Reprints

Understanding Land-Use and Land-Cover Change in Global and Regional Context

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CHAPTER

13

Land Use in Brazil: Major Contemporary Changes and Their Driving Forces

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Introduction

Brazil—one of the largest agricultural powers in the contemporary world – represents a very interesting case for geographical studies of land-use changes. The scale of these changes, occurring so fast that they are not always captured by geographers. This paper is mostly based on analysis of Brazilian agricultural statistics and observations made by the author in 2000–2003 during field trips to different regions of the country, as the coordinator of a joint research project of the International Potash Institute and Brazilian Corporation for Agricultural Research (EMBRAPA) on adequate use of mineral fertilizers, land-use potential, and colonization.

The enormous Brazilian territory with regional contrasts in land resource availability and climate is characterized by very sharp geographical differences in degree of intensity of agricultural use in general and land-use patterns in particular. Physical-geographical conditions for agriculture along Brazil vary due to relief, climate, and soil differences (Fig. 13.1).

Alluvial plains and low plateaus of the *North region (Amazonia)* with equatorial climate (permanent heat, high humidity) and acidic soils with a

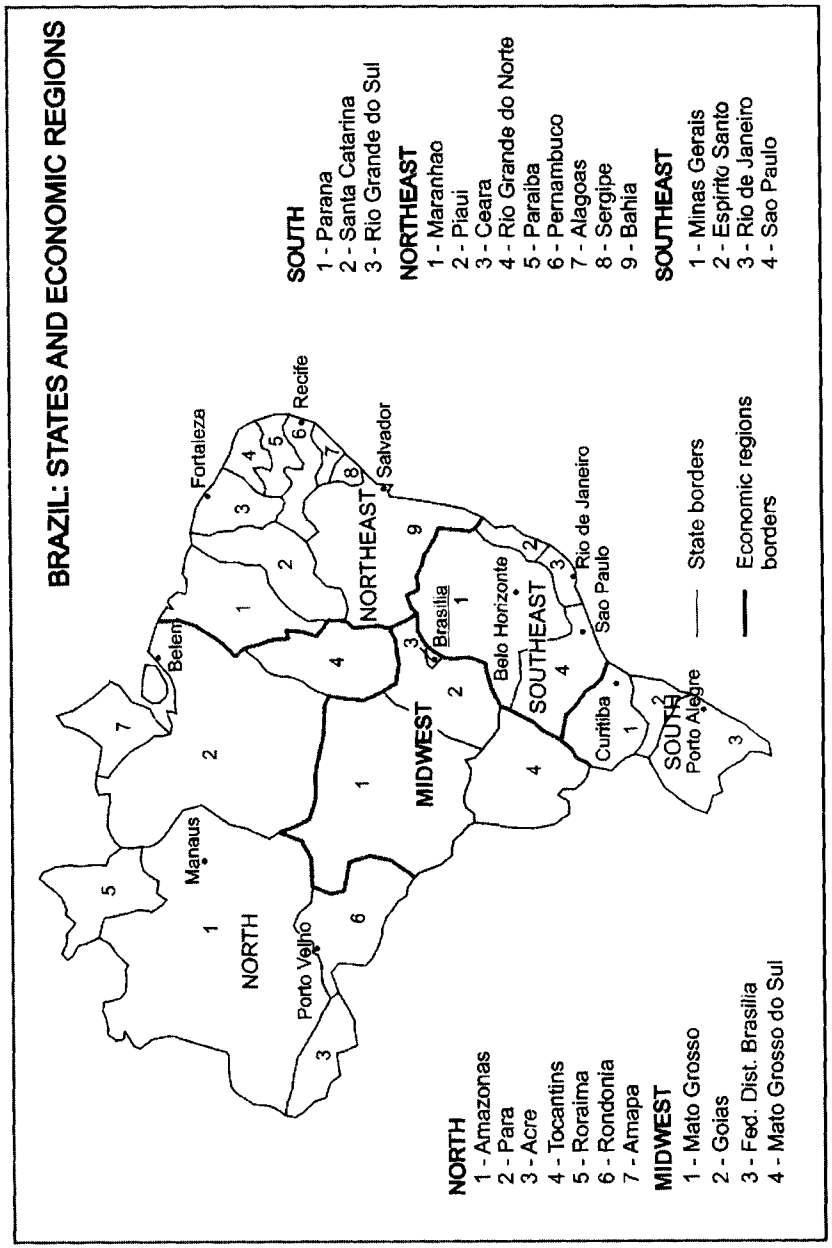


Fig. 13.1 States and regions of Brazil.

