



Universidade de Brasília
Departamento de Economia

Série Textos para Discussão

**Expansion and modernization of agriculture
in the *Cerrado* – the case of soybeans in
Brazil's Center-West**

Charles Curt Mueller
Universidade de Brasília

Texto nº 306
Brasília, novembro de 2003

Department of Economics Working Paper 306
University of Brasilia, November 2003

**UNIVERSIDADE DE BRASÍLIA
DEPARTAMENTO DE ECONOMIA**

TEXTO PARA DISCUSSÃO Nº 306

**Expansion and modernization of agriculture in the Cerrado –
the case of soybeans in Brazil's Center-West**

Charles Curt. Mueller
Universidade de Brasília

Brasília, 07 de novembro de 2003

© Charles Curt Mueller, 2003

UNIVERSIDADE DE BRASÍLIA
DEPARTAMENTO DE ECONOMIA
Campus Universitário Darcy Ribeiro
Instituto Central de Ciências
Caixa Postal 04302, 70910-900 Brasília, DF, Brasil
Tel.: (55-61) 3072498, 2723548
Fax: (55-61) 3402311
E-mail: econ@unb.br
<http://www.unb.br/ih/eco>

Chefe do Departamento
Prof. Jorge Madeira Nogueira

Sub-Chefe do Departamento
Prof. Rodrigo Peñaloza

Coordenador de Pós-Graduação
Prof. Roberto Ellery Jr

Coordenador de Pesquisa e Extensão
Prof. Maurício Soares Bugarin

Coordenadora de Graduação
Profª. Maria Eduarda Tannuri-Pianto

SÉRIE DE TEXTOS PARA DISCUSSÃO

Comissão Editorial, mandato de abril de 2003 a março de 2005

Bernardo Mueller

Charles Mueller (editor)

Jorge Nogueira

José Roberto Novaes

Maurício Bugarin (editor)

Mauro Boianovsky

Paulo César Coutinho

Roberto Ellery Jr.

Rodrigo Peñaloza

Milene Takasago (representante dos alunos de pós-graduação)

Expansion and modernization of agriculture in the *Cerrado* – the case of soybeans in Brazil's Center-West

Charles C. Mueller
Departamento de Economia – Universidade de Brasília
(cmueller@unb.br)

This paper examines the expansion and the recent modernization of agriculture in Brazil's Cerrado region – one of the country's more important biomes, but one that has been subjected to intense human intervention, with negative environmental impacts. The conceptual framework employed is based on Sawyer's concept of *agricultural frontier* (Sawyer, 1983). Instead of viewing the latter as a line separating areas in agricultural activities from unoccupied space, the author considers the frontier a *space* with *potential* for the development of agricultural (and related) activities. And three elements are fundamental in determining this *potential space*: (a) the functioning of markets – of products, of labor, of land, of inputs; (b) the existence of a transportation system reaching the area; and (c) the availability of land to be occupied. Moreover, changes in these elements tend to induce alterations in the *potential space* of the frontier; and since the role of the public sector in inducing these changes can be substantial, public policies should also be emphasized.

What determines the realization of the frontier's potential? In Brazil, several elements have interfered in this: the rapid growth in the demand for food and agricultural commodities; the expulsion of peasants and farm workers brought about by technical change and by land tenure rigidities in the established agricultural areas¹; the demand for cheap land for speculative purposes; and, with an important role, both in the Amazon and in the *Cerrado*, public policy. These and other factors have originated movements, *within* the potential space of the frontier, of *activity fronts*.

Agricultural fronts expand and contract inside the frontier's potential space, in response to changes in the fundamental driving elements in each case. These elements include the main markets relevant to the front, the infrastructure, especially of transportation, in the frontier, and the availability of land to be incorporated into the activity by the front's leading agents. And these elements may considerably be affected by public policy.

¹ Such expulsion occurred in Brazil's center-south, as a result of a process of conservative modernization. See Martine, 1990.

Two or more fronts may coincide in time and in space – that is still the case with subsistence and speculative fronts in parts of the Amazon (see below). And two fronts may coincide in space and follow the other in time; this occurred in parts of Brazil's center-south where subsistence fronts occupied and cleared land originally in Atlantic forests, but later gave way to commercial agriculture fronts. In other words, movements of activity fronts in the potential space of the frontier usually involve a dynamic and multifaceted process.

For Brazil, we identify several agricultural related activity fronts which, over the second half of last century, evolved within the potential space of the frontier. The main are:

(a) *Traditional commercial agriculture front*. The rapid growth of the demand for agricultural product during the import substitution industrialization phase of the 1950's was, to a large extent met thanks to the horizontal expansion of a traditional, low yield, agriculture in the then potential space of the frontier. The main policy affecting this was road building; other policies were almost absent in the period, and the increase in agricultural production took place mainly through the incorporation of new agricultural lands in the frontier, then located to the south of the *Cerrado*, in the country's center-south. More recently the agriculture of these areas became modernized, and today they constitute the core of a high productivity segment of Brazil's agriculture.

(b) Peasant or *subsistence agriculture fronts*, molded by the country's demographic dynamics and – as a result of the modernization of commercial agriculture –, by the expulsion of farm workers from established agricultural areas. Brazil offers several examples of such fronts, but one of the more expressive is that of the hundreds of thousands of displaced workers which, over the 1970s and 1980s flowed into the *potential space* of parts of the Amazon region. (Mueller, 1983, 1995; Martine, 1990). The main driving force of the small settlers in the frontier is, at least in the short run, production for subsistence although, as argued below, their long run goal may entail speculative motives (see Romero, 1999).

(c) *Speculative fronts*, involving the search for land, usually by large operators, not primarily for production but for speculative gains. Again, the Amazon provides an instance of movements of this type of fronts. In the 1970s and 1980s the region saw the development of many large agricultural projects, the main objective of which was speculative. Most failed in generating marketable production, but they were implemented in order to benefit,

both from fiscal incentives and to reap speculative gains stemming from real increases in the price of land (Mueller, 1983).

Here we stress, again, the motivations of the small settlers in the Amazon; many occupied and cleared land there also aiming at long run speculative gains (see section 5).

(d) *Traditional cattle ranching* fronts. We can find examples of these in various parts of the country and in different historical periods. They have usually affected more remote areas, since the main product of the traditional cattle ranches – beef cattle to be finished closer to markets – is self-transporting, requiring minimal infrastructure. Obviously, elements of speculation have also interfered in the movements of these fronts.

(e) Especially relevant for the recent agricultural boom in the *Cerrado*, ***modern commercial agriculture fronts***. The movements of these activity fronts differ markedly from those of the *traditional commercial agriculture fronts* of the 1950s and 1960s, outlined above. As a matter of fact, the latter activity fronts stopped moving northwards in the late 1960s, when they reached the *Cerrado*; the main reason for this was the incompatibility of the production technologies of traditional agriculture to most of the savanna ecosystems. It took a while before commercial agriculture was able to penetrate the region; this required the development of technologies and of varieties of plants adapted to the *Cerrado*. But when, in the late 1970s, these elements were in place, the expansion of *modern commercial agriculture fronts* began to occur there, at a growing pace.

The paper analyses the spatial pattern of expansion in the *Cerrado* of one of the more dynamic component of the region's *modern commercial agriculture front* – the ***soybean front***. Next section describes briefly the *Cerrado*; section 2 outlines aspects of the region's recent agricultural expansion; section 3 discusses, in very broad terms, the sustainability of agriculture in the *Cerrado*; section 4 analyses the spatial pattern of expansion of the soybean front in Brazil's center-west savannas up to the year 2001; section 5 examines events regarding the soybean front, emphasizing its impacts on the Amazon; and section 6 presents concluding comments.

