Oksana Klimanova[1]*, Alexey Naumov[1], Yulia Greenfieldt[1], Rachel Bardy Prado[2], Daria Tretyachenko[1]
[1]Lomonosov Moscow State University, Moscow, Russia. Russian Federation, Moscow, GSP-1, Leninskie Gory, Faculty of Geography, 119991
[2]EMBRAPA National Soils Research center (Embrapa Solos), Rio de Janeiro, Brazil; Rua Jardim Botânico,1024, CEP: 22460-000, RJ
*** Corresponding author:** oxkl@yandex.ru

RECENT REGIONAL TRENDS OF LAND USE AND LAND COVER TRANSFORMATIONS IN BRAZIL

ABSTRACT. Regional trends of land use/land cover transformation in Brazil during 2001—2012 were analyzed in the following order: 1) identification of the types of transitions for different land use and land cover categories and aggregated groups of transformation processes based on the Global Land Cover Facility datasets, 2) analysis of national agricultural and forestry statistics to find out the principal socioeconomic drivers, 3) land cover and land use data merging to elaborate comprehensive typology of land use/land cover changes on a regional level. The study evealed 96 types of transitions between land cover categories, aggregated into 10 groups corresponding to driving processes. It was found that the main processes of land cover transformations is related to both natural and anthropogenic origins. Cropping and deforestation are anthropogenic processes, flooding and draining are the principal natural ones. Transformation of cultivated lands and reforestation are combined natural and anthropogenic. The contribution of natural factors is higher in the states of the North (Amazonia) and the Northeast macroregions; in the Center-West and the South anthropogenic factors make larger contribution. We have also detected considerable land use/land cover changes caused by agricultural development in densely populated states of the Southeast and the South. In both macroregions planted area expands due to increase of soybeans and sugar cane production, while area of pastures is shrinking. The trends of transformations of agricultural land use revealed as a result of statistical data analysis, match with transitions of land cover categories belonging to the aggregated group of cropping processes. Transformations of land cover types with predominance of shrub vegetation were the most problematic to interpret because of lack of comparable statistical data on pastures.

KEY WORDS: land use/land cover regional dynamics, Brazil, MODIS, agriculture, forestry

CITATION: Oksana Klimanova, Alexey Naumov, Yulia Greenfieldt, Rachel Bardy Prado, Daria Tretyachenko (2017) Recent regional trends of land use and land cover transformations in brazil. Geography, Environment, Sustainability, Vol.10, No 4, p. 98-116
DOI-10.24057/2071-9388-2017-10-4-98-116

INTRODUCTION

Conversion of virgin lands for agriculture followed by soil degradation, indiscriminate use of fertilizers and water pollution, loss of biodiversity, along with climate change has exerted strong pressure on terrestrial and aquatic ecosystems, compromising their sustainability. Over the past 50 years, humans were changing ecosystems more rapidly and extensively than in any comparable period of time before. This has resulted in a substantial and largely irreversible loss in the diversity of nature on Earth (MEA 2005).

The above mentioned transformations, mostly related with development of agriculture and forestry, require elaboration of appropriate action strategies, e.g. agri-environmental sustainability (Stallman 2011). Aiming the sustainability of rural landscapes as reconciliation of ecosystems preservation and satisfaction of demand in food, fiber, energy, water, raw materials and other goods and services, is a fundamental approach for studies of dynamics and functions of ecosystems and landscapes (Barkmann et al. 2004).

Modern studies of land use and land cover (LULC) transformation processes and specific features of land resources utilization are based on the analysis of remote sensing data of various spatial resolutions. Land cover means a present-day mosaic of vegetation cover, both natural and anthropogenic, the last one including agricultural crops, of settlements, industries and infrastructure, of lands without vegetation (fallow, glaciers, etc.) and water surfaces (Channan et al. 2014). Satellite imagery is a tool for highly precise identification of areas where land cover transformations are caused by particular anthropogenic and/or natural factors. However the interpretation of obtained results and the discovery of reasons of LULC changes, especially at the regional level, are possible only through the complex analysis of natural and socio-economic features of the territories.

In this context, characteristics of agriculture are considered as research priority for LULC studies. Geographical analysis reveals spatial heterogeneity of agricultural development, and provides bases for assessment of its role in land cover changes within different regions. This could be done with a great level of precision as statistical data on land use by administrative-territorial units become available for the increasing number of countries. As estimated in 2006, agricultural censuses were held in 134 countries of the world, and most of them contained data by states, provinces and similar units. For 2020, the UN Food and Agricultural Organization (FAO) plans to launch global data collection through the World Agricultural Census (World Programme FAO for the Census of Agriculture).

