Capítulo 8

Oh trilhas de rumo errante
Onde pasta o manso gado
Riscando o verde pujante
Dos campos do meu cerrado

É lá do alto da serra
Daonde o sol pinta o mundo
E doa aos filhos da terra
Este lar rico e fecundo

Geovane Alves de Andrade

Agricultural Activities, Management and Conservation of Natural Resources of Central and South American Savannas

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Abstract

Neotropical savannas are diversified systems, especially those of the Brazilian Cerrado, with a vascular flora exceeding 7,000 species, 45 % of these being endemic, which makes it the richest tropical savanna in the world. This biodiversity is threatened by the expansion of the agricultural frontiers, and the invasive African grasses. The savanna's soils are fragile, have low fertility, and high Al toxicity; nevertheless, in the savannas only the subsistence agriculture and the extensive cattle rising on low quality native grasses were practiced; but there was a quick monocropping expansion, of grains and grasses, with improved agricultural methods, government subsidies, and strong investments in fertilizers and machinery, especially in Brazil and Venezuela. Savannas became the world's most productive agricultural frontiers. These systems showed productivity loss and soil degradation, due to inadequate farming techniques, giving way to soybean-corn rotation systems with minimum tillage but a high use of herbicides. Savanna-adapted species were selected: cereals, grains, forage, and crop/livestock-integrated systems with conservationist farming were implanted. The result was a soil improvement, higher meat and milk agricultural production, and a stabilization of the agricultural expansion. There is an agreement to deepen and popularize the results of the research. Governments and NGOs are taking actions to expand the protected areas, but the world food scarcity and the run towards biofuels could generate a new agricultural expansion.

Introduction

Tropical savannas are one of the most important biomes of the world, covering around 15 to 24 million Km^2 of land surface in South America, Africa, Asia and Australia. (SILVA; BATES, 2002; LÓPEZ-HERNÁNDEZ et al., 2005). Neotropical savannas are systems with a relatively important specific biodiversity, and a high ecological and life forms diversity (SARMIENTO; MONASTERIO, 1983; SARMIENTO, 1996; SILVA et al., 2006). The Brazilian Cerrado, for example, has a rich and generally unappreciated biodiversity, the number of vascular plants exceeds 7,000 species (KLINK; MACHADO, 2005), 45 % of the Cerrado flora is endemic, which makes it "the richest tropical savanna in the world" (KLINK; MACHADO, 2005). The Orinoco Plains are not as diverse as the Brazilian Cerrado. Riina et al. (2007) report the existence of 3,219 species of vascular plants for the Venezuelan Llanos, of which only 35 are endemic (1,1 %), and for the Colombian Orinoquia, Romero et al. (2008) report 2,692 species of plants. This biodiversity is threatened by the expansion of the agricultural frontiers, which has produced an intense fragmentation (SILVA et al., 2006); in the Cerrado, for example, pastures cultivated with African grasses cover at least 500,000 Km^2, and crops cover more than 100,000 Km^2. The area under conservation is roughly 33,000 Km^2 (KLINK; MACHADO, 2005), and the indications are that 20 % of endemics and threatened species remain outside of any protected area (MACHADO et al., 2004). On the other hand, the African grasses have invaded the savannas, notably reducing its biodiversity (FARIÑAS; SAN JOSÉ, 1985; PIVELLO et al., 1999). These aggressive non-native grasses have spread from cultivated pastures and for revegetated rangelands at alarming rates (WILLIAMS; BARUCH, 2000). In the present chapter the agricultural activities, management and conservation state of the Neotropical savannas are reviewed.

