*Araucaria angustifolia*) and "bracatinga "(*Mimosa scabrella*) are the most important native forest species. Annual cash crops, mainly soybeans, corn, rice, wheat and black beans, are grown on over 12 million hectares, producing around US$ 6.5 billion per year (IBGE, 1997).

Research activities on agroforestry systems have been conducted since the 1980's, mainly at the EMBRAPA/CNPF (National Forestry Research Center) located at Colombo, in Paraná state. As a result, a great deal of information has been generated (Montoya and Medrado, 1994 a, b,c). In one of these studies, which dealt with the evaluation of the tree (*Pinus elliottii*) component and animal performance on native pasture, the average LWG of steers between August 1980 and April 1983, was 40 kg/ha/year. This was considered very low compared to that of an improved pasture system at full sun. However, the drastic reduction of potentially inflammable understory dry material due to the presence of the grazing animals inside the forest was considered a bonus (Schreiner, 1992). Further information on the early research activities coordinated by EMBRAPA/CNPF are provided by Graça (1992) and Montoya and Medrado (1994a, b,c).

In the early 1990's, a research program on pastoral agroforestry was jointly initiated by the Department of Forage Crops and Agrometeorology, Federal University of Rio Grande do Sul (UFRGS), the Klabin Riocell forestry company, and the State Research Funding Agency (FAPERGS). The main objective of this program is to conduct multidisciplinary investigation on pastoral agroforestry systems using eucalyptus, in order to define alternative technologies that will allow the development of integrated and more sustainable land use systems under the agroecological conditions of southern Brazil. The experimental site is located in Eldorado do Sul county (30^o05'52"S and 51^o39'08"W).

Association of eucalyptus x pasture x animal production

In Rio Grande do Sul state around 100.000 hectares are devoted to eucalyptus plantations, concentrated in the "Depressão Central " ecoclimatic region, using mainly *E. grandis, E. saligna, E. viminalis* and *E. dunnii* for cellulose, energy and timber production (AGEFLOR, 1999). In a preliminary study conducted in a two year old forest, 45 replacement heifers and 42 weaned calves grazed an area of 180 ha from June 17 to December 30. During spring, heifers reached an ADG of 0.567 kg/head, but total gain/area was very low, only 12.55 kg/ha , as a consequence of the low stocking rate and reduced forage quality. Under heavy shade conditions inside the forest, frequency of C_4 native herbaceous grasses (*Paspalum notatum , Axonopus affinis*) was reduced while C_3 types (*Piptochaetium montevidense, Briza subaristata*) were increased, indicating a potential usefulness of these species to be used in association with trees. Beginning in December 1994, a field experiment was conducted to evaluate the productivity of an *E. saligna* forest at 1,666 and 833 trees/ha plant densities (3m x 2 m and 6m x 2 m between and within rows, respectively) and beef steer performance when grazing a cool-season pasture understory. Annual ryegrass (*Lolium multiflorum*) and 'Yuchi' arrowleaf clover (*Trifolium vesiculosum*) were broadcast in May 1995 and grazed for 64 days beginning in September, at three levels of forage on offer: 6%, 9% and 12% liveweight , as kg DM/100 kg LW/day. Grazing was begun when trees had an average plant height of 2.3 meters. Six treatment combinations were arranged in a complete random design with two replications, over an area of 24 ha that had been subdivided into 12 paddocks. Grazing was accomplished by continuous stocking with adjusted stocking rate as needed to keep forage allowance at indicated levels. The relationships between forage on offer, ADG , Gain/area and average stocking rate for the first grazing season in spring are shown in Figure 1.

At the highest tree density, the relationship between daily forage on offer and ADG is a positive straight line, while the relationship for G/area is curvilinear (1a). At the low tree density, these relationship are represented by curvilinear models (1b). The linear relationship shows that ADG increased with increasing forage on offer up to its maximum level, possibly indicating that the full ingestive capacity of animals was not reached or that the animal's potential for LW gain was higher than those recorded. At the lower level of forage on offer G/area was low due to poor animal performance induced by overgrazing. At forage on offer levels higher than 11% LW, gain/area was also low due to low stocking rate (1c). At intermediate stocking rates the best ADG with high LW gains/area were achieved. The optimum stocking range is placed between 9% and 11.5% LW (1a, 1b). In Rio Grande do Sul, recent work revealed that the optimum stocking range is situated at 9.5% and 12% LW for both native and exotic pastures at full sun (Moraes et al.,1995; Maraschin, 1997). These results show that regardless of growing conditions, the levels of forage on offer which maximize animal performance are identical under moderate shade or at full sun. In addition, the results clearly indicate that better animal performance was achieved at the low forest density, up to when the forest was 11 months old. When the forest was two years old, total animal production at the low tree density was 455 kg/ha LW, at 10% LW level of forage on offer, At high tree density, animal production was only 218 kg/ha (Table 4). These results reveal the advantage of the low tree density on increasing animal performance, from establishment until when the forest is two years old. At the high tree density, the grazing period was reduced to 18 months, due to heavy shade at soil level, which prevented pasture growth (Table 5). In this particular experiment, some other relationships among individual system components were also investigated. It was concluded that tree survival , plant height and growth