low natural fertility, saturated with aluminum, have reduced capacity for agriculture. The *Northeast region* capacity for agriculture differs from high and medium in the tropical humid climate of the coastal zone to low in the semiarid inner parts, belonging to the so-called "polygon of droughts". Natural soil fertility in this region, even in the most suitable for agriculture areas, is not high; sandy soils with shallow profiles predominate. In the *Southeast region* plateaus and ridges are typical, the climate is tropical with hot summers in the lowlands. This region has well-developed soils, generally with low natural fertility (the famous *terra-rossa*, or red soil). *South region* soils, derived from basic rocks of the plateaus and sediments, are the most fertile in the country. Subtropical climate with defined seasons differentiates the potential agricultural use of this region from the rest of Brazil. Huge spaces of the Brazilian Central Plateau in the *Midwest region* with humid to subhumid tropical climate and low natural fertility but deep, well-drained soils, affected by erosion processes, enable development of large-scale mechanized agriculture.

Terra-rossa, or *Latasola* according to the Brazilian Soil Classification System, being the most extensive among agriculturally suitable soils of Brazil, occupy 39% of the total country area, and 56% of the *Southeast* area, 53% *Midwest*, 34% *North*, 31% *Northeast*, and 25% of the *South*. 5.5 million km^2 of the 8,5 country land area is evaluated as suitable for potential farming use, but according to statistics only 2.4 million km^2 are already under different categories of agricultural use, including 1.8 million km^2 of pastures (GEO Brazil, 2002).[1]

Table 13.1 data show the contrast between projected potential and current agricultural land use within 26 Brazilian states and the Federal District. Only 12 states register 1 million ha or more of planted area of the main crops each. In Paraná 8 million ha of planted area represent more than half the total state territory. The other 11 states (in parentheses – planted area, thousand ha) are Rio Grande do Sul (6,899), São Paulo (5,591), Mato Grosso (4,830), Minas Gerais (4,027), Goiás (3,076), Mato Grosso do Sul (2,053), Ceará (1,907), Santa Catarína (1,686), Pará (1,296), Maranhão (1,230), and Pernambuco (1,176). In these states the share of planted area in the total territory varies from 5% in Mato Grosso and Mato Grosso do Sul to 25% in Rio Grande do Sul state (Estudos e Pesquisas Informacao Geografica, 2002).

As huge areas are still virgin or underwent very little agricultural development, colonization is one of the most important driving forces of land-use changes. From colonial times agricultural activities spread steadily from coastal zones toward the Brazilian heartland. In the 19th–20th centuries agriculture spread beyond the coastal *serras* (mountain ranges) to plains

[1] 90 million ha of planted pasture – mostly cultivated, not natural pastures

Table 13.1 Structure of land use in Brazil by regions and states

Regions and states	Arable lands 1000 ha	Share of arable lands in the total area, %	Structure of land use, as % of the total area				
			Perennials	Seasonal crops (planted)	Seasonal crops (fallow)	Planted pastures	Out of use
North (Amazonia)	21,233.2	5.49	0.19	0.32	0.28	3.82	0.88
Acre	728.4	4.76	0.11	0.39	0.29	3.61	0.36
Amazonas	758.1	0.48	0.06	0.09	0.04	0.13	0.16
Amapá	82.9	0.58	0.07	0.07	0.01	0.18	0.26
Para	8,567	6.84	0.21	0.44	0.41	4.65	1.14
Rondonia	3,316.9	13.91	1.07	0.75	0.29	10.81	0.99
Roraima	572.6	2.54	0.29	0.3	0.18	1.31	0.46
Tocantins	7,207.5	25.89	0.08	0.88	1.29	18.95	4.68
Northeast region	35,160.2	22.56	1.7	4.94	2.62	7.77	5.54
Alagoas	1,415.1	50.66	2.38	27.95	3.06	13.34	3.93
Bahia	13,684.5	24.12	2.38	4.48	1.67	11.73	3.87
Ceará	3,256	18.39	3.25	6.1	1.34	1.35	6.35
Maranhão	6,786	20.36	0.24	2.22	3.05	8.72	6.12
Paraiba	1,495.1	26.42	1.68	9.65	4.33	3.41	7.36
Pernambuco	2,640	26.68	1.32	11.14	2.43	7.08	4.72
Piauí	3,713.4	14.71	0.67	2.01	2.14	1.82	8.07
Sergipe	883.9	40.08	5.11	7.53	1.21	24.01	2.22
Rio Grande do Norte	1,286.3	24.13	3.19	7.86	4.25	1.65	7.18
Southeast region	33,416.2	36.04	3.53	7.9	1.15	22.06	1.4
Espírito Santo	2,031.8	43.99	13.75	4.19	1.14	22.92	2
Rio de Janeiro	1,058.2	24.11	1.79	5.89	0.87	14.67	0.89
Minas Gerais	17,630.9	29.96	2.02	5.07	1.27	19.88	1.73
São Paulo	12,694.6	51.02	5.5	15.62	0.92	28.36	0.62
South region	21,127.9	36.6	1.12	20.2	2.05	12.16	1.07
Paraná	11,049.5	55.33	1.56	23.98	1.95	26.54	1.3
Rio Grande do Sul	7,654	27.14	0.74	19.24	2.28	4.1	0.78
Santa Catarina	2,424.4	25.4	1.33	15.13	1.61	5.87	1.47
Midwest region	55,179.2	34.23	0.15	3.93	0.54	28.11	1.49
Goiás	17,245.5	49.2	0.16	6.21	0.75	41.8	0.27
Mato Grosso	20,154.7	22.23	0.19	3.07	0.55	16.83	1.59
Mato Grosso do Sul	17,633.8	48.37	0.05	3.82	0.33	43.91	0.26
Federal District	145.2	24.94	0.88	10.52	0.82	10.73	2
Brazil	**166,116.6**	**19.43**	**0.88**	**4.01**	**0.97**	**11.66**	**1.91**