1. Background – the Cerrado region.

Brazil's *Cerrado* region comprises a large and heterogeneous tropical savanna – its core occupies more than 2 million hectares, nearly 20% of the area of Brazil. To its north lays the Amazon complex; its western portion has boundaries with Bolivia and Paraguay; in

its southwest is the Pantanal habitat; to the south is Brazil's southeast geographical region; and to the east of the *Cerrado* we find mostly the semi-arid region of Brazil's Northeast.

The region's natural vegetation is composed mainly of grasses mixed with shrubs and scattered trees, in different combinations. Its soils are ancient, deep and well drained, but they are also acid and have low natural fertility (Dias, 1992). The human occupation of the *Cerrado* goes back almost to Brazil's colonial period but, as indicated above, a more intensive agriculture began to take place there only in the 1970s, as a result of policies to induce the development of the region (Mueller, 1990). The activities stressed by these policies were 'modern' agriculture, together with a more intensive and productive cattle rising. It is worth noting that these two types of activities require space. Consequently, the three last decades of the XX century saw widespread land clearing in parts of the region, with worrying environmental impacts.

2. *Aspects of the recent agricultural expansion in the Cerrado*

Data on Table 1 gives an idea of the spatial dimension of the agricultural expansion in the *Cerrado* between 1975 – when the modern agriculture began to evolve there – and 1996, the date of the last agricultural census. We observe that, in 1975, the area in agricultural establishments in the *Cerrado* – exceeding 110 million hectares, or around 57,4 % of the region's geographical area – was already substantial. However, then there still was a wide margin for the expansion of land-using activities within the existing farms; in 1975 only 31,3 % of the total area in agricultural establishments had been cleared.² Regarding the main land-using activities in 1975, more than 16 million hectares were in planted pastures, and almost 6,8 million hectares were in crops (in 1975 the area in soybeans was insignificant).

Between 1975 and 1996 the total area in agricultural establishments increased only moderately, from 110.8 to 124.3 million hectares (in the period the annual rate of growth was only 0.5 %), but the area cleared in farms almost doubled, from 34.7 to 64.5 million hectares. The main element in this was the expansion of planted pastures, which increased from 16.0 to 49.2 million hectares between 1975 and 1996. The formation of pastures for beef cattle has long been a traditional mode of land use in the region. As for the areas in crops, however, they increased only from 6.9 to 8.2 million hectares in the period.

² As can be seen in Table 1, the area cleared was defined to include: land in crops, in planted pastures, in planted forests, in fallow and cleared lands which, for some reason, were not used in the census year.

At a first glance, the data in Table 1 seem to indicate that beef cattle production was the main element prompting the recent occupation of land for agriculture in the *Cerrado*. However, although the area in crops has not increased spectacularly, the dynamics of land clearing was significantly affected by the behavior of the region's agricultural crop sector. Crop production is a much more intensive activity, and recently its profitability has been substantial, prompting, not so much the incorporation of land in farms, but the intensification of land clearing within existing farms. Traditionally, pastures are planted in areas which were first used for agricultural crops.

Table 1. The Nucleus of the Cerrado: Area in Agricultural Establishments, Area of Establishments Cleared, and the Main Types of Land Use, 1975 and 1996.

AREA IN AGRICULTURAL ESTABLISHMENTS, BY CATEGORIES OF USE	1975 (HECTARES)	1996 (HECTARES)	ANNUAL RATE OF GROWTH 1975-96 (%)
Area in agricultural establishments	110,797,993	124,313,799	0.5
Area Cleared in Establishments	34,694,561	64,487,055	3.0
<i>Land in Crops</i>	<i>6,888,825</i>	<i>8,208,268</i>	<i>0.8</i>
<i>Land in Planted Pastures</i>	<i>16,053,490</i>	<i>49,206,510</i>	<i>5.3</i>
<i>Land in Cultivated Forests</i>	<i>586,207</i>	<i>757,179</i>	<i>1.2</i>
<i>Land in Fallow</i>	<i>355,583</i>	<i>1,671,446</i>	<i>7.4</i>
<i>Land Cleared but not Used</i>	<i>10,818,456</i>	<i>4,642,652</i>	<i>-9,0</i>
Proportion of the Region's Geographical Area in Agricultural Establishments	57.4	64.4	-
Proportion of the Area in Establishments Cleared for Agriculture	31.3	51.9	-
Proportion of the Region's Geographical Area in Establishments	18.0	33.4	-

Source: IBGE, Censo Agropecuário de 1975; e Censo Agropecuário de 1995/96.

An additional look at the recent expansion of agricultural crops in the *Cerrado* is in order. Table 2 has information on the area in the region's main crops in 1990 and in 2000. We see that the combined area of the six main crops listed there increased, from 7,4 to 10,4 million hectares in the period, at an annual rate of growth of 3,4 % – a much higher rate than that which one might infer examining the data on land in crops of Table 1, for the period

between 1975 and 1996. In part this reflects problems of sub-enumeration of the 1995/96 census, but there is no doubt that the vegetable crop sector grew very rapidly in the last decade.

Note the substantial increases in yields of the 1990s. Data in Table 2 indicate that agriculture in the Cerrado is both, expanding horizontally, and becoming more productive. The general increase in yields reflects the technological development of the region's agriculture in the period. For various crops the 2000 yields were above the national average; and for soybeans the yields in parts of the *Cerrado* (especially those for the state of Mato Grosso) were among the world's highest.

Table 2. The Core of the Cerrado: Harvested Area, Production and Yield of the Main Crops – 1990 and 2000.

CROPS	AREA HARVESTED (1000 HECTARES)		PRODUCTION (1000 TONS)		YIELD (KG/HA)	
	1990	2000	1990	2000	1990	2000
	Beans	368.4	289.6	265.2	486.8	720
Cotton	111.2	456.2	168.7	1560.8	1517	3421
Coffee	243.5	194.5	324.0	376.1	1330	1934
Maize (corn)	1740.9	2220.0	3621.4	8742.1	2080	3938
Rice	968.2	1014.2	957.2	2642.1	989	2605
Soybeans	4015.9	6266.6	6297.7	17609.4	1568	2810
Total of the area	7448.1	10441.1				

Source: IBGE, *Produção Agrícola Municipal*, 1990 and 2000.

The other important segment in the Cerrado agriculture is the beef cattle industry; it also had a remarkable expansion over the last quarter of the 20th century. As indicated, the area with planted pastures increased substantially, reaching 49.2 million ha in 1996; region's cattle herd totaled 47.8 million in that year. This segment of the region's agriculture has also experienced modernization, but semi-extensive cattle raising still prevails in the region's more remote areas – the areas of *traditional cattle ranching fronts*.

An important point regarding the Cerrado's beef cattle sector is that a large portion of its substantial stock of planted pastures is, to some extent, degraded. Together with other areas already opened and, for some reason, also degraded, there is a considerable stock of underutilized land. With appropriate technology and well conceived incentive

programs it would be possible to induce their conversion into more intensive and productive farming and cattle raising activities. And an important spin-off of such a conversion is that it would reduce the need to incorporate virgin lands in the frontier, preventing, to some extent the destruction of habitats and the loss of biodiversity.