in diameter, regardless of tree density, were not influenced by grazing pressure. Similarly, it was found that the grazing animal did not significantly damage the trees, independently of grazing pressure and tree density. These findings help support the idea that grazing animals can be advantageously introduced into the forest before it reaches two years of age without causing significant harm to the trees. However, in order to be successful with this approach it is important to be certain that the growing points of the trees are located above the grazing line (in other words, the tree apical meristems won't be removed by grazing), pasture management won't limit forage intake, and quality of available pasture is higher than leaves and thin branches of the arboreal substrate. Results from an experiment established in 1995 on native pasture and designed to investigate the effect of grazing by cattle or sheep as agents to control growth of herbaceous vegetation under an *Eucalyptus saligna* forest established at three densities (204, 400 and 816 plants/ha), showed that physical damages and tree leaf area reduction were very low as a consequence of grazing initiated when the forest was only seven months old (Varella and Saibro, 1999). Regardless of tree density, cattle grazing was more harmful to eucalyptus tree than sheep grazing. In addition, heavier damages occurred when trees were lower than 1.82 m when grazed by cattle and 1.54 m when grazed by sheep. Finally, it was concluded that both cattle and sheep grazing controlled native vegetative growth better than any of several herbicide treatments, therefore lowering establishment costs and considerably reducing the agrochemical burden for the environment. From December 1997 to May 1998, another study was conducted on these same experimental plots to determine the effect of grazing by sheep compared to no grazing on tree growth, pasture dynamics and animal performance (Fucks, 1999). The available forage mass, sheep ADG and number of grazing days was reduced as tree density increased (Figures 2 and 3). On the other hand, trees on grazed plots showed significant ($P<0.05$) differences in diameter at breast height and plant height compared to those on plots without grazing (Tables 6 and 7). These results were probably the most striking ones shown by this study, pointing out a real benefit of the grazing animal and its effects on the growth and development of the forestry component, regardless of tree density.

Association of black wattle x pasture x animal production

In Rio Grande do Sul state, there are around 130,000 ha under cultivation with black wattle (*Acacia mearnsii*), which is used mainly for tannin production (extracted from the bark), cellulose, fuel and charcoal (AGEFLOR, 1999). In October 1995, a joint project between the State Foundation for Agricultural Research (FEPAGRO) , the Agroseta forestry company and FAPERGS was established in Tupanciretã county, in the "Planalto Médio" region (Castilhos, 1999). The main objective was to study interactions involving forest productivity and beef steer performance at the pasture x tree x animal interfaces, in a black wattle forest established at two densities (1,666 and 1,000 plants/ha) associated with *Brachiaria brizantha* cv. Marandu, *Panicum maximum* cv. Gatton and *Eragrostis plana* pastures. The soil is a sandy, red latosol, with low native fertility, that was amended with 2 t/ha of dolomitic limestone and fertilized with a total of 210N – 100 P_2O_5 – 100 K_2O kg/ha, between November 1996 and March 1999. Sixteen hectares divided into 12 paddocks and two replications were used. Pastures were grazed by beef steers using continuous stocking with stocking rate adjusted as needed in order to maintain 10% to 12% LW level of forage on offer. The first grazing period was during the winter of 1998 and animal performance was considered very satisfactory (Table 8), particularly because this is the time when native pastures are "burned" by frost and usually animals consequently lose LW. However, a strong "shelter effect" provided by trees prevented green forage grasses from being

burned by frosts inside the forest, a condition which allowed the steers to graze a better quality forage, and thus increase LW. The second grazing period was in spring 1998 – summer 1999, and totaled 78 grazing days. Residual green forage, ADG, LWG/area, and average stocking rate at low tree density were higher ($P<0.05$) compared to high tree density, probably due to heavy shading imposed on the herbage at soil level. Steer ADG on *P. maximum* and *B. decumbens* pastures were higher than on *Eragrostis plana* pasture (Table 9) and average LWG/area on pastures established at low tree density was 60% higher than at high tree density and more than three times as much as the state average animal productivity, which is around 50 kg/ha/year.

Comments on research, economics and adoption aspects of agroforestry systems in Brazil

There is a great deal of research on agroforestry systems in progress in Brazil at present, mainly dealing with interactions between system components at the soil x tree x pasture x climate interfaces. The information being generated can potentially be of great benefit in planning research activities on pastoral agroforestry systems under varied agroecological conditions in different parts of the country. On the other hand, it should be realized that reliable information on animal performance under grazing in silvopastoral systems, in practical terms, does not exists. Furthermore, the scarce information that is available has a very narrow range of influence, because few forest or pasture species have been tested, and the evaluations conducted have been of limited scope. When we compare information available on these two production systems, questions arise: Why is data on animal performance so limited ? Is such data necessary or important ? The answers to these questions are not easily found, because many points need to be considered. However, we believe that for several reasons it is essential to have such data. First, the evaluation of silvopastoral systems is complete only when the animal component is evaluated along with all other system components, in a true integrated system. This is the only way by which all interactions among the system components can realistically be fully and properly expressed according to their respective intensities of action within the system and without constraints on their biological responses. Therefore, the presence of the grazing animal, with its strong effects on all other components, is mandatory. Besides, in well planned experiments, the evaluation of animal performance allows economic analysis to assess margin of profits on financial investments and to help farmers or forest companies make sound management decisions. Such information is of great value and greatly facilitates the adoption of recommended technologies. On the other hand, it is also important to consider that the evaluation of animal performance using grazing experiments is a very complex task that requires expensive field facilities and a substantial labor force, including a well qualified and trained technical staff. Unfortunately, these are conditions that are seldom found at institutions responsible for conducting research on pasture based animal production systems in Brazil. The lack of multidisciplinary research teams and a shortage of funding for planning and conducting this kind of experimental work is, unquestionably the most limiting factor associated with running animal performance evaluation trials. Perhaps more focus on national coordination of agroforestry research activities would help reduce or prevent most of these problems.