Characterization

Localization

The Neotropical savannas extend around 269 million of hectares with: 76 % in the Brazilian Cerrado, 11 % in the Llanos of Venezuela, 6 % in the Oriental Llanos of Colombia, 5 % in the savannas of Bolivia, 1.5 % in the savannas of Guyana, and smaller percentages in Central America and the Caribbean; they are also present in the French Guyana and in

Suriname (COCHRANE, 1990; RIPPSTEIN et al., 2001); other small savanna extensions are located as enclaves in the Amazonian, some valleys of Colombia and Venezuela (SARMIENTO, 1990). In Mexico savannas are developed at the largest in the southeast, and they also occur, much reduced in size, on the Pacific coast. In Mesoamerica, patches of pine savanna occur in SE Chiapas, Izabál and central Petén of Guatemala, and along the coasts of Belize, Eastern Honduras, and Eastern Nicaragua. These savannas are characterized by a tree stratum composed by *Pinus caribaea, Curatella americana,* and *Byrsonima crassifolia* (RIPPSTEIN et al., 2001; LAUGHLIN, 2002). In the Caribbean, sizable savannas are found in Cuba. Some of them are floristically similar to continental savannas, but many have a high degree of endemism due to different soil types, either siliceous or derived from serpentine (SARMIENTO, 1983).

Climate

Generally, the Neotropical savannas are macrothermic and thrive in seasonal weather areas, mainly under seasonal wet tropical climate: Köppen's type Aw, where dry and wet seasons are markedly contrasting. The mean precipitation fluctuates between 800 mm and 2,500 mm, with a variable dry period increasing as one getaway from the Andes (COCHRANE, 1990; GOEDERT, 1990; LÓPEZ-HERNÁNDEZ et al., 2005; HUBER, 2007). In South America the savannas come in contact with the Amazonian and the Chaco in Bolivia and in Paraguay, and they are continued in an almost uninterrupted form toward the south of the continent (SARMIENTO, 1983; VERA, 1999). In the southern limit of the American savannas (Cerrado), freezing temperatures can occur occasionally during the southern winter, not more than three days per year. In contrast, the Chaco, exclusively subtropical, can present up to 10 days per annum of freezing in their southern limit (SARMIENTO, 1990). The Neotropical savannas have their greatest development under precipitations not smaller than 1,000 mm, generally in the range 800-1,800 mm, which differs it from the African savannas which have a lower precipitation range (400-1,000 mm) (HUBER, 2007). According to Cochrane (1990) some authors include part of the semi-arid Caatinga as savanna vegetation. Cochrane (1990) and Sarmiento (1990) agree in pointing out the existence of savannas in the subtropical Chaco. In the present chapter we strictly focus on the Neotropical savannas, excluding other extra tropical biomes that have been considered as savannas by some authors based on its physiognomy (COCHRANE, 1990; SARMIENTO, 1990; ARCHER, 1990).

Savannas can be classified as seasonal, semi seasonal and hyper seasonal (SARMIENTO, 1990). In the seasonal savannas a dry and a rainy season alternate; in the latter one, short periods without rains, between 8 and 10 days, are intercalated (GOEDERT, 1990; LOPES et al., 1999; RODRÍGUEZ et al., 1999). This constitutes one of the biggest limitations for the agricultural production in systems without watering (LOPES et al., 1999). The dry season can last from two to six months (in exceptionally dry years it can last up to 8 months). In the hyper seasonal savannas, due to the floods, four seasons are observed: two humid seasons separated by a dry one and another per humid; and in the semi seasonal savannas a humid season alternates with another per humid (SARMIENTO, 1990).

Seasonal savannas, also called dry savannas, cover about 77 % of America's savannas; they have soils that are well drained and free from wet-season flooding and/ or water logging; however, it is known that most have minor inclusions of poorly drained soils (COCHRANE, 1990). Well drained savanna (Cerrado) covers central Brazil at altitudes ranging from about 200 to 1,200 m, on plateau surfaces of diverse age and geological origin, but with a high proportion of flat to relatively easy topography, which has facilitated the rapid expansion of agriculture. The same basic landscape extends across Eastern Bolivia at altitudes of approximately 400 to 800 m, and about 150-200 m in Northern Bolivia. There are extensive tracts of well-drained savanna lands in Eastern Colombia, mainly south of Meta River. Well-drained savannas of the Venezuela llanos, north of Orinoco River, are flat to gently rolling lands, suitable for agriculture expansion. Other low altitude well drained savannas cover a high proportion of the Boa Vista-Rupununi savannas to the north of Amazonian (COCHRANE, 1990).