The positive socioeconomic impacts associated with the expansion and modernization of farming and cattle ranching in the *Cerrado* are not negligible. The more obvious of such impacts are in terms of the contribution to Brazil's supply of agricultural products both, for domestic use and for exports; and, direct and indirectly, to the generation of income. And there are also favorable – although selective – impacts inside the region. According to Bonelli (2001), the economic activities associated with the expansion of agriculture, the incorporation of modern technology and the resulting gains of productivity, resulted in the diversification of local economies, and increased significantly agricultural and non-agricultural incomes and municipal revenues. And there have been improvements in welfare (measured by indicators like the UN's Human Development Index).

An interesting aspect of Bonelli's study is that the successful municipal cases he examined – especially those in the *Cerrado* – had the following distinctive features: they were served by a fairly good transportation infrastructure; there was technical assistance and adequate financing for agricultural activities; and the municipalities were well located regarding markets for their main agricultural products. In some cases there had been a recent burst of investment in processing industries not far from the municipality, increasing markedly the value added in their areas of influence. But in the *Cerrado*, such cases are few. In substantial parts of its zones of agricultural expansion, there are considerable deficiencies. Their removal is required to enable dissemination of economic development throughout the already occupied portions of the region. If this occurred, the ensuing agricultural intensification there would certainly contribute to the reduction of pressures at the frontier.

For this is to happen, however, it is necessary to reformulate, develop and enlarge the scope of action of: the supply of basic public services; technical assistance to improve and to democratize the results of advanced agricultural research currently available; and of policies to provide incentive and support for the expansion of activities that can add value to agricultural production. Such actions and initiatives would surely bring about a more significant and comprehensive economic development to a larger portion of the *Cerrado*'s already occupied areas.

An important aspect, somewhat overlooked by many evaluations of recent developments in the *Cerrado* is the environmental sustainability of the agricultural expansion there. Next section addresses this briefly.

3. *Sustainability of the agricultural expansion in the Cerrado?*³

In principle, sustainable farming and cattle ranching are not incompatible with the *Cerrado* ecosystems, but in practice, this is probably not the rule. In general terms, the rapid expansion of agriculture in the region has generated two types of effects: those associated with the removal of natural vegetation to place land in production – this occurs both, in the region's frontier areas, and in the areas already settled (within existing farms); and the effects of activities undertaken in the areas of more intensive agriculture, resulting from the prevailing agricultural practices.

Environmental impacts from the removal of the natural vegetation in the frontier

The widespread land clearing for crop and pasture formation in the frontier can generate impacts in terms of the destruction of habitats and of biodiversity. The former incentives programs for the occupation of this region – an important factor in the expansion of its agricultural frontier – were based in the implicit assumption that, unlike to the Amazon ecosystems, those of the *Cerrado* are inferior and can, therefore, be occupied and exploited without major consequences. Thus, the conversion of cerrado lands into agriculture took place without care to protect habitats and preserve the native biodiversity. The effects of such practices – amply emphasized in relation of the expansion of activity fronts in the Amazon – also deserve attention with reference to the *Cerrado*.

The nature and magnitude of land clearing in the region was discussed above. We saw that, between 1975 and 1996 farms in the region cleared almost 30 million hectares in order to carry out agricultural activities.

Environmental impacts in the already established agricultural areas in the Cerrados

The main environmental impacts of the intensification and modernization of agriculture in these areas are:

- ***Problems of soil management.*** Serious damages resulting from inadequate soil management associated with conventional agricultural practices in the *Cerrado*, led to the

³ This section is based on: Bustamante, 2002.

introduction, in the early 1980s, of minimum till systems. In Brazil, minimum till began to be employed in the southern states, where it proved quite effective in the control of erosion. As a result, it spread to other parts of the country; today this system of land management already prevails, with success, in the more developed agricultural zones of the *Cerrado*; in the areas where it is not in use, its introduction should be stimulated.

In the regions in which the conventional management of soils prevails, the main environmental problems usually found are:

Erosion: This was a major concern in the initial phase of the soybeans boom in the *Cerrado*; then most farmers did not employ even the more basic conservation practices. Under natural conditions, the region's *Latosolos* soils resist erosion, due mainly to their high permeability, great depth, high level of aggregation, and especially, due to their natural vegetation cover. But the removal of vegetation followed by annual and intensive planting, undertaken without care, substantially alters the ability of the *Latosolos* to resist erosion.

Furthermore, the cultivation of the *Cerrado* requires a substantial use of fertilizers and soil correctives. The loss caused by erosion in soils with "constructed fertility", apart from being a serious environmental problem, is also an economic waste.

As indicated, the replacement of the conventional systems by minimum till brought about a considerable reduction in the damages caused by erosion.

Loss of Nutrients: Due to hydraulic erosion, the conventional cultivation systems tend to increase the loss of nutrients and of organic matter in the soil, with both economic and environmental costs. To reduce these, it is necessary to add to soil management systems – including minimum till –, conservation practices such as terracing. With these precautions, minimum till can be an efficient system for reducing the loss of nutrients and organic matter.

Soil Compaction: The intensive use of implements such as disk plows, pulled by heavy tractors brings about the formation of compacted areas in the majority of soil under continuous planting. And this results in a decline in productivity. With minimum till, however, the use of machines is reduced, resulting in less compaction.

• ***Impacts on water resources.*** The conservation of water resources deserves special attention. In the plateaus of the *Cerrado*, where – as occurs almost everywhere in Brazil – agriculture tends to be conducted without special care and where most riparian forest have

been removed,⁴ we find important drainage systems responsible for the fresh water supplies to some of the major cities in the region. These systems can be seriously harmed by improper agricultural practices

Irrigation in the Cerrado: Compared to the total planted area in the region, irrigated cultivation is not yet substantial, but its expansion has been put in place in a rapid and disorderly fashion. If this expansion continues, it may result in important negative environmental impacts.

- ***The use of chemical inputs.*** Pesticides and herbicides are widely employed in modern agriculture and particularly in the soybean farms in the *Cerrado*. They are used to control insects, plant and animal diseases, and to combat invading weeds in crops and in pastures. The short term efficiency of these biocides has increased substantially its use, with negative impacts in terms of bioaccumulation, persistency, toxicity to various organisms, *mutagenic impacts*, carcinogenic and *teratogenic* potential. (Vieira et al. 2001, apud Bustamante, 2002).

A pest control system more friendly to the environment is that of ‘integrated pest management’ - a technology that consists, basically, of regular inspections of the farming areas, to check the level of attack, and of the use pesticides only when this level is high. In Brazil, soybeans have received the attention of researchers in this respect; today this is one of the most advanced crops in terms of integrated pest management. However, in spite of these advances, unrestrained use of pesticides is still the rule in the *Cerrado*.

- ***The control of weeds.*** Modern agriculture requires the control invading weeds, which can cause significant reduction in production. There are chemical, mechanical, cultural, and also biological methods of control. The chemical method of weed control involves the utilization of herbicides, which can be found in various forms. The advantages of this method are: it requires reduced labor inputs; and herbicides can be applied swiftly. But there are also substantial disadvantages in terms of environment contamination. Furthermore, an intensive use of herbicides may generate resistance in the noxious weeds, requiring more intense uses of such products at each succeeding crop.

The chemical method is fundamental in minimum till. As indicated, this method of land management has expressive environmental advantages, but it requires special care to

⁴ In Brazil – and not only in the Cerrado – land clearing in farms tends to occur with no regard to the legislation on the preservation and protection of riparian forests and hilly areas.

avoid negative environmental effects stemming from intensive use of herbicides. There are forms of controlling this, but it is important that they be used; but this is not always the case.