In recent years, several attempts were made to integrate the statistical and remote sensing data in order to evaluate geographical variety of agricultural production systems. An example is the project on global mapping of the differences in productivity of the main crops fulfilled by US and Canada researchers (Monfreda et al. 2008; Ramankutty et al. 2008). Factors influencing the yield differences, such as water and nutrients supply, were also taken into account. However, the yield was considered as a function of biological productivity, and the socio-economic features of agricultural production were ignored. A number of similar global projects are carried out under the auspices of FAO: the GLC2000 (studying the global land cover for the assessment of the state of ecosystems), the Global Livestock Information System, and the so-called Agro-maps project, involving compilation of universal cartographical database on agriculture at the "subnational" level (Agro-maps). The International Food Policy Research Institute (IFPRI) also has launched the program of global localization of harvest data (Global Mapping... 2006).

Joint analysis of remote sensing and agricultural statistics is also applied at the national level. E.g., in Brazil, the Companhia Nacional do Abastecimento uses remote sensing and analysis of the municipal statistical data for estimate crops productivity, being the GeoSafras (yield forecasting) and SIGABrasil (mapping of agricultural indicators) projects two basic components of this research (CONAB).

LULC studies are quite common at the level of one country, but usually they emphasize only main drivers of land use and land cover changes. E.g. publications on land use dynamics in Brazil focus on deforestation, expansion of soybeans and other commercial crops (Naumov 2005; Lapola et al. 2014). More often, rather short periods of time, usually 3—5 years are covered (Richards et al., 2014). At the same time, large-scale studies concerned with the detailed analysis of land cover changes basing on the remote sensing data for certain territories are common (Ferreira et al. 2009).

The objective of our paper is to evaluate regional trends of land use/land cover transformations in Brazil during 2001—2012, focusing on agricultural and forestry development as their driving forces. The methodology was based on the GIS assisted extrapolation of the big array of statistical data for small administrative-territorial units to the natural (soil and landscape) areas identified through the interpretation of space imagery.

STUDY AREA

Extensive territory of Brazil (8.5 million sq. km) consists of both densely populated areas and natural ecosystems of global value in different biomes (Fig. 1). It is rapidly colonized and developed, generally because of agricultural expansion. Understanding the current LULC dynamics will enable assessment of anthropogenic impact on the natural-territorial complexes and could serve as a base for the forecast of the future LULC changes.

Fig. 1. Brazil: biomes (Ferreira et al. 2013)

Brazil possess extremely high biodiversity, estimated the number of species from 1 to 8 million (Lewinsohn and Prado 2005) At the same time, it is one of global leaders in agricultural production (FAO 2015), playing an increasingly important role supplying food to the humanity (Foley et al. 2011). Reconciling agricultural production and environmental conservation is one of the greatest challenges this country currently faces (Ferreira et al. 2012).

Brazil ranks high in the rates of such processes as deforestation (mainly because of agricultural development and logging), conversion of natural pastures into cultural ones and cultivated fields, and the urban sprawl, which are the most important in the context of LULC changes. According to the Brazilian Institute of Geography and Statistics (IBGE), in 2010—2014 the forested area in the country was reduced by 2%. The area of natural pastures was also rapidly decreasing: in 2010—2012 its size dropped by 7.8%, and in 2012—2014 – by 9.4%. During the same two periods of time the area of agricultural lands has increased by 8.6% and 8.2%, respectively. Increase of the area of improved pastures (ameliorated and planted by cereals and leguminous forage crops) has slowed down (11.1% in 2010—2012, and 4.5% in 2012—2014), and some of them were converted to agricultural lands. At the same time, there was a significant increase in the area of planted forest (by 23.8% during 2012—2014), which substituted cleared forests and/or pastures (IBGE. Mudanças... 2016). Degradation of pastures is one of the main environmental issues in Brazil. Besides the low efficiency of cattle ranching, from the total of 190 million ha of improved pastures it is estimated that some 27—42% are degraded (Ferreira et al. 2014).