Soils

The savannas soils are acid, highly meteorized, extremely poor, mainly Oxisols, Ultisols and Entisols, of variable texture, susceptible to degradation and compaction (LÓPEZ-HERNÁNDEZ; OJEDA, 1996; LOPES et al., 1999; RIPPSTEIN et al., 2001; RODRÍGUEZ et al., 1999; LÓPEZ-HERNÁNDEZ et al., 2005); they are categorized by Sarmiento (1990) as dystrophic and hyperdysthrophic. Their P total contents are very variable, and the P and N contents available for the plants are generally very low (GOEDERT, 1990; LÓPEZ-HERNÁNDEZ et al., 2005). These soils present limitations for the agricultural production, mainly due to their natural low fertility, and to the toxicity generated from the high Al saturation, toxicity that produces Aluminum-accumulating plants (HARIDASAN, 1987). The Al saturation combined with low Ca volumes limits the radicular growth (LOPES et al., 1999; RIPPSTEIN et al., 2001).

Traditional Management of the Savannas

Traditionally the savannas, in general, have been regarded as unsuitable for agriculture because of their harsh climate and poor soils (NEUFELDT et al., 1999), basically being reserved for the subsistence agriculture and the extensive cattle raising, with grazing on native plants of very low nutritional quality, combined with the use of fire to eliminate lignified parts of the grasses and to allow the re-sprout of more tender and palatable grasses as the only agricultural practice (FARIÑAS; SAN JOSÉ, 1987; TERGAS, 1987; LOPES et al., 1999; HERNÁNDEZ-VALENCIA; LÓPEZ-HERNÁNDEZ, 1999; LÓPEZ-HERNÁNDEZ et al., 2005). The savannas, due to their total surface area, constitute a land extension with great potential for agricultural or forestry use, constituting the main available agricultural frontier (GUIMARÃES et al., 1999; NEUFELDT et al., 1999; VERA, 1999; LÓPEZ-HERNÁNDEZ et al., 2005), mainly due to their gentle topography that allows the agricultural mechanization (RIPPSTEIN et al., 2001), which has resulted in the deforested area in Brazilian Cerrado being three times the deforested area in the Amazonians (KLINK; MACHADO, 2005), representing thus the biggest threat for the savanna biodiversity (KLINK; MACHADO, 2005; SILVA et al., 2006). The physical conditions of the savanna soils demand a careful use; however, in the nineties, the savannas, especially those of Cerrado, were conceived among the most productive agricultural frontiers in the world (NEUFELDT et al., 1999). For example, around 1999, more than 12 million ha were dedicated to annual cultivations, such as corn and soybean that requires a great deal of external supplies such as agrochemicals, energy and administration (VERA, 1999). The surface dedicated to the soybean culture, in the Cerrado, in 1994-95 extended to a total of 20 million hectares; similarly, a minimum of 30, and 50 million hectares have probably been transformed into pastures sowed as single-crop. Smaller surfaces have been planted with sugar cane and African palm, and some other trees (VERA, 1999). This huge expansion was accomplished by the introduction of improved agricultural methods, government subsidies, and heavy investments in fertilizer and machinery (NEUFELDT et al., 1999), especially in Venezuela and Brazil.

The traditional use of savanna was heavily influenced by the socioeconomic framework of particular countries; until the mid-1950s, the lack of communications or highways constrained any significant commercial development (SILVA et al., 2006). In Brazil, the foundation of the capital city of Brasilia, and in Venezuela the discovery of oil, led to the development of a network of roads and infrastructure. In Colombia, the situation contrasts markedly with that in the rapidly expanding agricultural frontiers of Brazil and Venezuela (COCHRANE, 1990; KLINK; MOREIRA, 2002).