Finally, the use of herbicides can be reduced through the development and dissemination of biologic methods of control.

Summing up, the *Cerrado* seems to present a case in which the social and economic benefits from agricultural expansion and modernization are, at least to some extent, offset by environmental costs, with potential effects in terms of loss of sustainability. However, policies can be adopted to reduce the environmental costs and to correct the distortions of development in the *Cerrado*.

4. *A case-study: the dynamics of the soybean fronts in the Cerrado*

Although agricultural crops are not the main users of land in the *Cerrado*, they have an important effect in inducing the incorporation of areas in the frontier, and the clearing of land in farms for crop and livestock activities. In the *Cerrado*, one of the crops – that of soybeans – has produced important effects of this type. We saw, above, the very rapid growth of soybeans and the extraordinary increase in yield of this crop in the region.

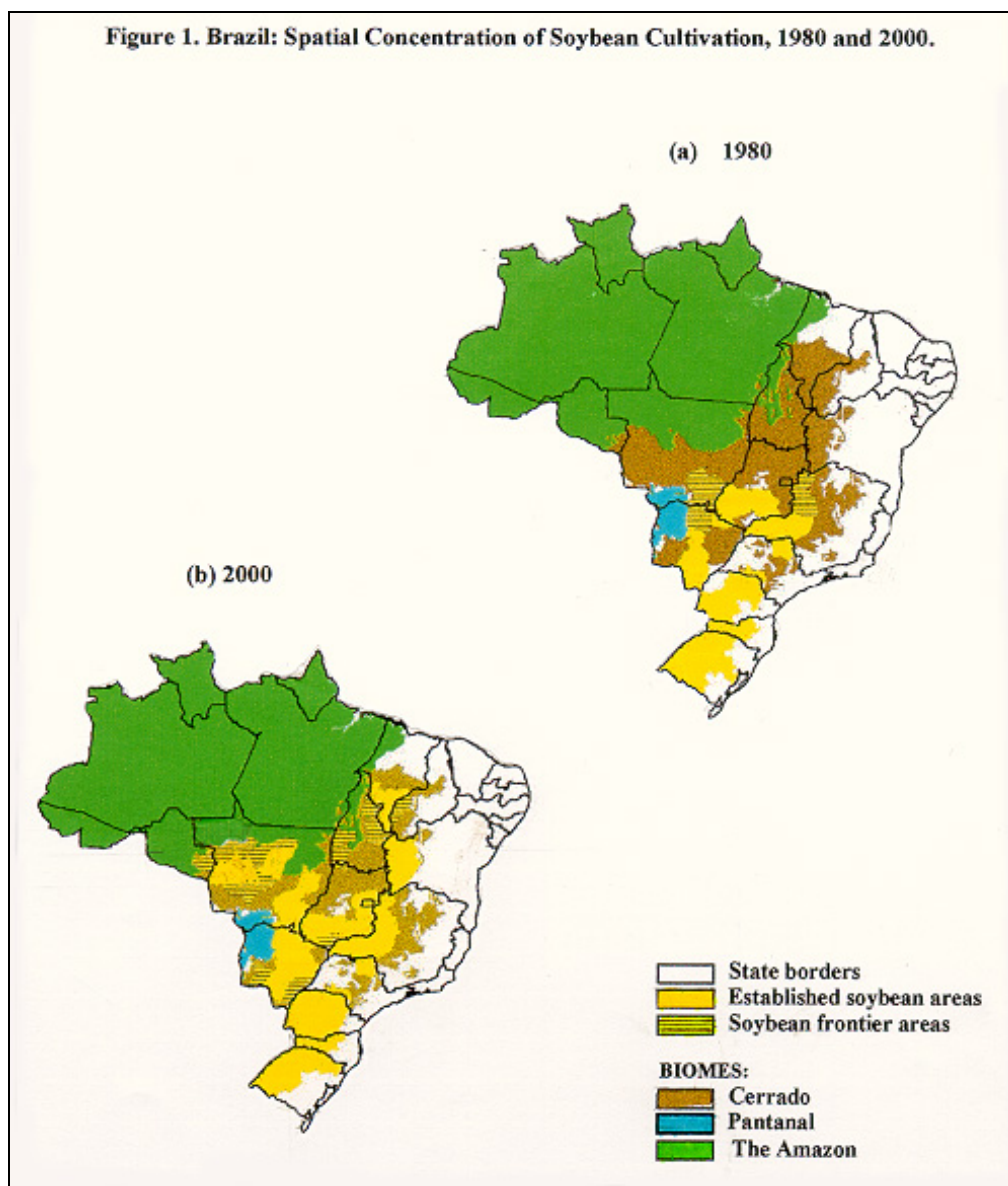
This section examines the spatial pattern of the expansion of the *soybean fronts* in the *Cerrado*. This is done to evaluate its more direct impact in inducing the incorporation of land in the *potential space* of the region's agricultural frontier. We start with an overall view of the expansion of soybeans in Brazil; next, we focus the pattern of expansion of the crop in the country's Center West – a region which includes a very substantial portion of the *Cerrado* core.

4.1. The geographical pattern of soybean expansion in Brazil

The initial phase of the expansion – the prevalence of the South.

Soybeans began to be cultivated more vigorously in Brazil in the second half of the 1970s, propelled mainly by the growth in international demand. The crop was initially planted in the country's southernmost state of Rio Grande do Sul, in rotation with wheat. From this state the crop expanded northward, reaching the other southern states (Santa Catarina and Paraná) and, the state of São Paulo.

Figure 1 (a) highlights the areas in Brazil, which in 1980, concentrated, in decreasing order of importance, somewhat more than 80% of the total land harvested with soybeans.



The figure shows clearly the prevalence of the crop in the three southern states. In that year, they were responsible for 85.3% of the country's total area in soybeans (8.8 million hectares) and 85.5% of the total production (approximately 15.2 million tons).

In 1980, therefore, soybeans had not significantly penetrated the Cerrado. Only about 15% of the Brazil's total area in this crop was harvested outside the three southern states. They included in the south of Mato Grosso do Sul, the south of Goiás and in the Triângulo Mineiro region, in the *Cerrado's* southern border. Soybeans cultivation had started in these areas induced by special development programs, initially by the government

of the state of Minas Gerais, and later by the federal government, aimed at the *Cerrado* (Mueller, 1990). Prevalence

The soybean expansion of the 1980s and 1990s – the predominance of the Cerrado.

Between 1980 and 2000 the production of soybeans in the southern states continued important, but as shown in Figure 1 (b),⁵ the crop had moved deep into the *Cerrado*. In that year, the southern states were responsible for 48.8 % of the country's total area in soybeans; the remaining 51.5 % (a little over 7 million ha) were, almost wholly, in the *Cerrado*. In 2000, Rio Grande do Sul remained the largest producer (3.0 million ha), but the cultivation of soybeans in the savannas of the state of Mato Grosso made it the second largest producer, with 2.9 million ha. The third main producer was the southern state of Paraná (2.86 million ha), but ranking from the 4th to the 7th places were states containing substantial savanna areas: the states of Goiás (1.5 million ha), of Mato Grosso do Sul (1.1 million ha), of Bahia (0.63 million ha), and of Minas Gerais (0.6 million ha).

The pattern that emerged in Figure 2 shows, therefore, the clear consolidation of the crop in the *Cerrado*. Comparing Figures 1 (a) and 1 (b) we see that some of the region's marginal areas in 1980 became established producers; and that new soybeans fronts emerged in the region.