MATERIAL AND METHODS

The methodological scheme of the study includes three main stages: 1) identification of the types of transition between the land use and land cover categories and of aggregated groups of transformation processes on the basis of the Global Land Cover Facility (GLCF) data, 2) analysis of national agricultural and forestry statistics aiming to find out the principal socio-economic LULC drivers, 3) integration of both kinds of above mentioned data and elaboration of a complex typology of LULC changes. Our research is based on data, generalized for states of Brazil (26 states and 1 Federal district). As data source, we have used official publications and web pages of IBGE (this institute is responsible on population and agricultural censuses in Brazil, hold each 10 years), CONAB, and other institutions. The cycle of agrarian production in Brazil because of its geographical location mainly in the Southern hemisphere passes over the calendar New Year, therefore 2001–2002 and 2011—2012 agricultural seasons are the starting and the ending points of the studied period.

Understanding LULC transformation at different territorial levels requires to use remote sensing data (space imagery along with databases derived from their interpretation). The use of global land cover databases projected at the regional level seems quite adequate for such big countries as Brazil, which territory ranks fifth in the world. The state of land cover in Brazil during 2001—2012 was evaluated using the open data of the Global Land Cover Facility (GLCF) obtained through the MODIS satellite survey with the resolution of 5′x5′. These sources were considered as the most reliable basing on the comparison of a series of heterochronous global land cover data (Alekseeva et al. 2017). The data were analyzed using the environment of the ArcGIS Desktop for Desktop Spatial Analyst.
The legend to the land cover map compiled on the basis of MODIS data includes 17 classes, corresponding to the classification of the International Geosphere-Biosphere Program (IGBP) (Loveland et al. 2000). The classes were identified according to the height of trees and shrubs, canopy coverage of a forest stand, etc. (Table 1).

To find out social and economic drivers of LULC transformation, the analysis of national agricultural statistics was carried out. Changes in the harvested area under main grains (soybeans, corn, sorghum, wheat, rice, beans and others) and under other

Table 1. Classification of LULC of the International Geosphere-Biosphere Program (IGBP)

Classes with a predominance of woody vegetation	Classes with a predominance of shrubby and grassy vegetation	Classes with antropogenic transformed vegetation	Other categories
1. Evergreen Needleaf Forest	6. Closed Shrublands	12. Croplands*	11. Permanent Wetlands
2. Evergreen Broadleaf Forest	7. Open Shrublands	13. Urban and Built-up	15. Snow and Ice
3. Deciduous Needleaf Forest	8. Woody Savannas	14. Croplands/Natural Vegetation Mosaic	16. Barren and Sparsely Vegetated
4. Deciduous Broadleaf Forest	9. Savannas		17. Water surface
5. Mixed Forest	10. Grasslands		

* Any fields in which seasonal crops are grown, including minimal and zero plowing.
Source: Modified from Loveland et al. 2000.

commercial crops (soybean, sugar cane, cotton, coffee) were analyzed. The above-mentioned crops, except rice, account for a considerable share of cultivated land in Brazil, and the essential changes of growing and harvested area were typical for all of them during the studied period. According to the Ministry of Rural Development of Brazil, in 2009 soybeans covered 37.3% of all acreage under seasonal cultivation, sugar cane — 14.6 rice — 4.9 and cotton — 1.4% (Estatísticas... 2011). Sugar cane is cultivated on the same field during 4—5 years; it grows up after harvest and is poorly distinguishable from perennial crops on the space imagery. Rice is particularly interesting for our study, because the expansion of this irrigated crop causes a specific type of land cover transformation. Corn accounted for 23.4% of seasonally cultivated lands, however in Brazil it is most often grown up in one-year crop rotation with soybean. Because of overlapping of cropping area under these two crops it was not possible to consider data on corn cultivation separate from soybean. Coffee ranked first among perennial crops accounting for 35.4% of the total area (Estatísticas... 2011). Statistical data on afforestation were also used. Unfortunately, data on the area of pastures in Brazil are not published annually; they are available only in census years which do not coincide with the first and the last years of the period under our study. Therefore it was impossible to analyze the dynamics of areas under pasturing.

The processes described on the basis of statistical data analysis, i.e. expansion of agriculture and creation of forest plantations, do not cover all the types of changes identified through the use of MODIS data. However, we decided it was feasible to consider these two processes as the main drivers of LULC changes in Brazil.