The cultivated area in the Cerrado tripled from 10 millions ha in 1970 to 30 million ha in 1985, and was expected to be doubled in the year 2000 (NEUFELDT et al., 1999). The single-crops system in the Neotropical savannas was very productive and very profitable, while the governments subsidized it, which subsequently resulted in the introduction of machineries, liming, high dose of fertilizers, agrochemicals for the control of plagues and weeds, and the substitution of the native grasses by pastures of high nutritional value, mainly the African one. This technification was reflected in an improvement of production (LÓPEZ-HERNÁNDEZ; OJEDA, 1996; LOPES et al., 1999), but these systems began to deteriorate, and to show losses of productivity and problems of soil degradation, increment of plagues and diseases, decrease of the fertility, compaction and erosion of the soils, decrease of the micro-organisms activity, and a diminution of the OM % of up to 20 %, (LOPES et al., 1999; LÓPEZ-HERNÁNDEZ et al., 2005). Soil organic matter plays a key role in regulating both the physical and chemical properties of soils. Mummified organic matter is responsible for most soil fertility, because it provides most of the exchange sites and controls the formation of stable micro aggregates (THOMAS et al., 1999). Fire generates re-sprout with a high nitrogen and phosphorous content (MEDINA et al., 1978), but induces nitrogen, carbon, phosphorous and potassium loss (KLINK; SOLBRIG, 1996). Hernández-Valencia and López-Hernández (1999) report a phosphorous loss of 1.1 kg (ha^{-1}year^{-1}) by the dispersion of ashes in the atmosphere, which is not restored by the rain. Around 1999 pastures degraded to the extent that more than 50 % of the pastures sown in the Cerrados show problems of vigor loss, weed invasion and disease (AYARZA et al., 1999).

The Current Management of the Savannas

The cultivation systems with conventional tillage, lost profitability, and the single-crop systems gave way to soybean-corn rotation systems with minimum tillage and a high use of herbicides (LOPES et al., 1999). As a consequence of soil degradation, several agencies and national and international institutions, belonging to the Consultative Group for the International Agricultural Investigation, GCIAI, were devoted to detect and to select native species adapted to the savanna, to obtain germplasm of high genetic potential, and to carry out research on chemistry, physics and biology of the soils, in order to develop and to establish exploitation and cultivation of new methods, pointing toward contributing by means of the technology generation to the development of an agricultural sector being capable to maintain high levels of productivity, minimizing the environmental risks (VERA, 1999).

In Colombia, at the International Center of Tropical Agriculture, Ciat, in colaboration with the Colombian Corporation of Agricultural Investigation, Corpoica, and in Brazil, at the Brazilian Company of Agricultural Research, Embrapa, different varieties of unirrigated land rice were obtained, tolerant to Al and with high production potential, some like Oryzica Savanna 6 and Oryzica Savanna 10 tolerate up to 90 % Al saturation. Soybean, Sorghum and Corn varieties were also obtained with different grades of tolerance to Al, Table 1 (VALENCIA; LEAL, 1999). Some corn cultivars came from the International Center of Improvement of Corn and Wheat, Cimmyt, of Mexico; this germplasm presents Citric acid exudation by the roots as part of the tolerance mechanism to the acidity (NARRO et al., 1999).

Table 1. Cultivars for acid soils developed at Colombia. From Valencia & Leal (1999).

Cultivar	Variety	Al tolerance	Agreement	Year
Rice	Oryzica sabana 6	90 %	ICA-Ciat	1991
Rice	Oryzica sabana 10	90 %	ICA-Corpoica-Ciat	1995
Soybean	Soyica altillanura2	70 %	ICA-Corpoica-FAA	1994
Sorghum	Sorghica Real 40	40 %	ICA-Intsormil	1991
	Sorghica Real 60	60 %	ICA-Intsormil	1991
	Icaravan 1	40 %	ICA-Intsormil-Alcaravan 1993	
Corn	SikuaniV-110	55 %	ICA-Corpoica-Cimmyt	1994