The expansion of soybeans in the *Cerrado* was strongly affected by a growing domestic and international demand for this crop; but on the supply side, three factors were decisive: the natural conditions of the savannas of these areas; technological development which made viable the cultivation of the crop in formerly inhospitable agro-ecosystems; and, we should stress, investments in transportation infrastructure in these portions of the *Cerrado*. The latter strongly influenced the changes in the spatial pattern of the soybean fronts over the two final decades of last century.

An interesting case, which illustrates the role played by the transportation network in the expansion of the soybean front, is that of the south of the state of Maranhão, in the northeastern tip of the *Cerrado*. Until the early 1990's, this state's soybeans production was insignificant, although the media was already drawing attention to the agricultural potential of the savanna areas in the south of the state. But due to the implementation of the "Corredor de Exportação Norte" program, which markedly improved the transportation of soybeans produced there to Maranhão's Itaqui harbor, the crop began expanding rapidly and

⁵ Figure 1 (a) and (b) highlight areas that in 1975 and in 2000, respectively, concentrated, in decreasing order of importance, more than 80% of the area in soybeans.

now it is the main economic activity in the south of that state. In 2000, Maranhão had already harvested soybeans from 176.4 thousand hectares. And the crop had expanded to parts of the adjacent states of Piauí and Tocantins.

The soybeans yield in the Cerrado. As a stronghold of *modern commercial agriculture fronts*, soybeans cultivation began “technologically developed” in the *Cerrado*. The development of new soybeans varieties, adapted to different agro-ecosystems, together with other technological improvements, mainly carried out by the technical development system coordinated by EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), brought about continuous increases in the crop’s yields. Thus, the yield in the state of Rio Grande do Sul, went up from 1438 kg/ha in 1980, to 2000 kg/ha in the 2001. In Paraná, the yield jumped from 2240 kg/ha to 2740 kg/ha in the same period. We stress, however, the recent results obtained in the Center-West, the region concentrating a substantial portion of the *Cerrado* soybean production. For the whole of the region the 2000 yield was 2845 kg/ha, way above the national average; and the 2000 yield of Mato Grosso reached 3050 kg/ha, the highest soybeans yield in a state that year; and this state maintained very large yields in the subsequent years. In fact, the adoption of technologies developed to increase yields and reduce costs has proved essential to counter the high soybeans transportation costs of the main soybeans areas of the *Cerrado*.

4.2. Expansion of the soybean front in the Center-West in the last decade.

This section focuses the vital question of the impacts on remote areas – mainly in the Amazon – of the expansion of the soybean front Brazil’s Center-West. This is a particularly interesting region; it not only includes a very substantial portion of the *Cerrado* core, but it also has significant shares of two other fragile habitats: that of the Amazon (in the region’s north); and that of the Pantanal in the region’s southwest, bordering Paraguay and Bolivia.

The idea behind our evaluation is simple; we assume that, if the expansion of soybean cultivation is taking place in a widely dispersed pattern over the region’s geographical area, the movement of the agricultural front associated with this highly profitable crop (at least recently) can be considered a central factor in the process of incorporation of land in farms, and especially, in the removal natural vegetation for agricultural activities in the potential space of the frontier. A more concentrated pattern, however, would indicate that the direct impact of soybeans on the frontier is less important than commonly thought.

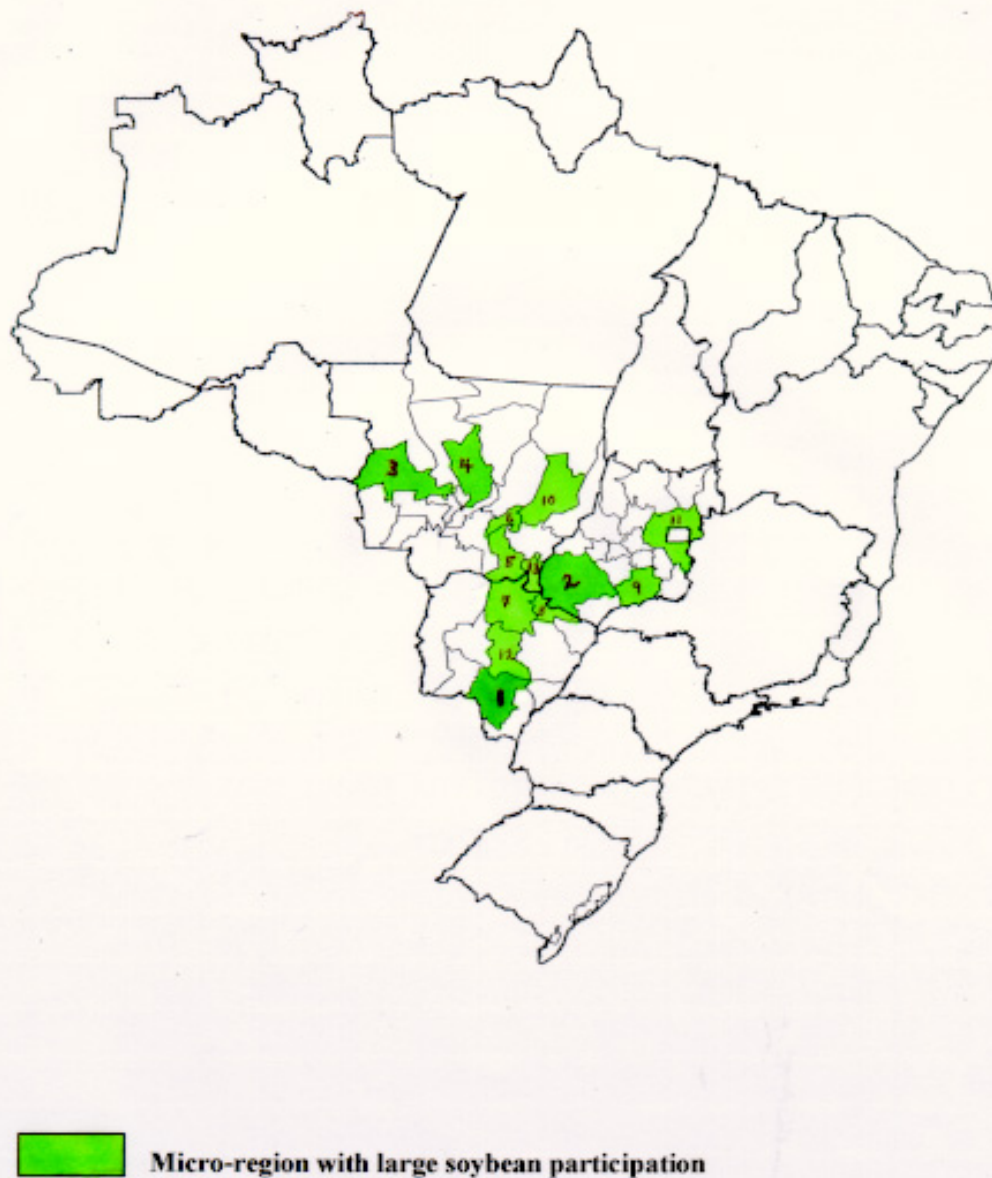
We employed IBGE's municipal crop statistics for the years 1990 and 2001 (the last year for which such data were available). Working with the area harvested of soybeans at the level of geographical micro-regions,⁶ we ranked, in descending order, these geographical units which were responsible for around 85 % of the region's total area in the crop in 1990; and around 86 % in 2001. The areas of concentration of soybean production in these two years are highlighted in charts (see Figures 2 and 3). A comparison of the charts for 1990 and for 2001 helps us to appraise the recent pattern of soybeans expansion in the savannas of the Center-West.