RESULTS AND DISCUSSION

Structure and main process related to the LULC dynamics

The comparison of data for 2001—2012 made it possible to identify the types of land cover changes; each of them was assigned a two-digit index according to the IGBP classification (Table 1). The first digit corresponds to the land cover type in 2001, and the second — to the same in 2012. For example, type "2/9" means the change "evergreen broad-leaved forest — savanna"; 12/5 — "croplands — mixed forest". In total, 96 types of changes were identified and subsequently combined into 10 groups according to the processes causing the changes (Fig. 2, Table 2).

Table 2. The main processes of LULC transformation and corresponding types of changes

№	Process	Types of changes
1.	Draining	All changes for transitions from the 0 category; 11/2, 11/8, 11/9
2.	Flooding and partial flooding	All changes resulting in transitions to categories 0 and 11
3.	Conversion to cropland*	All changes resulting in transition to category 12 and changes causing the transition of non-cultivated lands to category 14
4.	Agricultural transformations (changes of vegetation cover on agricultural lands)	All changes relating to categories 12 and 14
5.	Deforestation	2/14, 2/10, 2/8, 2/9, 8/9, 8/10, 9/10
6.	"Savanization" (savanna vegetation replacing the deciduous forests)	4/9, 4/8, 5/8
7.	Decreasing share of shrubs in the vegetation cover	7/10, 6/7, 6/9, 6/8
8.	Increasing share of tree vegetation (in some cases, reforestation)	7/8, 7/9, 8/2,8/4, 8/14, 9/2, 9/4, 9/8, 9/14, 10/2, 10/8, 10/14, 14/2, 14/8,
9.	Increasing share of shrubs in the vegetation cover	9/7, 10/9, 10/7
10.	Construction and other forms of anthropogenic transformation within settlement territories	2/13, 8/13, 9/13, 10/13, as well as all transitions from category 13**

* Including minimum and zero plowing. ** To avoid the distortion of results because of relatively small size of areas of settlements, the impact of urbanization process is not specially considered in this study.

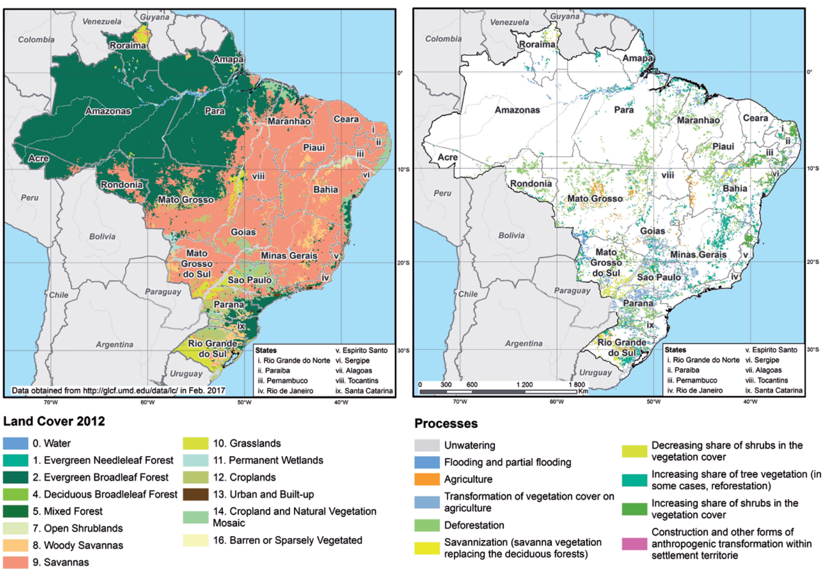

Fig. 2. Brazil: land cover, 2012 and LULC changes (by processes), 2001—2012. Data Source: GLCF, MODIS 2001—2012

Each type of changes and group of processes were characterized by: 1) area of changes; 2) share of each type of changes and group of processes in the area of each state; 3) share of each type of changes and group of processes in the total area of all types of changes in particular state. Similar approach was already used on the global scale, data generalized for the main biomes (Klimanova et al. 2017). Final results of the complex analysis of LULC changes are presented in Table 3.

The area of changes revealed by comparison of land cover data on MODIS space imagery for all categories of lands in the states of Brazil differs significantly: in 3 states of 27 (Mato Grosso, Bahia, Pará) it exceeds 100.000 sq. km, in 8 states it is less than 10.000 sq. km. Minimum area of changes registered was 1.600 sq. km in the Federal District Brasilia. However, the total area of this units just 5.800 sq. km. Minimum share of the area of change in the total area of the state is 0.9% (Amazonas) and the maximum – 36.2% (Paraná). In the North and Northeast there are states with low, average and high degree of land cover change, and in all states of the South the share of the area of changes is the highest in the country.