Potentially, pastoral agroforestry enterprises are of great importance to several areas of the national and various areas of regional economies. Therefore, public or private organizations, universities, environmental protection agencies, etc., commited to sustained agroforestry development could be called upon to help support research activities in this field. In addition , there is a need to develop new experimental techniques for agroforestry systems studies, particularly on pastoral agroforestry (Huxley,1990), to increase the scientific value of

information, and generate such information at lower costs. Another very important issue that also deserves top research priority is the identification of forage materials that exhibits a high level of shade tolerance. To date, this search has been limited to examining well known forage grasses and legumes (Wilson and Ludlow, 1990; Wong and Stur, 1996; Reynold, 1995 ; Castro, 1999), since no specific selection or breeding work has been done to identify such materials. However, if active pasture growth under shade is a fundamental step toward succesful pastoral agroforestry systems, then the use of highly productive, shade tolerant, forage materials will be essential, in order to achieve high levels of animal production.

The adoption of new agroforestry technologies is a complex process (Vergara and MacDicken, 1990), which depends largely on making a profit. On the other hand, the financial success of an agroforestry enterprise depends upon the use of a set or package of technologies generated or recommended by research and validated on its technical, economical and environmental merits (Hoekstra, 1990). At present, the adoption of pastoral agroforestry systems in Brazil is very low. In fact, it is almost non-existent as an economic activity, a fact that can be attributed to the lack of sound technical information or lack of profit, the former being the most likely reason.

However, particularly due to favorable environmental conditions, within Brazil there is much opportunity for the development of pastoral agroforestry systems. Due to strong increasing pressures by environmental organizations and by the general society worldwide, it is reasonable to expect that the predatory wood and timber extraction from the Brazilian native forest ecosystems will be greatly reduced in coming decades. As a consequence, forest plantations will be significantly expanded, creating the opportunity for the establishment of true pastoral agroforestry enterprises. The level of adoption of these systems by landowners will largely depend on the availability of sustainable technologies. Therefore, both short and long term research activities on pastoral agroforestry should be planned and conducted in coming years, so they will be available when needed, in the first decades of the 21st century.

Acknowledgements

I am grateful to Dr. Don Ball, Auburn University, Alabama, USA, for his helpful suggestions and comments and for critical reading of the manuscript and to Jamir L.S.Silva, Zélia M.S. Castilhos and Luis F. M. Fucks for providing experimental data.

References

Ageflor (1999). Consolidação dos dados disponíveis sobre a cadeia produtiva de base florestal no Rio Grande do Sul. Ed. Assembléia Legislativa do estado do Rio grande do Sul. 50 p.

Andrade, C.M.S. and J.F. Valentim (1999). Adaptação, produtividade e persistência de *Arachis pintoi* submetido a diferentes níveis de sombreamento. Revista Brasileira de Zootecnia **28**: 439-445.

Araújo Filho, J.A., F.B. Souza and F.C. Carvalho (1995). Pastagens no Semi-Árido: Pesquisa para o desenvolvimento sustentável. p. 63-75. In R.P. Andrade, A .O . Barcellos and C.M.C. Rocha (eds). Simpósio sobre pastagens nos ecossistemas brasileiros: pesquisas para o desenvolvimento sustentado. XXXII Reunião Anual da Sociedade Brasileira de Zootecnia, 1995, Brasília, DF. *Anais*.

Barcellos, A.O., A. Viana Filho, L.C. Balbino, I.P. Oliveira and L.P. Yokoyama (1997). Produtividade animal em pastagens renovadas em solo arenoso de Cerrado. In R. S. Lizieire, M.

M. Carvalho, O. J. Fajardo, L. A. Carvalho, C. E. Martins (eds). XXXIV Reunião Anual da Sociedade Brasileira de Zootecnia, p. 207-209, 1997, Juiz de Fora, MG. *Anais.*

Carneiro, J.C., J.F. Valentim and G.N. Pessôa (2000). Avaliação agronômica do potencial forrageiro de *Arachis* spp. nas condições ambientais do Acre. In D. Nascimento Jr., R. A. Torres and J.C. Pereira (eds).XXXVII Reunião Anual da Sociedade Brasileira de Zootecnia , 3 p. 2000, Viçosa, MG. *Anais.* CD ROM.

Carvalho, M.M. (1998). Arborização de pastagens cultivadas. . Juiz de Fora, MG. EMBRAPA-CNPGL, 1998. 37 p. (EMBRAPA-CNPGL. Documentos, 64).

Carvalho, M.M., V.P. Freitas and D.F. Xavier (1999). Comportamento de cinco leguminosas arbóreas exóticas em pastagem formada em latossolo vermelho-amarelo de baixa fertilidade. Revista Árvore, Viçosa-MG, **23**: 187-192.

Castilhos, Z.M.S. (1999). Sistema Agrossilvipastoril: Desempenho animal e da pastagem em bosque de acácia-negra (*Acacia mearnsii* De Wild). Relatório Técnico, Fundação Estadual de Pesquisa Agropecuária, RS. Porto Alegre, RS. 15 p.

Castro, C.R.T., R. Garcia, M.M. Carvalho and L. Couto (1999). Produção forrageira de gramíneas cultivadas sob luminosidade reduzida. Revista Brasileira de Zootecnia, Viçosa, **28**: 919-927.

Costa, N.L., C.R. Towsend, J.A. Magalhães and R.G.A. Pereira (1999). Avaliação agronômica de gramíneas forrageiras sob sombreamento de seringal adulto. In A. M. Penz Jr., J. F. P. Lobato, L. O. B. Afonso and I. B. Morão (eds). XXXVI Reunião Anual da Sociedade Brasileira de Zootecnia, 3 p. 1999, Porto Alegre, RS. *Anais*. CD ROM.