In Venezuela, the National Fund of Agriculture and Cattle Research, Fonaiap (INIA today), established, in 1992 the plan “Research Program on Management of Savannas”, in the oriental Llanos, in order to evaluate this ecosystem, and to generate technologies for their exploitation, based on the environment preservation and the rational use of supplies. At the zone there were cultivated pastures of different *Brachiaria* species, grasses and leguminous associations with: swazi pasture (*Digitaria swazilandensis*), which are evaluated at the moment in associations with adapted leguminous, like: *Centrosema macrocarpum* CIAT 5713, 5735, *Centrosema brasilianun* CIAT 5657, *Leucaena leucocephala* CIAT 17492 and *Stylosanthes capitata* CIAT 10280, showing good compatibility and persistence (RODRIGUÉZ et al., 1995). At the present time the INIA Anzoátegui has a Bank of germplasm of evaluated forager species, enriched with species coming from the Ciat, Embrapa and the CIRAD (Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement).

Another result from the cooperation between agencies and countries was the achieving of forager leguminous, also tolerant to the soil acidity, especially *Stylosanthes capitata* (Capica), and *S. guianansis* cv. Mineirão (Estilosantes), *Centrosema acutifolia* (Centrosema Vichada) and *Arachis pintoi* (Arachis, Perennial forage Peanut). New production systems were tested with the varieties obtained; in Colombia, two systems were organized, one starting from dry-farmed rice intended to establish gramineous-leguminous enhanced pastures in native savanna, and another one using a dry-farmed rice cultivation and a component of leguminous to recover degraded pastures; in both cases, high yields of rice and dry matter have been obtained (SANZ et al., 1999). In Brazil, producers are using several integration systems, with different variants; one of them is the Barreirão system, consisting of associating cultivations like rice, corn, sorghum and *Pennisetum typhoides* with foragers, mainly of the genus *Brachiaria* and *Andropogon*, and leguminous like *Stylosanthes*, *Calopogonium* or *Arachis* (KLUTHCOUSKI et al., 1999; LOPES et al., 1999); similarly in Venezuela these new management techniques have been used mainly with systems of low supplies (LÓPEZ-HERNÁNDEZ; OJEDA, 1996; MATA et al., 1996).

In Central America, new forage technologies have also been developed to increase livestock productivity. Ciat has distributed 11 selected grasses, mostly from *Brachiaria* genus, to be used as commercial cultivar, and another 16 legume cultivars were also distributed. When *Brachiaria* grasses were compared with local species in on-farm experiments, they showed superior biomass production, leading to higher milk production. Furthermore, Ciat developed technologies to increase feed availability and quality throughout dry season, including forage legumes like *Lablab purpureus, Vigna ungiculata*, and *Canavalia brasilensis*. For the first time in the history of Nicaragua, a forage species was officially released as a cultivar in June 2006. *Cratylia argentea* was launched as “Inta Cratylia”, as a joint effort of Instituto Nicaraguense de Tecnología Agropecuaria, Inta, and Ciat’s Tropical Grasses and Legumes Project. Annual, drought-tolerant, multipurpose, legume germplasm is already in the pre-release stage to be launched in 2008 (HESSE, 2007).

A significant advance toward a more sustainable agriculture in the savannas was the adoption of the conservationist farm systems (LÓPEZ-HERNÁNDEZ ; OJEDA, 1996), that is, minimum tillage and zero-tillage; those systems, according to Hernández-Hernández and López-Hernández (2002), create conditions that allow for a functioning of the soil very close to that of the natural savanna, since in both cases the compartments of the organic matter that conserve N and C are favored in the short-term, and the erosion is minimized by the stability of the aggregates. In Venezuela these systems have been used for several years in the sow of corn, and it is estimated that between 1995 and 1997 there was an increment of 78 % in the savanna area sowed under conservationist farming (HERNÁNDEZ-HERNÁNDEZ; LÓPEZ-HERNÁNDEZ, 2002). In 1980 it was calculated that in the Cerrado there were 150,000 ha under this sow system, and in 1990 there were a million ha, and ten years later it was calculated that they would have 10 million ha. There are several modalities of zero-tillage and minimum tillage cultivations, for example: zero-tillage on residuals, zero-tillage without covering cultivation, zero-tillage on living covering, minimum tillage, zero-tillage and minimum-tillage in annual cultivations simultaneously under watering, zero-tillage and conventional tillage, intermittent zero-tillage. With the minimum tillage a minimum removal of the covering occurs, leaving most of the residuals on the soil; on the other hand, in the case of zero-tillage, the idea is to sow the main cultivation without eliminating the residuals of the previous cultivation, or without eliminating the weeds that serve as living covering, or to use as covering leguminous alive like *Glycine javanica* (perennial soybean), *Pueraria phaseoloides* (Kudzú), *Centrosema* spp., *Stylosanthes guyanensis* or *Arachis pintoi,* to afterwards sowing corn or rice.