Regional differences are also legibly traced in the basic processes causing land cover changes. In the states of the North deforestation makes the greatest contribution to these changes. The contribution of agriculture is the most valuable in the state of Tocantins, which is located on the transition zone between the Amazon forest (port. Amazônia) and Savanna (port. Cerrado) biomes. In the states of Northeast processes of shrub vegetation change (considered in the our analysis as "others") have the greatest value; these states differ markedly from the rest of the country. Interpretation of driving forces of these changes is complicated; perhaps, they are caused by the natural transformation of shrubby vegetation. We can also assume that a considerable proportion of areas here were converted into pastures, which could hardly be distinguished from shrubby savannas or grasslands, especially during first years. In some states of the Northeast (Maranhão and Piauí) deforestation plays the most important role, in some other states of this macroregion (Pernambuco and Alagoas) the main process is conversion of deforested lands to agriculture.

The states of the Center-West which lay in the area of predominance of the Savanna biome, since 1980s are characterized by the most intense agricultural development, causing drastic changes in the structure of land use. In the state of Mato Grosso the deforestation is very important accounting for a half of area of all land cover changes. In the South and Southeast the role of agricultural development is also high, and the considerable proportion of already cultivated land is characterized by the transformation of land cover as a consequence of replacement by traditional crops by the new ones, also of conversion to cultural pastures.

The contribution of flooding or, on the contrary, draining as driving forces of transformation processes is more complicated to determine and requires verification. The pattern of these processes could be related to the annual changes of river flow and respective expansion or shrinking of wetlands. It could be implicitly proven by the greatest contribution of such processes to the structure of land cover changes in the states of the North, where they are obviously caused by natural factors. Reforestation could be considered as a result of both expansion of forest plantations establishing and natural vegetation dynamics.

MAIN DRIVERS OF LULC CHANGES

The calculations reflecting the dynamics of agricultural and planted forest areas by the states of Brazil made it possible to reveal the main types of changes in agricultural and forestry LULC. The results of this analysis can be found in Table 4.

AGRICULTURE

Analysis of agricultural development is most important for understand the reasons of land

Table 3. Structure and the main processes of land cover changes in the states of Brazil during 2001—2012

States by Macroregions	All land cover changes		Components of land cover changes in 2012*, %							Statistical data	MODIS data	Statistical data	MODIS data	CAS+FAS/ CAM+FAM, %***
	1.000 sq.km	% of total area of the state	Draining	Flooding (also partial)	Conversion to cropland	Agricultural transformations	Deforestation	Afforestation	Other processes**	Increase of cropland area, 2001—2012, % of total area of the state		Increase of planted forest area, 2001—2012, % of total area of the state		
										CAS	CAM	FAS	FAM	
North (Amazonia)														
Acre	4.6	3.3	0.0	0.0	0.0	9.9	78.1	9.8	2.3	-0.0	0.0	0.0	0.3	0.0
Amazonas	14.2	0.9	7.9	7.9	1.2	0.0	14.01	31.7	3.6	-0.0	0.0	0.0	0.3	0.0
Amapá	16.6	12.0	0.6	0.6	3.7	6.2	2.6	67.1	1.0	0.0	0.4	-0.3	8.0	0.0
Para	105.4	8.5	0.0	0.0	1.7	14.1	52. 6	22.4	0.3	-0.1	0.2	0.1	1.9	1.1
Rondônia	35.6	15.0	0.0	0.0	0.0	0.9	91.2	5.1	0.3	0.4	0.0	-0.5	0.8	2.5
Roraima	13.2	5.9	0.0	0.0	2.0	0.8	34.9	48.0	-0.0	0.1	0.1	0.0	2.9	0.1
Tocantins	7.2	2.6	0.0	0.0	9.6	3.6	27.7	47.0	1.0	2.0	0.2	0.4	1.2	91.5
Northeast														
Alagoas	8.9	32.5	0.0	0.0	6.8	46.4	0.0	2.4	44.4	-3.8	6.8	0.0	0.8	0.0
Bahia	115.8	20.6	0.0	1.6	15.2	16.3	17.8	17.2	31.9	0. 8	3.1	0.6	3.5	6.8
Maranhão	41.9	12.9	0.3	2.9	4.0	24.6	65.1	2.4	0.6	1.6	0.5	0.5	0.3	16.8
Paraíba	4.9	8.7	0.0	0.0	31.2	12.6	3.6	8.8	43.8	-2.5	2.6	0.0	0.7	0.0