Costa, N.L., C.R. Towsend, J.A. Magalhães and R.G.A. Pereira (2000). Avaliação agronômica de leguminosas forrageiras sob sombreamento de eucaliptus. In D. Nascimento Jr., R. A. Torres and J.C. Pereira (eds).XXXVII Reunião Anual da Sociedade Brasileira de Zootecnia , 3 p. 2000, Viçosa, MG. *Anais.* CD ROM.

Couto, L., R.L. Roath, D.R. Betters, R. Garcia and J.C.C. Almeida (1994). Cattle and sheep in eucalypt plantations: a silvopastoral alternative in Minas Gerais, Brazil. Agroforestry Systems **28**: 173-185.

Couto, L., O. Daniel, R. Garcia, W. Bowers and F. Dubé (1998). Sistemas agroflorestais com eucaliptos no Brasil: uma visão geral. Viçosa: SIF, 1998. 49 p. (Documento SIF, 17).

Euclides, V.P.B., M.C.M. Macedo, M.P. Oliveira (1997). Desempenho animal em pastagens de gramíneas recuperadas com diferentes níveis de fertilização. In R. S. Lizieire, M. M. Carvalho, O. J. Fajardo, L. A. Carvalho, C. E. Martins (eds). XXXIV Reunião Anual da Sociedade Brasileira de Zootecnia, p. 201-203, 1997, Juiz de Fora, MG. *Anais.*

Fucks, L.F.M. (1999). Dinâmica da pastagem nativa, desempenho de ovinos e desenvolvimento arbóreo em sistema silvipastoril com três populações de ***Eucalyptus saligna.*** Departamento de Plantas Forrageiras e Agrometeorologia, UFRGS. Porto Alegre, RS. 174 p. 1999. (Dissertação de Mestrado em Zootecnia – Plantas Forrageiras).

Garcia, R. and L. Couto (1997). Silvipastoral systems: Emergent technology of sustainability. p. 281-302 In J. A. Gomide (ed). International Symposium on Animal Production under Grazing (1997 : Viçosa, MG). 471 p.

Graça, L.R. (1992). Encontro Brasileiro de Economia e Planejamento Florestal, 2., 1991, Curitiba. *Anais*. Colombo : EMBRAPA-CNPF, 1992. v. 1: Sistemas agroflorestais no Brasil: Aspectos técnicos e econômicos. 446 p.

Guimarães Filho, C., J.G.G. Soares and G.R. Riché (1995). Sistema caatinga – buffel – leucena para produção de bovinos no semi-árido. Petrolina, PE : EMBRAPA – CPATSA. 1995. 39 p. (EMBRAPA-CPATSA. Circular Técnica, 34).

Hawke, M.F. (1997). The changing focus of pastoral agroforestry in temperate zones. Proceedings of XVIIIth International Grassland Congress, Winnipeg, Canada: 121-128.
Hoekstra, D.A. (1990). Economics of Agroforestry. p. 310-331. John Wiley & Sons. In K. G. MacDicken , N. T. Vergara (eds). Agroforestry: Classification and Management. 382 p.
Huxley, P.A. (1990). Experimental Agroforestry. p. 332-353. John Wiley & Sons. In K. G. MacDicken , N. T. Vergara (eds). Agroforestry: Classification and Management. 382 p.
IBGE. 2000. Web site Instituto Brasileiro de Geografia e Estatística : http://www.ibge.org
INPE. 2000. Web site Instituto Nacional de Pesquisas Espaciais: http://www.inpe.br
Mac Dicken, K.G. and N.T. Vergara (1990). Agroforestry: Classification and Management (ed). John Wiley & Sons, New York, 382 p.
Magalhães, J.A., Costa, N.L., R.G.A. Pereira, C.R. Towsend and A.C. Tavares (1996). Desempenho produtivo e reações fisiológicas de ovinos deslanados em sistema silvipastoril. Comunicado Técnico, N^{o} 120, EMBRAPA-RONDÔNIA, June 1996, p. 1-6.
Magalhães, J.A., Costa, N.L., R.G.A. Pereira, C.R. Towsend and A.C. Tavares (1999). Desempenho produtivo de bubalinos em sistemas silvipastoris. In A. M. Penz Jr., J. F. P. Lobato, L. O. B. Afonso and I. B. Morão (eds). XXXVI Reunião Anual da Sociedade Brasileira de Zootecnia, 3 p. 1999, Porto Alegre, RS. *Anais*. CD ROM.
Maraschin, G.E. (1997). Produção de carne a pasto. In A.M. Peixoto, J.C. Moura, V.P. Faria (eds). Produção de bovinos a pasto: Simpósio sobre manejo da pastagem, 13. September 1996, Piracicaba-SP, FEALQ. p. 243-274.
Melo, J.T., V.P.G. Moura and J.F. Fialho (1992). Sistemas agroflorestais na região dos Cerrados. In Montoya, L.J. and M.J.S. Medrado (1994a). Congresso Brasileiro sobre Sistemas Agroflorestais, 1., 1994, Porto Velho. *Anais*. v. 1: Trabalhos convidados. p. 123-131. Colombo : EMBRAPA-CNPF, 1994. 522 p. (EMBRAPA. CNPF. Documentos, 27).
Montoya, L.J. and M.J.S. Medrado (1994a). Congresso Brasileiro sobre Sistemas Agroflorestais, 1., 1994, Porto Velho. *Anais*. v. 1: Trabalhos convidados. Colombo : EMBRAPA-CNPF, 1994. 522 p. (EMBRAPA. CNPF. Documentos, 27)
Montoya, L.J. and M.J.S. Medrado (1994b). Congresso Brasileiro sobre Sistemas Agroflorestais, 1., 1994, Porto Velho. *Anais*. v. 2: Trabalhos voluntários. Colombo : EMBRAPA-CNPF, 1994. 496 p. (EMBRAPA. CNPF. Documentos, 27).
Montoya, L.J. and M.J.S. Medrado (1994c). Seminário sobre sistemas agroflorestais na região sul do Brasil, 1., 1994, Colombo. *Anais*. Colombo : EMBRAPA-CNPF, 1994. 260 p. (EMBRAPA. CNPF. Documentos, 26).
Moraes, A., G.E. Maraschin and C. Nabinger (1995). Pastagens nos ecossistemas de clima subtropical: pesquisas para o desenvolvimento sustentável. p. 147-200. In: R.P. Andrade, A.O. Barcellos, C. M C. Rocha. Simpósio sobre pastagens nos ecossistemas brasileiros: pesquisas para o desenvolvimento sustentado. XXXII Reunião Anual da Sociedade Brasileira de Zootecnia, 1995, Brasília, DF. *Anais*.
Nair, P.K.R. (1993). An Introduction to Agroforestry. Kluwer Academic Publishers, Dordrecht/Boston/London. 499 p.
Pauwels, G.J. (1999). Novo Atlas Meridional. Companhia Melhoramentos de São Paulo, São Paulo. 96 p.
Pereira, J.M., R.M. Boddey and C.P. Rezende (1995). Pastagens no Ecossistema Mata Atlântica: Pesquisas para o desenvolvimento sustentável. p. 94-146. In: R.P. Andrade, A.O. Barcellos, C. M C. Rocha. Simpósio sobre pastagens nos ecossistemas brasileiros: pesquisas para o desenvolvimento sustentado. XXXII Reunião Anual da Sociedade Brasileira de Zootecnia, 1995, Brasília, DF. *Anais*.