A highly successful strategy to intensify agricultural production in a sustainable way and resolve problems of degradation involves the integration of crop/livestock system in time and space (agro pastoralism). The strategy is based on the assumption that a beneficial synergistic effect on productivity and on soil occurs when annual and perennial species are combined: available nutrients are used more efficiently and chemical, physical and biological properties of the soil are improved (AYARZA et al., 1999). Since 1992, Ciat and Embrapa Cerrados have worked together with other institutions to develop agro pastoral systems that are based on forage legume adapted to low and high input, and to quantify their impact on productivity and on soil. The project focused on legumes with potential to adapt to grassing system of low inputs and to cropping systems of high inputs, and as components of rotations and permanent ground covers. The experiment design includes a comparison between a crop + grass-only pasture system and a crop + grass pasture + legume cocktail (AYARZA et al., 1999). Results showed that Estilosantes was efficient in the low-supply systems, with poorer soils, keeping enough green biomass during the dry season, while Arachis adapted better to richer soils, high-input systems, crop rotation, or as a permanent ground cover in direct sowing. However, chemical or mechanical methods were needed to control the competitiveness of Arachis with crops. The results of a crop/livestock case study confirmed the synergistic effect on production and soil quality. Soil fertility increased during the cropping cycle, whereas soil aggregation and soil organic matter increased during the pasture phase. After 3 years under pastures, animal production in the low-input system with legumes was higher than that under crop/pasture without legumes, Table 2 (AYARZA et al., 1999). Other advantages of the agro pastoral system are: the increase of the biological activity, a more efficient recycling of nutrients, bigger food availability for the livestock in the dry season, better use of water and nutrients, lesser invasion of weeds, an economically more solid system (LOPES et al., 1999) and possibly an enrichment of C in the soil (FISHER et al., 2002).

Table 2. Animal weight gain under different culture combination at Uberlandia Brazilian Cerrado. Modified after Ayarza et al. (1999).

Production system	Imput	Soil type	Combination	Animal production (Kg/ha year)	Weight gain %
Pasture	Low	Sandy	Culture + grass	160	-
Pasture	Low	Sandy	Culture + grass + legume	254	58 %
Pasture	Low	Clayed	Culture + grass	230	-
Pasture	Low	Clayed	Culture + grass + legume	354	54 %
Culture	High	Sandy	Culture + grass	236	-
Culture	High	Sandy	Culture + grass + legume	267	10 %

In the dry savannas of Bolivia a different orientation was carried out. According to Martínez (1999), some farmers are integrating crops like rice or corn with pastures, but the Tropical Agricultural Investigation Center (Ciat/SC) has not carried out research work in agro pastoral systems, but it is advancing, together with the British Mission of Tropical Agriculture (MBAT) in research on agro-silvo-pastoral systems. Among the utilized trees are: *Leucaena leucocephala*, *Flemingia congesta*, *Swietenia macrophylla* or *Schizolobium amazon*; and among pastures *Brachiaria decumbens*, *B. brizantha* or another gramineous. On the other hand, leguminous trees are being implanted in established grasslands, mainly: *Erythrina fusca*, *Samanea tubulosa* and *Prosopis* sp. These systems are still in experimental phase (MARTÍNEZ, 1999).