Source: Estudos e Pesquisas Informacao Geografica (2002)

and plateaus of the *South* and *Southeast* regions. Since the last decades of the 20th century agriculture has been expanding in the inner states, mostly in the *Midwest* and *North (Amazônia)* regions.

Colonization is a key characteristic of the contemporary land-use changes in Brazil. Due to environmental concerns colonization of the tropical rain forests (*selvas*) has been delayed since the 1980s but colonization of *cerrado* (savanna) areas begun. The scale of land-use changes in both the mentioned

regions is so large that agricultural colonization and its environmental consequences are widely discussed outside Brazil, constituting one of the most provocative global topics. *Amazônia* in the 1930s and especially in the 1960s was thought to be the main reserve for development of agriculture, but to date only a few areas in the region have been agriculturally colonized. Agriculture (cropping and pasturing) entered Amazon forests along Tocantins and Araguaya rivers and roads. But environmental concerns and absence of scientifically based recommendations for agricultural use of Amazonian landscapes are obstacles for its further expansion (Naumov, 1983).

The national Forest Code (Law No 477165), issued in July 1996, established severe restrictions for agricultural land use for rural properties in the so-called *Amazônia Legal*.[2] Landowners developing economic activities had to preserve from every use except forestry 80% of their total area.[3] Later, Agricultural Law established compulsory reforestation norms; rural territory tax now exempts areas with forest cover from payment of property tax and provides tax reductions for areas with forest management plans. These measures partly stopped deforestation, which affected approximately 15% of 4 million km^2 of the Amazon area. Nevertheless, by 1991 according to LANDSAT data based research mapping (scale 1:250 000), detecting forest cuts from 6.25 ha, deforestation in *Amazônia* affected more than 440 thousand km^2 and now affects nearly 600 (IBGE, 2002).[4] New openings, especially along roads in the southern parts of Amazonian states, are clearly seen from the airplane (Fig. 13.2). The largest agricultural core emerged along highway BR-319 (Porto Velho – Manaus) in Rondônia state. Space images with long linear contours of fields, entering deep (up to 100 km) into the *selva*, and constant smoke of forest burnings became common "icons" for illustrating the environmental problems of *Amazônia*.

The Forest Code encourages mixed field/forest land-use patterns. Stimulating agroecosystems development may represent an advantage for environmental preservation, and increment in agricultural productivity increasing. For example, coffee trees are often grown under forest shade, which helps to develop coffee production in very hot areas and produce high-quality beans. So-called *extractivismo vegetal*, or use of wild spices, fruits, nuts, and other products is also very important in this region. According to estimates, in Brazil there are more than 3,000 large enterprises, specializing in this business, with a yearly income of 20 million US $. Many individuals also live from gathering *gevea* latex and other *selva* natural products. Recently, the Brazilian government established in *Amazônia* 10

[2] Within administrative borders of seven states: Amapá, Amazonas, Pará, Rondônia, Roraima, Acre, and Tocantins.

[3] For the previous years amnesty was declared.

[4] More than one third of deforested area concentrated in Para state.