Reynolds, S.G. (1995). Pasture-Cattle-Coconut Systems. FAO/Rome, 668 p.
Ribaski, J. (1992). Sistemas agroflorestais no semi-árido brasileiro. p. 81-94. In L. R. Graça (ed). Encontro Brasileiro de Economia e Planejamento Florestal, 2., 1991, Curitiba. *Anais*. Colombo : EMBRAPA-CNPF, 1992. v. 1: Sistemas agroflorestais no Brasil: Aspectos técnicos e econômicos. 446 p.
Ribeiro, J.F., C.E.L. Fonseca, S.P. Almeida, C.B. Proença, J.A. Silva and S.M. Sano. (1994). Espécies arbóreas de uso múltiplo na região do Cerrado: Caracterização botânica, uso potencial e reprodução. p. 335-356. In L. J. Montoya and M. J. S. Medrado. 1994 a. Congresso Brasileiro sobre Sistemas Agroflorestais, 1., 1994, Porto Velho. *Anais.* v. 1: Trabalhos convidados. Colombo : EMBRAPA-CNPF, 1994. 522 p. (EMBRAPA. CNPF. Documentos, 27).
Sanchez, P. A. (1976). Properties and management of soils in the Tropics. 618 p.
Schreiner, H.G. (1994). Pesquisa em agrossilvicultura no sul do Brasil: Resultados, perspectivas e problemas. p. 53-64. In L. J. Montoya, M. J. S. Medrado (eds). Seminário sobre sistemas agroflorestais na região sul do Brasil, 1., 1994, Colombo. *Anais*. Colombo : EMBRAPA-CNPF, 1994. 260 p. (EMBRAPA. CNPF. Documentos, 26).
Serrão, E.A., C. Uhl and D.C. Nepstad. Deforestation for pasture in the humid tropics: Is it economically and environmentally sound in the long term ? Proceedings of the XVIIth International Grassland Congress , Rockhampton, Australia: 2215-2221.
Silva, J.L.S. (1998). Produtividade de componentes de um sistema silvipastoril constituído por *Eucalyptus saligna* e pastagens cultivada e nativa no Rio Grande do Sul. Departamento de Zootecnia- UFV. Viçosa/MG. 174 p. 1998. (Tese de Doutorado).
Simão Neto, M. and Dias-Filho, M.B. (1995). Pastagens no ecossistema do trópico úmido: Pesquisas para o desenvolvimento sustentado. p. 76-93. In R.P. Andrade, A.O. Barcellos, C. M C. Rocha. Simpósio sobre pastagens nos ecossistemas brasileiros: pesquisas para o desenvolvimento sustentado. XXXII Reunião Anual da Sociedade Brasileira de Zootecnia, 1995, Brasília, DF. *Anais*.
Souza Filho, A.P.S. and S. Dutra (2000). Desempenho de bovinos em pastagens nativas de savanas e de *Brachiaria humidicola* em diferentes cargas animais. 3 p. In D. Nascimento Jr., R. A. Torres and J.C. Pereira (eds).XXXVII Reunião Anual da Sociedade Brasileira de Zootecnia , 2000, Viçosa, MG. *Anais.* CD ROM.
Sousa Neto, J. , Araújo Filho, J.A. and Sousa, F.B. (1999). Análise de investimento de sistemas de manejo da caatinga para a produção de ovinos no semi-árido nordestino.
Veiga, J.B. (1991). Desenvolvimento de sistemas silvipastoris para a Amazônia. In Sociedade Brasileira de Zootecnia. *Anais*. Palestras. XXVIII Reunião Anual da Sociedade Brasileira de Zootecnia, João Pessoa, PB. p. 59-79.
Veiga, J.B. and E.A. Serrão (1990). Sistemasa silvipastoris e produção animal nos trópicos úmidos: A experiência da Amazônia Brasileira. In Sociedade Brasileira de Zootecnia. *Anais.* Palestras-Pastagens. XXVII Reunião Anual da Sociedade Brasileira de Zootecnia, Campinas, SP. P. 38-68.
Varella, A.C. and J.C. Saibro (1999). Uso de bovinos e ovinos como agentes de controle da vegetação nativa sob três populações de eucalipto. Revista Brasileira de Zootecnia **28**: 30-34.
Vergara, N.T. and K.G. MacDicken (1990). Extension and Agroforestry Technology Delivery to Farmers. p. 354-373. John Wiley & Sons. In K. G. MacDicken , N. T. Vergara (eds). Agroforestry: Classification and Management. 382 p.
Wendling, I.J., J.C. Carneiro, J.F. Valentim and J.E. Feitosa (1999). Efeito da altura e frequência de corte na produção de matéria seca de *Arachis pintoi* (BRA-031143) nas condições edafoclimáticas do Acre. In A. M. Penz Jr., J. F. P. Lobato, L. O. B. Afonso and I. B. Morão