Pernambuco	12.9	13.0	0.0	1.3	2.8	21.9	1.9	7.6	64.5	-2.8	0.4	0.0	1.0	0.0
Piauí	24.8	9.8	0.1	0.2	2.4	0.9	90.8	2.4	3.2	2.2	0.2	0.1	0.2	23.3
Rio Grande do Norte	12.5	23.9	0.0	1.3	8.0	1.5	0.0	9.8	79.4	-2.8	1.9	0.0	2.4	0.0
Ceará	3.1	2.1	0.0	9.3	6.8	18.8	5.5	16.7	42.9	-3.0	0.1	0.0	0.4	0.0
Sergipe	7.3	33.7	0.0	0.0	22.6	12.4	0.9	0.0	64.1	4.2	7.6	0.0	0.0	12.4
Center-West														
Goiás	36.0	10.6	0.1	0.9	19.4	36.8	1.2	40.8	0.8	4.9	2.1	0.2	4.3	48.0
Mato Grosso	129.8	14.3	0.1	5.9	20.6	4.8	50.9	14.8	3.0	8.5	2.9	0.1	2.1	59.8
Mato Grosso do Sul	72.4	20.2	1.1	11.7	11.9	6.9	6.6	35.4	26.5	4.9	2.4	1.5	7.2	68.2
Fed. District	1.6	27.5	0.0	0.0	13.9	24.2	0.0	51.3	10.7	8.4	3.8	0.0	14.1	30.6
Southeast														
Minas Gerais	91.0	15.5	0.3	2.4	12.64	24.8	8.5	50.9	0.4	0.99	0	2.5	0.0	0.0
Rio de Janeiro	3.8	9.2	0.0	1. 9	15.48	8.9	27.4	42.1	4.2	0.35	1.4	0.1	3.9	4.5
Espírito Santo	7.6	16.9	0.0	0.0	16.73	28.6	10.0	44.7	0.0	-0.86	2.8	0.6	7.6	3.7
São Paulo	55.6	22.4	0. 9	2.0	33.35	33.3	12.1	16.3	2.0	-1.38	7.5	3.2	3.7	14.2
South														
Paraná	72.0	36.2	0.2	1.04	38.85	31.6	21.6	5.8	1.0	10.33	14.1	2.5	2.1	35.5
Rio Grande do Sul	84.5	32.2	0.0	1.02	22.95	20.5	32.7	21.0	1.9	5.37	7.4	1.4	6.7	21.2
Santa Catarina	25.2	27.0	0.0	0.99	19.43	29.6	41.3	8.4	0.3	-1.48	5.3	5.6	2.3	20.7

* Total area of changes within each state equals 100%.** Other processes include numbered as 6,7,9,10 in the Table 2. *** Hereafter types of transitions match with the processes listed in Table 2. *** Comparison of the sum of cropland and planted forest area changes estimated by analysis of statistics (CAS and FAS) and remote sensing data (FAS and FAM), %.

Table 4. Main types of changes in agricultural and forestry land use in the states and regions of Brazil, 2001/2002 — 2011/2012[1]

Process (according to remote sensing data)	Type of changes[2]	Regions
Deforestation	Insignificant	The North: Acre (NA), Amazonas (NA), Amapá (N), Roraima (A)
Conversion to cropland	Forests → seasonal crops	The North: Rondônia (A)
Conversion to cropland	Savannas → seasonal crops	The Northeast: Maranhão (A), Piauí (A), Sergipe (NA)
Conversion to cropland	Savannas →seasonal and perennial crops	The Northeast: Bahia (A)
Agricultural transformations	Seasonal crops → perennial crops	The North: Pará (NA) The Southeast: Rio de Janeiro (A) Espírito Santo (A)
Agricultural transformations	Seasonal crops → pastures	The Northeast: Alagoas (A), Paraíba (A), Pernambuco (A), Rio Grande do Norte (NA), Ceará (NA)
Agricultural transformations	Seasonal crops, pastures → seasonal and perennial crops	The Southeast: São Paulo (A)
Agricultural transformations	Perennial crops → seasonal crops	The North: Tocantins (A)
Conversion to cropland, afforestation	Pastures → seasonal and perennial crops, forest plantations	The Southeast: Minas Gerais (NA)
Conversion to cropland, afforestation	Pastures → seasonal crops, forest plantations	The South: Rio Grande do Sul (NA); The Central-West: Mato Grosso (NA), Mato Grosso do Sul (NA), Goiás (A), Fed. District (A)
Agricultural transformations, afforestation	Pastures, perennial crops → seasonal crops, forest plantations	The South: Paraná (A)