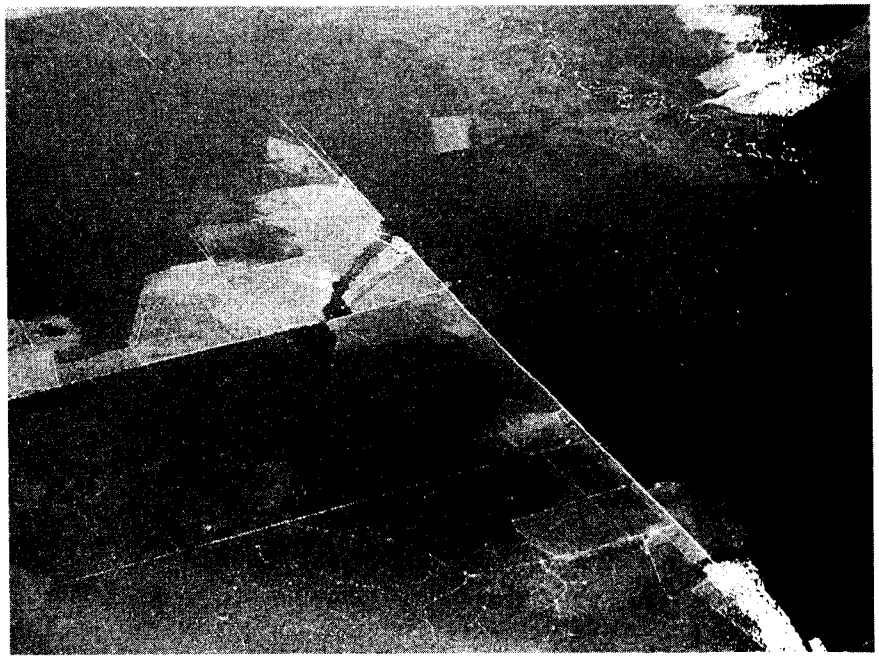


Fig. 13.2 Deforested area with recent agricultural development in Amazonas state south of Madeira River (photo: Naumov, July 2003).

large reservations, where only these activities are permitted, with a total area of 900,000 ha. Pasturing in partly deforested areas under sparse trees is also an alternative, sometimes a formal one, as it is difficult to measure tree density and prove whether the holding is under environmentally impropriate use.

South of the *Amazônia Legal* the Forest Code norms oblige preservation of only 35% of the holding to be under forest cover. This norm was primarily established for *cerrado* (savanna) areas, and then extended to so-called "transitional zones" *selva/cerrado* and *selva/caatinga*.[5] These areas are suffering from deforestation much more, than Amazonian states (Fig. 13.3). More than half the total deforested area corresponds to the states of Mato Grosso in the *Midwest* region and Maranhao in the *Northeast* (GEO Brazil 2002).

Agriculture is expanding to these transitional areas from the *cerrado* zone, which may be considered one of the last agricultural frontiers of humanity. Huge savanna areas where during the past 10–15 years more than 60 million ha were colonized, now produce half of Brazil's soybeans, one-third of its corn, and 40% of its cotton.[6] Three-fourths of the colonized

[5] *Caatinga* is a local name for bush vegetation in semiarid areas of the Northeast region.



Fig. 13.3 New agricultural area in transitional zone *selva-cerrado* (photo: Naumov, July 2003).

surface is now used as pastures, steadily substituted by commercial crop fields and feedlots. As expected, soon 40–50 million ha more will be converted into agricultural areas (Cultura da Soja nos Cerrados, 1993; IBGE 2002).

Modernization of Agriculture, Environmental Concerns and Land-Use Changes

Colonization of *cerrado* may be considered an extensive development, but paradoxically goes along with modernization of agriculture, based on awesome amounts of capital investment. Poor tropical soils, acid and contaminated with Fe and Al oxides, need special preparation; without limestone and mineral fertilizer application they will not produce valuable yields. Without applying 40–60 kg of N and P each and 60–80 kg of K it is impossible to get 2 Mt soybeans per ha – an average yield for this region

[6] By acreage affected colonization of *cerrado* may be compared with the pioneering colonization of the virgin lands in Siberia and northern Kazakhstan in the 1960s or colonization of the U.S. and Canadian Great Plains in the 19th century.

(EMBRAPA Documentos 46, 2003). Agricultural development in the *cerrado* zone was so fast, that it started without adequate technologies; initially capital was invested inefficiently since the main goal was terrain conquest, even without profit. NPK blends, produced for soils of the *Southern* region but inappropriate for *cerrado* obtained poor results while expenses for their usage absorbed up to two-thirds of the future harvest cost (Bernardes, 1996). Agricultural machinery was used on a scale incomparable with other regions of the country, which helped to conquer the *cerrado* rapidly, but concomitantly generated severe environmental problems such as soil erosion.