(eds). XXXVI Reunião Anual da Sociedade Brasileira de Zootecnia, 3 p. 1999, Porto Alegre, RS. *Anais*. CD ROM.

Wilson, J.R. and M.M. Ludlow (1990). The environment and potential growth of herbage under plantations. In H. M. Shelton, W.W. Stur. Forages for plantations crop. Proceedings of a workshop, 32, 1990. Sanur Beach, Bali-Indonesia. Sanur Beach : Australian Centre for International Agricultural Research, p. 10-24.

Wong, C.C. (1990). Shade tolerance of tropical forages: a review. In H. M. Shelton, W.W. Stur. Forages for plantations crop. Proceedings of a workshop, 32, 1990. Sanur Beach, Bali-Indonesia. Sanur Beach : Australian Centre for International Agricultural Research, p. 64-69

Zimmer, A.H. and K. Euclides Filho (1997). Brazilian pasture and beef production. P. 1-29. In J. A. Gomide (ed). International Symposium on Animal Production under Grazing (1997 : Viçosa, MG). 471 p.

Table 1 -Wool-less sheep productive performance on a pastoral agroforestry system in Rondônia state, Brazil. Source: Magalhães et al. (1996).

Treatments	Liveweight gain					
	Dry season			Rainy season		
	G/an/day	G/an/day	kg/ha	G/an/day	G/an/day	kg/ha
Without shading	39.3 [b]	208.3 [b]	18.7 [b]	40.4 [a]	214.4 [a]	51.5 [a]
30% shading	44.9 [b]	237.8 [b]	21.4 [b]	44.6 [a]	120.4 [b]	27.8 [b]
45% shading	79.4 [a]	421.0 [a]	37.9 [a]	30.3 [a]	60.7 [b]	14.6 [b]

Means followed by the same letter within a column are not different (P>0.05) by Tukey test.

Table 2 - Steer buffaloes productive performance on a *Brachiaria brizantha* cv. Marandu pasture under rubbertree shading levels in Rondônia state. Source: Magalhães et al. (1999).

Treatments	Stocking rate	Dry season			Rainy season		
	AU/ha	kg/an/day	kg/an	kg/ha	kg/an/day	kg/an	kg/ha
Without shading	0.97	0.337 [b]	20.2 [b]	39	0.812 [a]	101 [a]	199
Moderate shading [1]	0.70	0.472 [a]	28.3 [a]	40	0.818 [a]	102 [a]	144
Heavy shading [2]	0.80	0.575 [a]	34.5 [a]	69	0.864 [a]	108 [a]	215

Means followed by the same letter within a column are not different (P>0.05) by Tukey test.
[1] Native woodland .
[2] Twelve years old rubbertree plantation.

Table 3 - Liveweight gains of one year old beef calves during the first 12 months grazing on a *P. maximum* pasture in a silvopastoral system using *E. citriodora*. Dionisio, Minas Gerais state, 1986-1988. Source: Couto et al. (1994).

Steer/sheep	Herd initial LW (kg)	Herd final LW (kg)	G/herd (kg)	G/head (kg)	ADG (kg)
9	1,592	2,620	1,028	114	0.46
6	1,104	1,790	686	114	0.46
9+10	1,749	2,890	1,141	127	0.51
6+10	1,093	1,830	7,37	123	0.49
Average					0.48

Table 4 - Effect of levels of forage on offer and tree density on steer liveweight gain/area, in a pastoral agroforestry system using cool-season and native pastures, in a two years old Eucalyptus forest. EEA-UFRGS. Eldorado do Sul, RS. Source: Silva (1998).

Forage on Offer	Plant Density					
	1,666 trees/ha (2 x 3m)			833 trees/ha (2 x 6m)		
	Rep. I	Rep. II	Average	Rep. I	Rep. II	Average
	---------- kg/ha ----------					
High	155	97	126	338	152	245
Medium	212	224	218	520	391	455
Low	218	169	194	272	394	333

Table 5 - Daily photosynthetic active radiation (PAR) under two tree densities at 10, 15 and 25 months on a *E. saligna* forest. EEA/UFRGS. Eldorado do Sul, RS. Source: Silva (1998).