In some countries, forest cultivations have been implanted to obtain wood and paper pulp, especially *Pinus caribea* and different species of Eucaliptus, or to obtain oil. In Venezuela, the oriental savannas were used for planting trees, on sandy soils, since the hydric limitation for the cultivations did not affect the pines or the eucalyptus. However, the productivity was not the expected one (LÓPEZ-HERNÁNDEZ; OJEDA, 1996). Results from eucalyptus and pine forestation are not directly comparable. Pine forestation results in an accumulation of a thick organic layer and the beginning of podsolization in a relatively short time. As a result of impeded incorporation of litter, and because the mineralization process continues, Particulate Organic Matter is lost. In contrast, under eucalyptus the litter is rapidly incorporated and organic carbon content even increases as a result of the higher litter fall, compared with natural savanna (THOMAS et al., 1999).

Regarding the conservation state of the savannas we cannot be optimistic; fortunately, the widespread transformation of the Cerrado landscapes and the threatened status of many of their species have led to an upsurge in conservation initiatives from government, nongovernmental organizations (NGOs), researchers, and the private sector. A network of NGOs (Rede Cerrado) has been established to promote sustainable-use practices for natural resources at the local level. In 2003 the network gave the Brazilian Ministry of the Environment a series of recommendations about an urgent action for the conservation of the Cerrado, and the ministry established a working group that in 2004 produced the program: Programa Cerrado Sustentável, taking in consideration the results and the resolutions of the Cerrado priority-setting workshop held in 1998, and integrating actions for conservation in regions where agro pastoral activities have been specially intense, damaging and widespread. Some state governments such as that of Goiás, organizations like Conservation International, the World Wide Fund for Nature, The Nature Conservancy, all have conservation programs in the Cerrado (KLINK; MACHADO, 2005).

Some problems that we cannot predict are the invasion of African grasses, the growing alimentary crisis and interest for the biofuels that could generate a new agricultural expansion or a substitution of cultivations, policy changes in some countries encouraging the dismemberment of properties, the abandonment of exploitations and experimental stations, and the increment of violence in the rural areas.

Final Considerations

The Neotropical savannas hold high potential for the sustainable production, but, to reach this objective it is necessary to develop appropriate systems for the soil management (GUIMARÃES et al., 1999). One of the ways of approaching sustainability is to substitute the monocultures for associated cultivations, and to perform the integration of agriculture and cattle raising (agro-pastoralism), either by extending functions in the respective properties, or through the association between the two landowner types, since the recovery of pastures, foragers association, leguminous and the livestock introduction is required, but equally it is necessary to implement annual cultivations, and correct acidity, to preserve the contents and to improve the quality of the organic matter, to protect the soil against the erosion and give to the plants appropriate and balanced dosage of nutrients. The use of fertilizers under the required amount and the unbalance of nutriments in the soil result in low yields (KLUTHCOUSKI et al., 1999). In the last few years, investigation has allowed for the creation of technologies for the recovery and renovation of pastures that are applied in specific cases, according to the preferences, the socioeconomic conditions, and the aptitude of the producer. The technological offer for the livestock farmers ranges from technologies of direct recovery to the rotation agriculture-cattle rising; by 1998 the cost of the recovery varied among US$ 86 and US$ 499 per ha (KLUTHCOUSKI et al., 1999), which limits the possible uses of those technologies. “The research must pay greater attention to seek the solutions for the small agricultural systems” (LOPES et al., 1999).

The perennial cultivations occupy a smaller space in comparison to the cultivations of grains and enhanced pastures. However, some cultivation like rubber, fruit-bearing trees, forest plantations with pine, eucalyptus and other species, and plantations of coffee in the specific case of the Cerrado, constitute successful experiences (LOPES et al., 1999). Tree plantations are apparently very efficient in maintaining fertilizer P available to plants, whereas crop and pastures need regular P amendments to keep availablility of P high (THOMAS et al., 1999).