As *cerrado* is sparsely populated, the only way to develop agriculture there is to find appropriate technologies, that ensure increased productivity but do not engender environmental problems.[7] This explains the success of no-till practices recently adopted by many local farmers. In Goiás state nearly half of the fields are now under no-till schemes, mostly soybeans and corn, or soybeans and cotton rotation including cover crops such as millet and tropical grasses (Fig. 13.4). Nowadays no-till in Brazil is practiced on approximately 14 million ha, of which three-fourths fall in the *cerrado* zone. Brazil became one of the world leaders in no-till agriculture, approaching the USA when, by the end of the 1990s the method prevailed in 19.5 million ha (Manzatto et al., 2002).

But even though much friendlier to the environment, no-till does not mean "organic" agriculture, and in terms of intensity of land use, based on capital investment, surpasses most traditional techniques. For example, chemicals are needed to hasten decomposition of harvest residues (leaves, straw) which protect the soil from erosion and in part compensate organic matter loses.[8] Heavily fertilized and highly mechanized agriculture needs a smaller labor force but is very expensive. Data provided by the owner of a *fazenda* (large estate) in Goias state, who may be considered a pioneer in scientifically based agricultural practices in the region, showed that the yearly costs of chemicals, fuel, etc. per ha reach 1,000 US $ (A. Peters, pers. comm.).

Fertilizer use is one of the key points of modernization of Brazilian agriculture. According to some calculations, production of 16 major commercial crops of the country during the last 25 years increased 2.7-fold. Yet their cropped area grew only 22% while productivity increased two-fold. In other words, 40 million ha were saved from cultivation because of

[7] Population density varies from 2.8 inhabitants per km² in Mato Grosso to 14.7 in Goiás state, while in 2000 in São Paulo state, e.g., there were 147.2 inhabitants per km² (Censo Demografico, 2001).

[8] At the same time, environment is damaged by herbicides, their use obligatory in no-till systems.

Fazenda Sta Maria do Mirante, GO



Fig. 13.4 No-till agriculture in Brazilian *cerrado* (Goias state): cotton planted after millet as cover crop.

improved technologies, especially fertilizer use (Malavolta, 2000). Brazil is still no contender among the leaders in mineral fertilizer use on the world scale. Among Latin American countries the 40 kg NPK per ha of agricultural land in Brazil is negligible versus 200 kg and more in Chile, Costa Rica and Colombia (FAO Statistics Division, 2002). Thus, increasing fertilizers use means stoppage, if not decrease in converting tropical forests and savannas into agricultural land.

According to the 1995/96 Agricultural Census, only 40% of Brazilian farmers apply scientifically recommended doses of fertilizers (Censo Agropecuario 1998), and it is easy to forecast that in the near future fertilizer use and, respectively degree of intensification of Brazilian agriculture will increase. This process will affect land use especially in the *Northeast* region where, according to the census, share of those "modernized" farmers is less than 25%. The *Northeast* is characterized by concentration of commercial crop production within some cores and growing contrast between those cores and extensive periphery, leaving aside technological development of agriculture (and social development of rural areas). As an example, Petrolina-Juazeiro area in São Francisco river valley may be mentioned. Plantations here produce huge amounts of tropical fruits for export. On plantations, modern fertigation networks are common, with kilos of NPK applied per plant per year.

Cerrado colonization brings to light another feature of Brazilian agriculture, very important if not determinant for land use patterns in this

country—land tenure system. *Cerrado* was colonized mostly by large-scale enterprises, established by rich farmers, who migrated from *Southeast* and especially *South* regions. Average size of rural ownership in *cerrado* is 2–4,000 ha; many estates are much larger. For benefit owners, facilitating access to credit and market, these large estates are often united into rural cooperatives and other corporate structures. In addition, one may find sporadic settlements of landless peasants, which are useless in highly mechanized fazendas. This phenomenon brings to light the problem of unequal land tenure distribution in Brazil, which is also very important for land- use analysis.

Static Land Tenure Structure, an Obstacle to Land-Use Pattern Improvement

Since the colonial period, Brazilian agriculture has been characterized mostly by extensive growth without considerable changes in the traditional land tenure and land-use structure. Large-scale colonization processes were followed by displacement of archaic forms of land tenure toward recently colonized regions. Thus contradictions, typical for the main agricultural regions, especially based on the contrast between the *latifundia* and *minifundia* (large estate and small parcel unit), were apparent over huge areas. Enormous land reserves, available in the inner parts of the country, further contributed to probably the most unequal distribution of land ownership in the World. The contemporary colonization of *cerrado*, as one of the main directions of the national agrarian policy, shows that radical agrarian reform is still not on the agenda in Brazil.