Observation	10 months (October 95)	15 months (May 96)	25 months (January 97)
PAR incident ($\mu Mol/m^2/s$)	933	558	1,151
PAR transmitted under 1,666 trees/ha %	43.3	28.7	17.4
PAR transmitted under 833 trees/ha %	70.7	42.1	29.3

Table 6 -Eucalyptus plant diameter at breast height (dbh) at three plant density (816, 400 and 204 trees/ha) in a 33 months old forest, under or without grazing by sheep, from December 1997 to May 1998. EEA-UFRGS. Eldorado do Sul, RS. Source: Fucks (1999)

Plant Density trees/ha	Grazing by sheep		Average
	with	without	
	---------- cm ----------		
816	10.73^{Ba}	9.47^{Ab}	10.10^{B}
400	11.62^{Aa}	9.95^{Ab}	10.79^{A}
204	12.36^{Aa}	9.70^{Ab}	11.03^{A}
Average	11.57	9.71	10.64

Means followed by same capital letter within columns and by same small case letter within rows are not different (P>0.05) by the LSD test.

Table 7 - Eucalyptus plant height at three plant density (816, 400 and 204 trees/ha) in a 33 months old forest, under or without grazing by sheep, from December 1997 to May 1998. EEA-UFRGS. Eldorado do Sul, RS. Source: Fucks (1999).

Plant Density	Grazing by sheep		
trees/ha	with	without	Average
	---------- (m) ----------		
816	11.25^{Aa}	9.90^{Ab}	10.10^{A}
400	10.85^{Aa}	9.43^{Ab}	10.79^{B}
204	9.62^{Ba}	8.32^{Bb}	11.03^{C}
Average	10.57	9.22	9.89

Means followed by same capital letter within columns and by same small case letter within rows are not different (P>0.05) by the LSD test.

Table 8 - Steer ADG, gain/area and stocking rate on a black wattle forest and warm-season pastures grazed by sheep during 63 days in winter of 1998. Tupanciretã, RS. Source: Castilhos (1999).

PASTURES	REP	Plant Density / Spacing					
		1667 trees/ha (2 x 3 m)			1000 trees/ha (2 x 5 m)		
		kg/an/day	kg/ha	steer/ha	kg/an/day	kg/ha	steer/ha
P. maximum cv.	I	0.536	66	2.2	0.683	108	2.5
Gatton	II				0.571	42	2.6
B. brizantha cv.	I	0.750	33	1.6	0.560	38	2.4
Marandu	II				0.893	81	3.2

Table 9 - Average residual DM forage (RDMF), steer daily gain (ADG), gain/area (G/ha) and stocking rate (SR) on a black wattle forest and warm-season grass pasture grazed by sheep from November 13, 1998 to February 18, 1999. Tupanciretã, RS. Source: Castilhos (1999).

Pastures	Plant density / Spacing							
	1.666 trees/ha (2 x 3 m)				1.000 trees/ha (2 x 5 m)			
	RDMF kg/ha	ADG kg/steer/d	G/ha kg/ha	SR steer/ha	RDMF kg/ha	ADG kg/steer/d	G/ha kg/ha	SR steer/ha
P. maximum cv. Gatton	2,422[A2]	0.644 A	104	1.70	3,200A	0.696 A	169	2.55
B. brizantha *cv. Marandu*	1,720B	0.573AB	105	1.85	2,995A	0.690 A	195	1.85
E. plana	1,182B	0.539 AB	95	1.80	1,417B	0.417 B	122	3.25
Average[1]	1,775a	0.585a	101 a	1.78 a	2,537b	0.601a	162 b	2.55 b

1-Means followed by same small case letter in rows, between plant density, are not different (P>0.05) by Duncan's test.

2- Means followed by same capital letter on pasture x plant density interactions are not different (P>0.05) by Duncan's test.