According to Amézquita et al. (1999) the construction of an “arable layer” should be the main objective of the management of tropical soils, once an arable, consistent and productive layer is obtained; it is possible to perform on it a sustainable agriculture. The research on farming, that is carried out by different agencies, is oriented toward the creation of that arable layer, defined as a superficial layer of 0 to 30 cm in depth (depending on the cultivation) that does not present physical, chemical, or biological limitations for the cultivations. With this strategy, the use of agro-pastoral and agro-silvo-pastoral systems is fundamental, since the roots of the plants are the only ones capable to maintain a favorable physical condition created by the corrective farming and to lead the soil toward a physical, chemical and biological sustainability. Once the arable layer is created, the soils should be converted to zero-tillage or minimum-tillage conservationist systems (GUIMARÃES et al., 1999) to tend toward sustainability. A sustainable agriculture means, among other things, that not significant amounts of pesticides should accumulate in the soil or to contaminate the superficial or the underground hydric resources (LAABS et al., 1999). It is necessary to better quantify the environmental impact of these systems, mainly regarding the effect of the biocides (LOPES et al., 1999; NEUFELDT et al., 1999). Laabs et al. (1999) report to have found biocides residues at average concentrations in the soils, and at low concentrations in the water and sediments, they also found antrazine and simazine residues inside the soil.

The agro-pastoral and agro-silvo-pastoral systems visibly improve the soil chemically, physically and biologically, due to the synergistic effect of the association of annual and perennial cultivations, but they still require the use of fertilizers, herbicides and pesticides, because that is necessary to continue investigating and improving the production systems, as well as selecting and developing new germplasm aimed at reducing to a minimum the input of supplies to the agro ecosystem. The sustainability of a system begins by the deep knowledge of the components that integrate it. It is necessary to know the regimen and volume of the precipitations, the components of the soil, particularly the organic matter, the phosphorous and the nitrogen, and the environmental tolerances of the cultivated varieties. The sustainability of the soils must be monitored through sustainability or degradation indicators indexes, that must be build, for this reason it is necessary to emphasize in the prerequisite of design research leading to the development of nondestructive methods for the monitoring and the sustainable management of the soils (AMÉZQUITA et al., 1999). These indicators should be easy to understand and to by handled by the producers. The research should be undertaken at different levels, from greenhouse level, through the parcel level, to property level, and in a parallel way to enrich the research with Simulation Models, it should be, also, multidisciplinary, cross-institutional and of long term (VERA, 1999), and should be broadly communicated to landowners. It is necessary that the new technologies and management options are supported by appropriate environmental policies that assure their adoption and success, "it is necessary to have a bigger effort of the scientific community to dialogue with the farmers, extensionists and authorities" (LOPES et al., 1999).

Among the topics with very little investigation are the soil microorganisms. They are responsible for the physical and chemical states improvement of the soils, and of the cultivations nutrition (VALENCIA et al., 1999), and it seems that the radius (C microbial / organic C) could be a sustainability indicator, but there is not enough information (NEUFELDT et al., 1999). On the other hand, the endotrophic vesicular-arbuscular mycorrhizae, VAM, are fungi whose hiphaes enter in symbiosis with the roots of many of the species of superior plants, creating a profit mainly in its mineral nutrition with not very mobile nutriments such as P, Zn, S, Ca, Mo and Br (VALENCIA et al., 1999), since they exploit large soil volumes and exert an important influence in the structure of the communities (HARNETT; WILSON, 2002). In the degraded pastures termites are treated as plagues that are fed by the forager grasses, and the termite mound considered as obstacles that interfere in farming. For this reason they are attacked with pesticides and the termite mound destroyed mechanically (NEUFELDT et al., 1999); however, it is known that the termite mound is richer in nutriments than the soils of the savannas. A study in the Cerrado showed that, in loamy soils, the termite mound had 109 g/Kg of Carbon against 26 g/Kg in the soil, and they had three times more N that the surrounding soil (ZECH et al., 1999). Evidently, termites and termite mound would require more research. It would be necessary to quantify termite-induced changes in Soil Organic Matter stocks and nutrients at the field and landscape levels to evaluate their influence on the ecosystem (THOMAS et al., 1999).

It would be desirable to continue the search for adapted and more productive germplasm, to adjust the sustainable management of the soils, to accentuate and to disclose the investigation. To increase the areas somehow protected, as it is being performed in the Brazilian Cerrado.

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