According to the Agricultural Census of 1995/96, small holdings (less than 10 ha) represented nearly half the whole number, but owned only 2% of the agricultural area. Concomitantly a small number of the largest holdings (more than 1,000 ha) – only 1% of the total— owned 45% of all agricultural land (Agricultural Census, 1998).

However, on analyzing the corresponding data at the regional level, sharp contrasts in agrarian structure could be seen. These contrasts are explained not only by physical-geographical differences (climate, soils, and land resource availability in general), but also by the history of colonization of different parts of Brazil.

Northeast is the region of predominance of *minifundias*; in some states smallest holdings represent 80% of the total number and only a few in area. Agrarian overpopulation and high pressure over land resources is typical, along with archaic land-use patterns. *Minifundia* owners depend on jobs in large estates as their parcels are not enough to feed their families. Rural exodus to the cities and areas of recent colonization in *Amazonia* and

Midwest partly decreased the land hunger, but spreads the problem all over the country. In the *Midwest* region large holdings predominate, e.g. in Mato Grosso estates with more than 10,000 ha occupy 41.4% of the agricultural land; together with holdings between 1,000 and 10,000 ha they consitute more than 80% of the area. *North (Amazonia)* region has practically similar characteristics. Only the *South* region is free from *latifundias*, with family farms of the descendants of European immigrants who arrived in Brazil in the early 20th century being typical. The *Southeast* region has a combination of traditional *latifundia-minifundia* pattern and modernized large-scale enterprises, mostly sugar-cane plantations.

In terms of land use, traditional (archaic) land-use patterns may be considered conservative. Modernization, followed by radical land-use changes, is associated mostly with large-scale holdings, emerging in the recently colonized areas.

Archaic land-use patterns are maintained in the old agricultural regions and become an obstacle to agrarian reform. Brazilian governments have considered expansion of agricultural frontier toward inner regions of the country (*certões*) as a measure for solving the socioeconomic contradictions in rural areas. In the 1960s, the military government declared "Operation Amazonia" for settlement in areas deforested sometimes with napalm, by peasants from the *Northeast* suffering from severe droughts. But practices of subsistence agriculture, transferred from the *Northeast* region to *selvas*, proved inefficient. The governmental program of migration was not accomplished; only 1/10 of 200,000 peasant families, which were supposed to settle in *Amazonia*, settled along the new roads and rivers. At the same time, according to estimates of the Ministry of Agrarian Reform, more than 10.5 million Brazilian rural dwellers are landless or need extra land for survival. In the 1980s, the Brazilian government determined 410 million ha of private and 72 million ha of public lands for redistribution in favor of landless peasants. But soon these radical promises were forgotten; only 12.5 thousand peasants got land from the state through agrarian reform mechanisms (Naumov, 1983; deOliveira, 2000).

Polarization between landlords and landless people in Brazil is a long story; it has provoked conflicts in rural areas since the famous *Contestado* rebellion in the 19th century. Contemporary land-use changes, related to *cerrado* colonization, feed and what similar conflicts. A. de Oliveira, Brazilian geographer, shows in his publications the relationship between landless peasant movement and land ownership conflicts, registered in a long belt-like peripheral zone from Pará state in the *North* to Mato Grosso do Sul in the *Midwest*. These conflicts usually begin with uncontrolled occupation of *latifundias* by landless peasants, and lead to intervention of gangs of armed security hired by large estate owners. In 1990, in rural areas of Brazil 448 armed conflicts were registered and 70 persons, mostly peasant leaders,

murdered (deOliveira, 2001). Landless peasants, united since the 1990s into the national political movement "Sem Terra", establish their camps near the roads bordering estates. They are claiming, sometimes starting crops on these lands without permission. These camps, found in many states, have become another reality of contemporary land use in Brazil .

Global Demand for Agricultural Exports as Driving Force for Land-Use Changes in Brazil

Half a century ago Leo Waibel, a German geographer by origin and academic studies who spent several years Latin America, predicted the tropics and in particular Brazil as the future world breadbasket. Nowadays this forecast, underestimated at that time, has become reality and encourages geographers to analyze his scientific heritage (Etges, 2000). Since the 1980s Brazil has begun to play in the world agricultural markets a role not only of supplier of the traditional "colonial" goods, but also of such basic food staples as grains and oils. Staying the major producer of coffee, sugar cane and oranges Brazil now also ranks second in the world in soybean production, and in 2002/03 agricultural season even overtook the USA in average yield of this crop (Table 13.2). Production of corn, rice and other food crops is also growing fast. The country ranks first in the world in meat exports, with one of the largest herds of cattle, pigs, and poultry, growing along with substitution of natural pastures by seeded ones and fodder production (FAO, 2002).