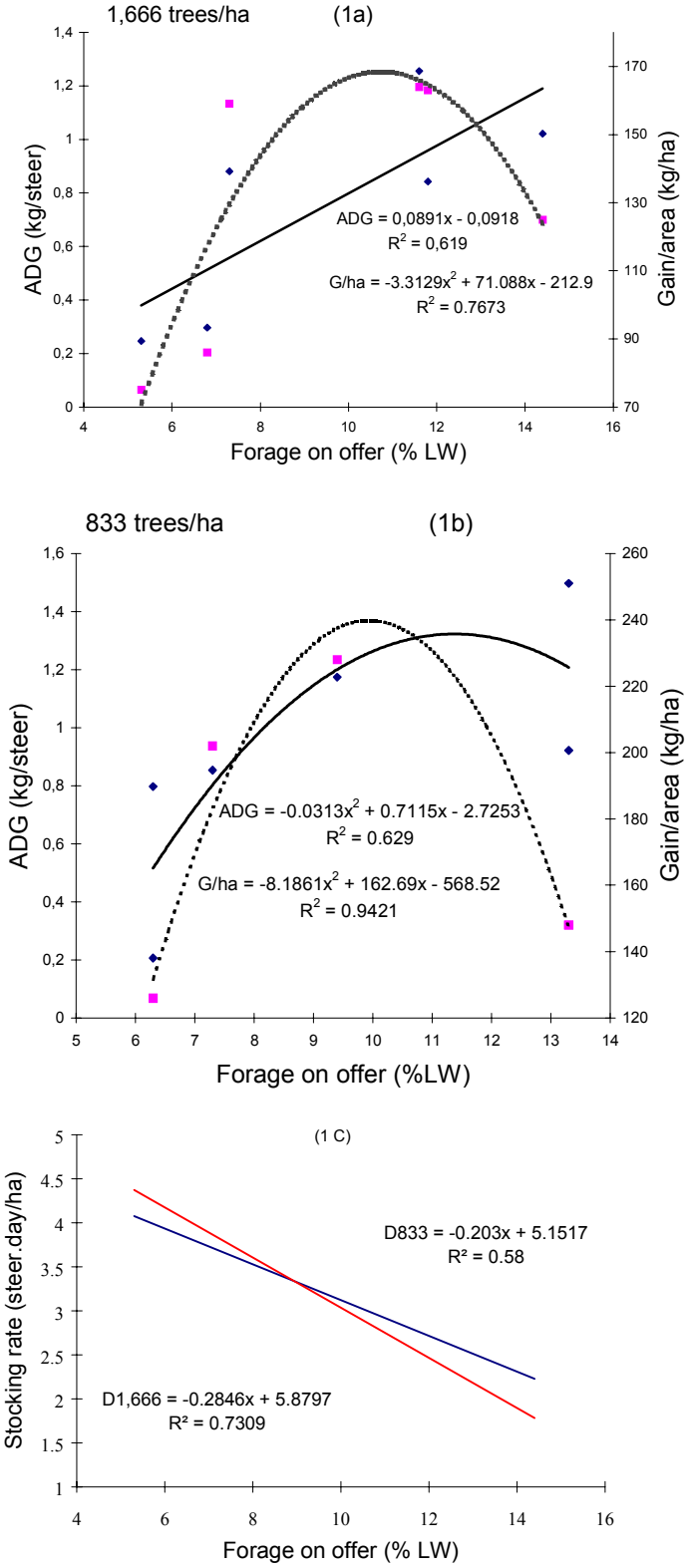

Figure 1 - Relationship between steer ADG (—), Gain/area (-----) and stocking rate with levels of forage on offer, at tree densities (1,666 and 833 trees/ha), on a ryegrass + 'Yuchi' arrowleaf clover pasture. September 6 to November 9, 1995. EEA/UFRGS. Eldorado do Sul, RS. Source: Silva (1998).

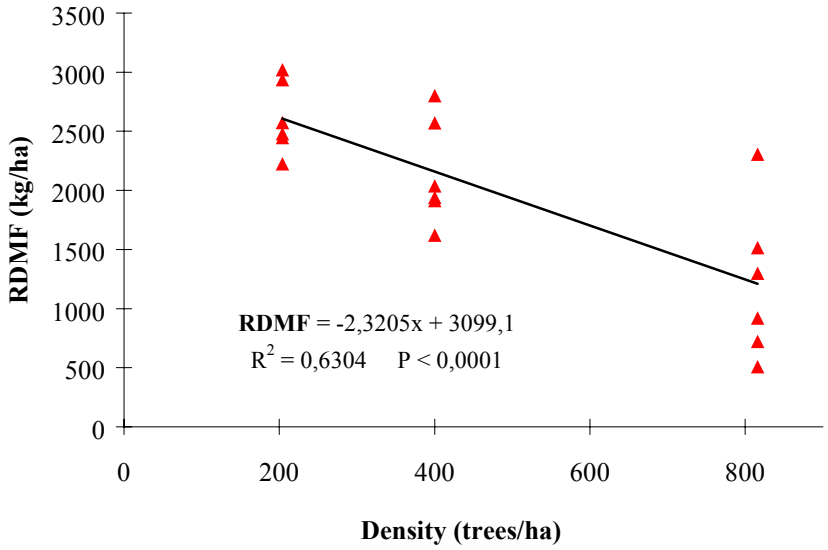

Figure 2 - Relationship between residual DM forage on a native pasture and *Eucalyptus saligna* tree densities of 816, 400 and 204 plants/ha on a silvopastoral system grazed by sheep. EEA-UFRGS. Eldorado do Sul, RS. Source: Fucks (1999).

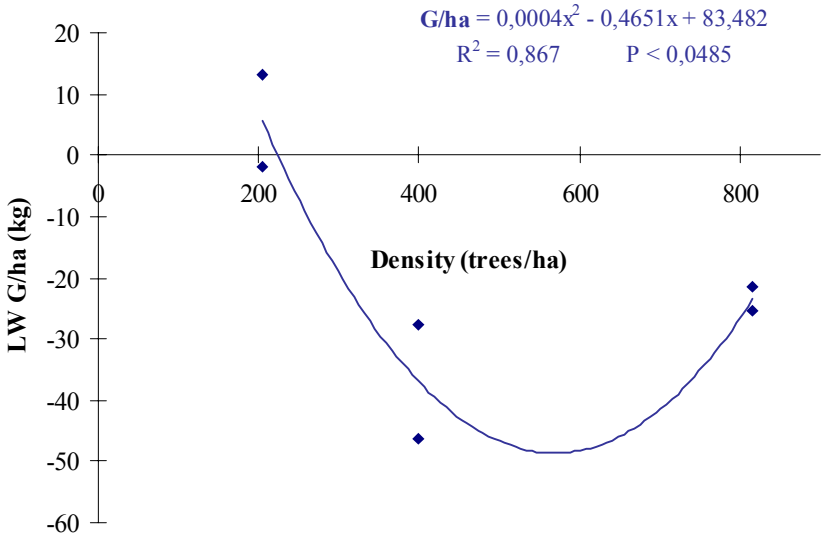

Figure 3 - Relationship of sheep gain/area and *Eucalyptus saligna* tree densities of 816, 400 e 204 plants/ha on a silvopastoral system, from December 24, 1997 to May 20, 1998 (148 days). EEA-UFRGS. Eldorado do Sul, RS. Source: Fucks (1999).