Examining Figure 2, describing the prevailing soybean areas of 1990, we observe a substantial spatial concentration of production in agricultural zones which, as shown by Cunha et al., (1994, chapter 3), were the ground of expansion of agricultural fronts in the early 1970s. Indeed, the two largest soybean micro-regions of 1990 (marked with numbers 1 and 2 in the map) are in the Center-West cerrados' southern extreme; together the two accounted for almost 30 % of the region's total soybean area of 3.7 million hectares of 1990. Moreover, most of the region's 1990 remaining areas are in its long settled segment.

But in this year there already were important exceptions: the micro-regions marked with numbers 3 and 4 (Parecis and Teles Pires), and to a lesser degree, that under number 10 (Canarana) – all located in the center-north of the savannas of the state of Mato Grosso, not too far away from the state's Amazon areas. In 1990 these geographical units were clearly the locus of expansion of the soybean front; together, they already accounted for over 20.5 % of the area in soybeans of the Center-West cerrados. The question is, to what an extent has this northward movement of the soybean front continued in the 1990s and early 2000s? Can we say that there was a recent soybean explosion more to the north, closer to the Amazon?

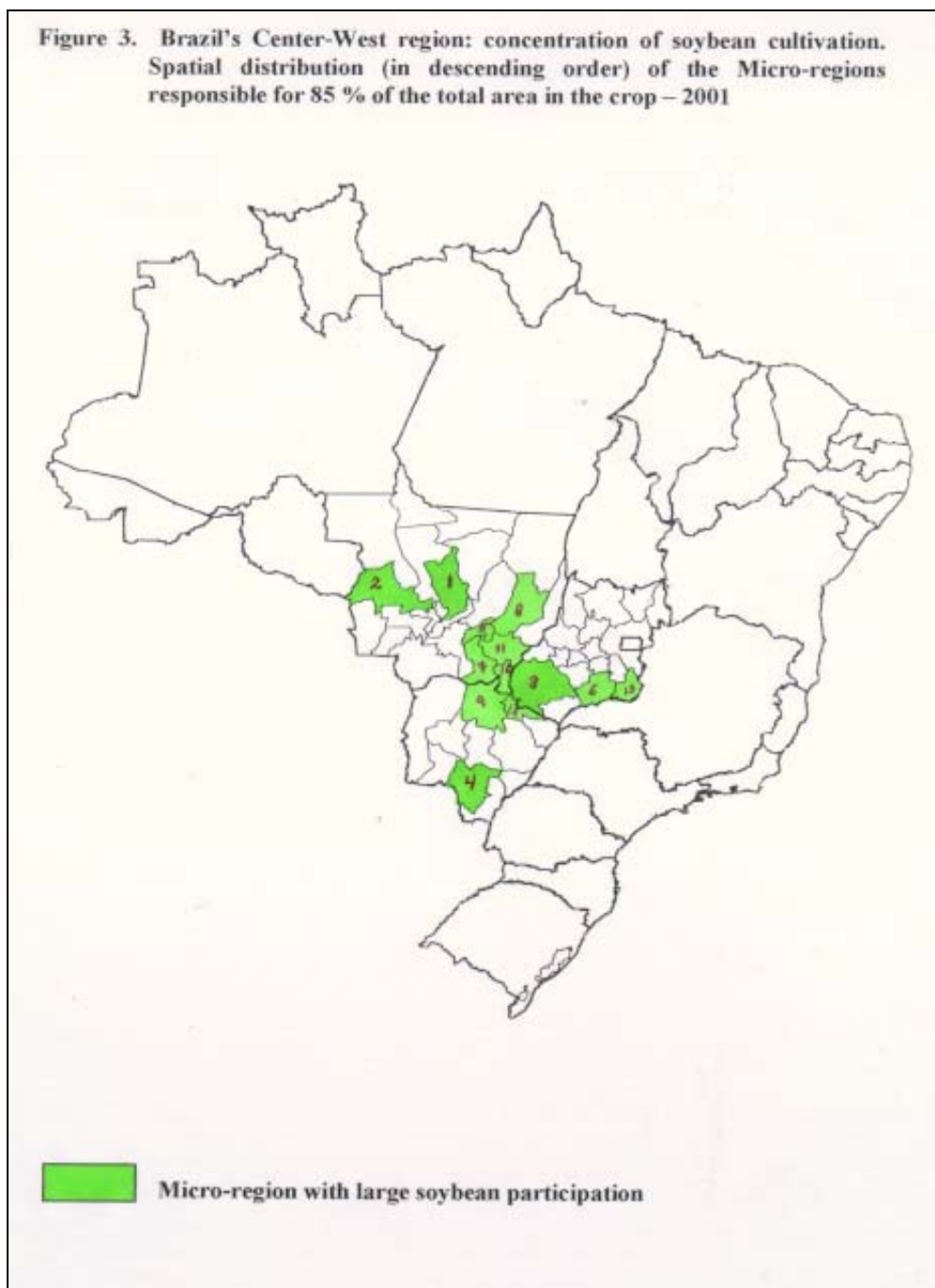
⁶ A micro-region is a geographical unit created by IBGE, composed of a group of municipalities with similar geographic characteristics. In the Center-West the micro-regional formation did not change between 1990 and 2000, in spite of the considerable creation of municipalities in the period, as a result of a fragmentation of the municipalities existing in 1990.

Figure 2. Brazil's Center-West region: concentration of soybean cultivation. Spatial distribution (in descending order) of the Micro-regions responsible for 86 % of the total area in the crop – 1990



Examining Figure 3, with the location of the areas of soybean concentration in the Center-West cerrados in 2001, we observed, with some surprise, a very large participation of this crop in almost the same set of micro-regions of the 1990 chart. Of the total of 5.7 million hectares harvested with soybeans in the region, over 86 % came from most of the

same micro-regions highlighted in Figure 2; the exceptions were the inclusion of one, and the exit of two micro-regions – all located in the previously settled portion of the region's savannas.⁷



A closer look at the charts and at the basic data drew attention to two outstanding features regarding the 1990-2001 soybean expansion in the savannas of the Center-West: First, the more scattered soybean location of 1990 gave place to a more concentrated

⁷ The two exited micro-regions appear predominantly among the 14 % of the units not included in the Figure 3 group.

spatially location pattern, along an axis running northwest to southeast in the region. The main common characteristics of this cluster of micro-regions are:

- The existence of a fairly adequate transportation infrastructure, linking the areas to the main markets and the main ports. Transportation is a fundamental element in explaining the movement of the soybean front in the Cerrado. A study of the US Department of Agriculture for the 2000 crop year showed that cost of production inside the farm was, in average, some 23 % lower in the Cerrado than in the US Midwest, but that the transportation costs, even in the Cerrado's fairly well located areas (such as those highlighted in Figure 3), made the region's soybeans reach Holland's port of Rotterdam at costs only some 7 % below those of the American soybeans. (Agroanalysis, 2003, p.19).

- The existence of industries demanding soybeans as inputs at a reasonable distance from the areas of cultivation; as a result, markets for soybeans and for agricultural inputs functioned well there.

- The existence of adequate storage and handling facilities.