New export-oriented agricultural commodities have made the Brazilian economy even more dependent on global demand for food and agricultural raw materials and their fluctuating conjuncture on the world markets than during the colonial sugar and coffee "cycles". According to estimates of the Ministry of Agriculture and Food Supply (2003), about one-third of the national export revenues were generated by agriculture, and during the

Table 13.2 Brazilian agricultural ranking in the World, 2001 (10 principal commercial crops)

Crops	World ranking	Share of the total world production, %	Share of the total world planted area, %
Coffee	1	25	20
Sugar cane	1	26	25
Oranges	1	37	27
Sizal	1	46	47
Soybean	2	20	18
Cocoa beans	2	7	10
Banana	3	10	13
Corn	3	5	8
Tobacco	3	8	7
Cotton (lint)	5	3	2

Source: FAO, 2002.

period of sale of yields of the main crops in June–August this share reached one-half. Agriculture is not losing its traditional position; on the contrary, it has transformed from the "relict" of the colonial economy into one of the key elements of the modern productive complex. Brazilian agriculture and related branches of industry count 17 to 20 million employees and serve as the main source of income for every second Brazilian family (deOliveira, 2000). Demographers, criticizing the official statistics data concerning the share of urban population, demonstrate that instead of the official degree of urbanization—82%, in reality by their basic economic activities and life conditions only 57% Brazilians may be considered urban dwellers (Folha do São Paulo, 2002).

Maximization of export revenues as a priority of the national agricultural policy and the principal goal of the majority of producers became for Brazil the main factor of mobility of land-use structure. Along with oscillation of share of the main commodities in Brazilian agricultural exports during the last decade of the 20th century, huge areas in different regions of the country suffered conversion of traditional land-use patterns. During 1990–2001 the total national coffee plantations' area decreased from 2,906 to 2,270 thousand ha as a consequence of unfavorable international prices and changes of geographical structure of the World market.[9] Soybean planted area grew from 11,551 to 12,672 thousand ha and sugar-cane plantation area from 4,271 to 4,906 thousand ha (IBGE, 2002). Recently Brazilian producers, pretending to substitute Zimbabwe farmers at the World tobacco market, started an ambitious program of plantation extension in the South region of the country.

The influence of the global market conjuncture factor on land-use changes in Brazil has become more evident on analyzing changes in geography of production of the main crops during the last decades.Historically, Brazilian agriculture is characterized by a high degree of territorial concentration of production of the main crop. The following Brazilian states are practically areas of monoculture, where only one crop occupies half and more of the total planted area: Mato Grosso and Mato Grosso do Sul (where soybean occupies 61.4 and 52.2% respectively); Alagoas, Pernambuco, Rio de Janeiro and São Paulo (sugar cane 56.3, 52.8, 58.8, and 43.9%); Espírito Santo (coffee 65.3%), Santa Catarina (corn 47.1%); Tocantins (rice 63.2%), Amazonas (cassava 50.6%). Taking into consideration crop rotations, two more states with a yearly corn/soybean cycle should be added: Parana and Goias with 30.1% and 36.2% corn, 35.6% and 40.7% soybean respectively

[9] [illegible] Brazil exports covered three quarter of the world coffee market in the [illegible] half and now just one fourth. Vietnam ranking [illegible] the World [illegible]

(IBGE, 2002)[10]. In some cases, the specialized area does not cover all the territory of state, as in the case of Bahia, where cocoa plantations occupy only 19.4% of the total state agricultural area. But this may be explained by the size and geographical diversity of state territory; cocoa plantations predominate in Bahia's southern part (region of Ilheus), in a typical area of monoculture.

This phenomenon may be illustrated by values of the so-called *Coefficient of localization (CL)*, calculated as:

$$CL_{ij} = S_{ij} \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} S_{ij}}{\sum_{i=1}^{n} S_{iq} \sum_{j=1}^{m} S_{pj}},$$

where i, p are given crops; j, q separate states; n total crops; m total states; S_{ij} planted area of crop i in region j.

The value of the coefficient shows the difference between selected state and the national average share of the given crop in total planted area. Thus the degree of territorial concentration of crop production and regional specialization of agriculture may be reflected. If the CL value is more than 1, the state may be considered specialized in the given crop production; more than 3 means a very high degree of territorial concentration (Censo Agropecuario, 1998). According to calculations made for 12 main commercial and subsistance crops (2002), CL value for cocoa in Bahia state equals 11.7; sugarcane plantations are concentrated in Sao Paulo and Rio de Janeiro states (CL respectively 5.7 and 4.2); oranges in Sao Paulo and Sergipre (CL 6.4 and 8.2); soybean in Mato Grosso and Mato Grosso do Sul (CL 2.6 and 2.2).

The geography of specialized areas of production of the main commercial crops in Brazil can be explained by both natural and economic factors. Narrow-specialized plantation agriculture is typical for states with tropical climate and lower level of socioeconomic development (*North* and *Northeast* regions); agriculture in *Southeast* and *South* regions is more diversified. Nevertheless, monoculture areas may be found in almost every state.

Comparison of location of the mentioned specialized areas in different periods of time since the 1970s revealed their ability to "migrate" all over the country. This migration may be explained a search for the optimal natural and economic conditions for production of each crop, consequent to deterioration of soils in the old areas of monoculture. Availability of reserve areas for colonization is also important.

[10] Not all of the mentioned states are leaders by contribution in the national gross volume production (e.g. in Minas Gerais state, ranking 1st in coffee growing, coffee plantations occupy 21.7% of the planted area).

Coffee plantation areas in the 1960s–70s shifted from São Paulo state to Paraná, by the end of the 20th century to the Minas Gerais and Espírito Santo states, and now are expanding in the Amazon region (in Rondônia state coffee occupies 26.2% of the total planted area). Plantations in Paraná state established for coffee production in *certões* (inner parts) of São Paulo with suitable red soils (famous *terrarossa*), which provided nearly half of all coffee yields, became inefficient because of fertility loses and high costs of labor force. In a few years, dramatic frosts of 1975 eliminated the main coffee plantations in Paraná state. National gross volume of coffee in 1976 dropped to just one-third of the previous amount. New plantations were established in Minas Gerais and Espírito Santo states (44 and 25% of the national production in 2000 respectively). The relatively small state Espírito Santo now produces more than twice the coffee of São Paulo, hardly justifiable given the territorial size of the latter. As a consequence of this process huge areas have undergone land-use conversion. Former coffee plantations in São Paulo were supplanted by oranges, the new priority in the state land-use pattern. In this state oranges occupy 14.9% of the total planted area; São Paulo's share in the national production of this citrus is 85% (in 1974, only 62%).

Sugarcane – the oldest Brazilian plantation crop, historically produced in northeastern states, shows much more stability. Since the 1950s the main area of sugarcane plantations belongs to São Paulo. In 1975, Brazil launched an ambitious program "PROALCOOL" of substitution of oil-based fuels by technical alcohol derived from biomass, which enabled expansion of sugarcane plantation area and production. As a consequence, sugar-cane plantation area up to 2000 had doubled, but mostly in the same state, São Paulo, which continues to increase its share in the national production: from 51% in1991 to 56% in 2000. Together with the bordering states of the *Southeast* and northern parts of Paraná, this specialized area now produces more than 85% of the sugar in Brazil. Further expansion of sugarcane plantations (up to 40%) may be predicted as Brazil is increasing exports of technical alcohol, mostly to Japan.

Cocoa, grown since the 18th century in Bahia state, recently entered *Amazonia*. Bahia's share in cocoa production decreased from 95% in 1974 to 53%; Para state where plantations were established in the middle Xingu River area, in 2000 produced 16% of the national gross volume of cocoa beans.

Soybean planting is the most dynamic sector of Brazilian agriculture. Brazil is a pioneer in producing soybean for export in Latin America. Since the late 1960s, when it started in the *South* region of Brazil, total soybean area in Latin America has increased 17 fold, from 1.5 to 26.2 million ha and production gross volume has leaped 36 times, from 2 to 69 million tons. Brazil became the main producer of soybean among Latin American

countries, is steadily losing its position (from 78.3% in 1970 to 54.4% in 2001), mostly because of expansion of this crop in the bordering countries: Argentina, Paraguay, and Bolivia. To offset this process, soybean planted area in Brazil is increasing (14.4% during 2000/01 agricultural cycle) along with growth of production gross value (11.6%). Soybean expansion is characteristic for the *cerrado* zone in the inner states. States of the *South* region with more than 80% of the national gross volume of soybean production in 1970, are now competing with Midwest states, where Mato Grosso state alone produces about 25% (for comparison: Rio Grande do Sul, which produced 45% of the national amount in 1970, registered only 17% in 2001).

Conclusions

The nature and reasons of main land-use changes occurring in Brazil during the last decades were analyzed. Colonization of new areas and modernization of agriculture, mainly influenced by the global market growing demand for traditional "colonial" and some new food and other related products, are considered the main driving forces of land-use changes. These changes, depending on geographical disparities within Brazilian territory, differ in macroregions and states. Statistical analysis, as well as field studies were used in land-use change investigations . Special attention was given to land tenure structure, considered a conservative factor for land-use changes.

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