- The role of public policy in the expansion of the soybean front was minimal in the period; in the 1980s, the production of soybeans in the Center-West depended heavily on subsidies and on low interest financing from the Federal Government, but these virtually vanished along the 1990s, following the demise of the regional development policies of the 1970s and 1980s (see Rezende, 2003, chapters 5 and 6). Moreover, due to the fiscal difficulties of the Federal and State governments, investments in the construction and improvement of roads and railways have been negligible. The only remaining public policy – hugely important for the advance of the crop – is the development by EMBRAPA of varieties of soybeans adapted to almost all portions of the *Cerrado*.

The second outstanding feature regarding the 1990-2001 soybean expansion is a very substantial growth of soybean fronts in areas identified as the frontier in 1990. Micro-regions in the center-northwest of the focused region that, in 1990, were the 3rd, the 4th and the 10th of the main producing units, moved strongly up in the ranking of the main producers, occupying, in 2001, respectively the 1st, the 2nd and the 8th places. Together, these three micro-regions showed an increase of 1.3 million hectares in the area harvested with soybeans between 1990 and 2001, or 65.5 % of the total of the almost 2 million hectares growth in the Center West's soybean area in the period.

Summing up, the comparison of the areas of soybean concentration in 1990 and in 2001 does not indicate a pattern of expansion towards the northern part of the Center-West (its Amazon section). We observe, instead, a more intense allocation of land to this crop within micro-regions which, in 1990, already were the locus of the soybean front.

This was the situation until 2001. What can we say regarding the period since 2001? This is discussed next section.

5. *Are soybeans ‘devouring’ the Center West’s Amazon?*

As this section was being written, a leading and highly respected Brazilian newspaper printed an article relevant to the theme focused here, under the headline: “*Amazon: soybeans move on in the forest*”.⁸ It starts by stating that “*After taking up the Cerrado, soybeans are now moving into Mato Grosso’s forests, avidly circling the Xingu National Park*”, in the state’s northeast. It mentions initiatives by the state government, in a joint effort with farmers and other segments of the private sector to improve the transportation infrastructure of this part of the state; this would intensify the flow of farmers in search of land to expand the crop. However, the first impression one has from the Estado de São Paulo article (ESP article) is misleading; in fact, other portions of the article expose the overstatement of its title and leading statement.

The ESP article focuses a relatively small portion of Mato Grosso’s Amazon, which comprises most of this state’s huge northern section; as a matter of fact, most of the area covered – a portion of the Araguaia river valley, originally in transition forests – is not typically Amazonian. It includes portions of the north of micro-region 8 (Canarana) of Figure 3, and of its two contiguous micro-regions to the east and north (micro-regions Médio Araguaia and Norte Araguaia). As the article concedes, most of the new soybean areas comprise lands that have been cleared many years ago by former cattle ranching enterprises, created by the deceased fiscal incentives programs. Today the clearing of land in forested areas not only is restricted by law,⁹ but it is also expensive, so much so that the

⁸ “Amazônia: a soja avança na floresta”. *O Estado de São Paulo*, October 26, 2003, p. B6 and B7.

⁹ There is legislation – recently enacted – restricting the clearing of land in farms in forested areas to 20% of the total farm area; in the cerrados, this proportion rises to 40%. In Mato Grosso, farms that had exceeded these proportions in the past can compensate for this by buying virgin areas elsewhere in the state and donating them to the government to constitute areas of preservation.

price of cleared land in the region tends to be considerably higher than that of lands in natural forests.¹⁰

There is, however, land being directly prepared for the cultivation of soybeans; in part this is being done in compliance to the strict legislation on the opening of lands in the Amazon and in the Cerrado, but there is no doubt that land is also being cleared illegally. An instance of the former, mentioned in the ESP article, is a huge soybean farm being formed by a venture controlled by the state's governor. And the article also denounce a scheme to clear the land far beyond the limits set by legislation, hoping to create a *fait accompli*, or attempting to claim that the clearing had been done before the enactment of such legislation.

There is little doubt, therefore, that today one of the soybean front areas is in the in the center northwest of Mato Grosso, in an area of transition between rain forest and savannas. But to infer – as the ESP article implies – that this front is now directly producing large indentations in the Amazon forest proper seems to be an exaggeration.¹¹ At any rate, the ESP article presents evidence on the acceleration of deforestation in the *soybean front area* of the Araguaia valley, starting around three year ago. And it uses satellite images to back its contention.¹²

We take issue, however, with the suggestion that soybean farmers are directly the main perpetrators. The events in Araguaia valley are not so simple and clear-cut. If this were the case, it would be relatively simple to curb deforestation. As shown in the ESP article, the government of Mato Grosso has an almost exemplary land clearing monitoring system, based on satellite images which allow the determination of alterations in the land cover in individual farms. Based on this, and on legislation imposing stiff fines on offenders, the state and the federal environmental agencies can, in principle, move to curb deforestation. However, the *potential area* of the Amazon frontier is huge, access is difficult and the staff in charge of controlling land clearing is inadequate. And to make things worse – and this is

¹⁰ As shown by Romero (1999, p. 24-25), land cleared and already worked on in the Amazon tends to cost over four times more than land in the same area, but forested. And his study precedes the recent soybean boom. In the Araguaia valley the difference is still larger.

¹¹ Unfortunately, there will be some time before there are data to determine exactly where soybean fronts are presently located.

¹² According to the ESP article, last September the NOAA satellite recorded over 16 thousand burning spots (locations where the vegetation removed was being burned) in the state of Mato Grosso alone, a good many in the state's center northeast, the area focused by the article.

our main point – there are different types of offenders and the number of agents involved in clearing in a given point in time goes far beyond the few hundreds of soybean ventures now moving into the frontier.

To understand what goes on in the potential space of the frontier penetrated by a soybean front (such as that of the Araguaya valley) it is important to consider other *activity fronts* – especially the *speculative* and the *subsistence fronts*, which also advance – or have advanced – in the frontier. As indicated, in the past, *speculative fronts* impacted considerably sections of the Amazon. An important part of this was cattle ranching ventures induced by fiscal incentives schemes; they occupied and cleared large areas in the forest – or in the transition areas such as the Araguaia valley. Most of such undertakings did not succeed as producers but many reaped speculative gains. The fiscal incentives scheme has been phased out and there no longer are large subsidized agricultural enterprises clearing land in the Amazon. However, there remain a large number of small ‘speculators’, clearing land and planting pasture in an attempt to reap the gains in the value of land – the vital asset they seek to control in the frontier.

This has to do with the waves of migrants that have been excluded by the process of modernization of the agriculture in the country’s center-south. As already indicated, many of such migrants have moved to the agricultural frontier. As shown in the far-reaching research of Almeida (1992) in the Amazon, and as conceptualized by Romero, 1999, what most of the small settlers aim at obtaining in the Amazon is land to clear, produce crops or extract products for subsistence, plant pastures, raise a few heads of cattle, gradually getting established as cattle ranchers. But since the obstacles are many,¹³ what the majority of the settlers hope to is, after some years, at least obtain capital gains by selling their land.

Land can be obtained by the Amazon settler by different means; they range from the purchase of a legalized area or the assignation of a plot a colonization project, to outright squatting on public or private lands. Cases of the former are rare; most of the migrants settle on squatted lands and this can originate disputes and violence.

A relatively small number of the Amazon settlers achieve their main goal; some are even able to expand. But most of the settlers face overwhelming difficulties and end up, after some years of struggle, selling the land and moving elsewhere. But note that, just by

¹³ Instances of the obstacles faced are: isolation, malaria, accidents resulting from clearing the land, the encroaching on the occupied area, and violence.

the fact that a significant portion of the settler's plot is cleared and pasture is planted there, its price will increase markedly.¹⁴ The price differential will be larger if the settler can prove that he has firm property rights over his farm, but it happens in almost all cases.

The stylized developments described above were constructed for the whole of the Amazon and under 'normal' conditions. What differs regarding the Araguaia valley?

In that portion of the state of Mato Grosso, now experiencing the impacts of different activity fronts with the dominance of a soybean front, other factors have recently intensified the occupation and clearing of land. The more important are:

- The sharp increases in the international price of soybeans over the last three years;
- The recent strong depreciation of the real, which increased further the soybean prices in terms of the domestic currency (the real).
- The consequent recent large profits reaped by soybean producers has provided them with the means to purchase more land.
- Until recently, the relatively low prices of land in the Araguaia valley; however, with the new growth in demand, these prices were sharply inflated (see the ESP article).
- The effort of the state government to improve the transportation infrastructure serving the region.
- The difficulty of controlling the process of deforestation. The legislation and the instruments are in place but, as indicated, the magnitude of the task is daunting, especially when we consider the number of agents involved, and the complexity of the situation.

6. Concluding comments

The significant occupation and clearing of land in the Cerrado's savannas – and also in its Amazon portions – resulted from processes of creation of potential spaces for the expansion of different agricultural activity fronts that have penetrated and expanded in parts of the region over the two last decades – among which deserves emphasis the soybean

¹⁴ Reviewing the research on the settlement of the Amazon, Romero (1999) found out that the price of a plot of land under original vegetable cover would range between US\$ 5 and US\$ 70 per hectare, depending on the conditions of the infrastructure serving the area and the plot's legal status – whether the seller has or not established property rights on the land being sold. The mean area of such plots was 50 hectares. After clearing and working some 20 hectares of his farm over a few year, forming pastures, the settler can sell his farm at a price ranging from US\$ 40 and US\$ 100 per hectares, again depending on its legal status and on the condition of infrastructure. Of course, squatters acquire their land without payment, but the risks they face can be huge.

boom. In the past, public policy had a significant role in this, but more recently some of the front movements occurred in spite of governmental inaction.

The agents in the process of land clearing in the *Cerrado* have been numerous and diverse. Among them there are, no doubt, large soybean operators; they probably are not numerous, although their impact in terms of the area affected can be appreciable. But deserve special attention the various small operators in other activity fronts, acting as outlined above. Individually, their impact may not be considerable, but they work in large numbers.

We saw that, although *directly* the agents of the soybean fronts cannot be considered major perpetrators in the removal of the vegetation in the Amazon and the savanna potential areas, they surely exert strong *indirect* impacts by inducing other agents to do so. And, the actions of the latter are much harder to monitor and control.

As for policy recommendations, the area under discussion is complex and it would be presumptuous to suggest specific measures. There are, however, two important lines of action that could be followed in order to reduce the pressure of agents involved in activity fronts in the region and to provide a more rational – and sustainable – ordering of its space. The first line of action would be to review the transportation infrastructure investment plans so as to redirect resources from roads and other means of transportation cutting deep into the virgin areas of the *Cerrado* and of the Amazon, towards the improvement of the transportation systems of already settled areas in the *Cerrado*, where there are considerable amounts of land already cleared but which are degraded and underutilized. Doing this it would be possible to substantially increase the production of commercial crops in the *Cerrado* without having to open and clear new areas. It is important to have in mind that the expansion of commercial agriculture fronts into Brazil's hinterland requires fairly good transportation systems. Therefore, investments in these reaching virgin and fragile portions of this hinterland should be avoided.

We saw, however, that other activity fronts – not too dependent on reasonably efficient transportation and on product markets – are clearing land in the transition forest areas of the north of the *Cerrado* and in the Amazon. The agents of these fronts are a large number of displaced agricultural workers which have been trying their luck in forested areas of the region. It is very difficult to deal with the underlying forces of these processes. A general – and, we concede, extremely vague – course of action would be a strategy to alleviate the main problems outside the frontier which cause the demographic pressures

there. This would require the implementation of well conceived land redistribution schemes in the country's center-south. By providing access to land outside the more fragile virgin areas of the *Cerrado* and the Amazon, such schemes would alleviate the pressure exerted by the landless in these regions.

REFERENCES

- Agroanalysis, 2003. *Agroanalysis, a Revista de Agronegócios da FGV*, Rio de Janeiro: FGV, vol. 23 n. 6, sept., 2003.
- Almeida, Ana Luiza O., *Colonização dirigida na Amazônia*. Rio de Janeiro, IPEA, 1992.
- Bonelli, Regis, "Impactos econômicos e sociais de longo prazo da expansão agropecuária no Brasil: revolução invisível e inclusão social". Rio de Janeiro, IPEA, *Textos para Discussão* 838, 2001.
- Bustamante, Mercedes, "A sustentabilidade ambiental da produção de soja no Brasil". IN: Mueller, C. (org.), *Avaliação de Sustentabilidade do Complexo Soja no Brasil*, Brasília, WWF, 2002 (versão preliminar), cap. 3.
- Cunha, Aécio, Charles Mueller, Eliseu Alves e José Eurípedes da Silva, *Uma avaliação da sustentabilidade da agricultura nos Cerrados*. Brasília, IPEA, 1994.
- Dias, Bráulio Ferreira de Souza, *Alternativas de Desenvolvimento dos Cerrados: Manejo e Conservação dos Recursos Naturais Renováveis*. Brasília, IBAMA/FUNATURA, 1992.
- Martine, George, "Internal migrations in Brazil". IN: C.B. Nam, W.J. Serow and D.F. Sly (eds.), *International Handbook of Internal Migration*. Westport: Greenwood Press Inc. :31-46, 1990.
- Mueller, Charles, "O estado e a expansão da fronteira agrícola na Amazônia brasileira". São Paulo, *Estudos Econômicos*, 13 (3), set./dez. 1983, p. 657-679.
- Mueller, Charles, "Políticas governamentais e a expansão recente da agropecuária no Centro-Oeste". Brasília, *Pesquisa e Políticas Públicas*, no. 3, junho de 1990: 45-74.
- Mueller, Charles, "Land settlement and sustainability: the process of colonization in South America's Amazon and in Brazil's savannas". Paper presented at The United Nations University Conference on the Sustainable Future and of the Global System, Tokyo, 16-18, UNU, October 1995 (38 p.)
- Rezende, Gervásio Castro de, *Estado, macroeconomia e agricultura no Brasil*. Porto Alegre: Editora da Universidade Federal do Rio Grande do Sul/IPEA, 2003.
- Romeiro, Ademar R., "Meio-ambiente e produção agropecuária na Amazônia". *Revista de Economia e Sociologia Rural*, vol. 37, n. 1, Jan./Mar., 1999, p. 8-33.

Sawyer, Donald, "Ocupación y desocupación de la frontera agrícola en el Brasil; un ensayo de interpretación estructural y espacial. In: CEPAL/PNUMA (Orgs.), *Expansión de la Frontera Agrícola y Medio Ambiente en América Latina*. Madrid, Naciones Unidas/CIFCA, 1983.

Vieira, L.M., S. Galdino, C.R. Padovani. "Utilização de pesticidas na agropecuária dos municípios da Bacia do Alto Taquari de 1988 a 1996 e risco de contaminação do Pantanal, MS", Brasil. EMBRAPA, 2001.