[1] – N – natural processes, A – anthropogenic processes, NA – both natural and anthropogenic processes.
[2] - Only changes caused by agricultural development and creation of forest plantations.

cover changes in Brazil, being this sector a trigger of the recent economic growth of the country and providing 28% of the total national value of exports (FAO 2012). Its contribution to the LULC changes can be considered as of highest value for the states of the Center-West and the South, but it was also significant for different states in all other macroregions.

In the North (Amazonia) the LULC changes were not so significant in relation to the size the states, which make part of this macroregion. The only exception is the state of Tocantins, where the cultivated area under seasonal crops during 2001—2012 nearly doubled and has reached more than 0.5 million ha, or nearly 2% of the total agricultural area in this state. More than 90% of this area was planted by soybeans. The area under this crop has also increased significantly in the other Amazonian state Rondônia (by more than 40% or, 140.000 ha). At the same time, the area of coffee plantations in this state decreased by 119.000 ha (49% comparing with 2001), which suggests that perennial plantations could be converted into fields.

In the Northeast, the change of the area under seasonal crops involves from 0.8 to 4.2% of the area of each state of this macroregion. The most profound changes have occurred in the state of Alagoas (-57.3%), where seasonal crops planted area has considerably decreased (by 106.700 ha), while the area under coffee trees increased by 42.600 ha. In Bahia, Maranhão, Piauí and Sergipe states the seasonal crops area considerably increased: by 18.5% (544.000 ha) in the first one, and in two others it has almost doubled, increasing by 549.000 and 92.000 ha respectively. This is due to both the formation of a new large agricultural region of MATOPIBA[1] where soybean and cotton are expanding, also due to increase of the area of sugar cane plantations in a coastal strip along the Atlantic Ocean. At the same time, the area under seasonal crops decreased significantly in the states of Alagoas, Pernambuco, Rio Grande do Norte and Ceará. In the state of Bahia, particularly in its western part, the area of coffee plantations increased. In this state, and also in the state of Maranhão, large areas of forest plantations (307.000 and 168.000 ha respectively) were created during the first decade of the 21st century.

In the states of the Southeast different directions of the dynamics of the LULC changes was detected. In the state of Minas Gerais, area under grains (mainly soybeans), sugar cane, and both coffee and forest plantations increased considerably. The total increase of the area under seasonal crops and sugar cane amounts to about 1% of this state area; coffee and forest plantations area registered 2.5% increase. The most developed parts of this state have experienced conversion of pastures into agricultural lands; at the same time, unused slopes of the Plateau of Brazil started to be used for new plantations of coffee, which made the Minas Gerais state ranking first in Brazil by the volume of coffee harvest. Expansion of the area of sugar cane plantations by 1.3 million ha, or by 40% compared with 2005, was the main process of land use changes in the state of São Paulo, harvesting this state ¾ of this crop in Brazil. At the same time, the area of coffee plantations decreased both in São Paulo and in the Espírito Santo states. A considerable increase of the area under forest plantations in Minas Gerais, São Paulo and Espírito Santo states (855.000, 240.000 and 78.000 ha respectively) is worth attention. It can be explained by both the growing demand for wood charcoal, and the development of and the cellulose and paper production.

In the South, the state of Paraná registered a significant increase in the area under grains and sugar cane (by 2 million and 200.000 ha respectively), along with reduction of the area of coffee plantations by 60.000 ha and growth of the area of forest plantations by 0.6 million ha during 2001—2012. In the state of Rio Grande do Sul, similar changes in agricultural land use were recorded, but in this subtropical state sugar cane is not planted. At the same time, the areas under irrigated rice have increased here by 126.000 ha; the growth of the area under this crop accounts to 0,4% of the total area of the state. In another state of the South, Santa Catarina, planted area of irrigated rice also has increased, though not so considerably, while the area under grains decreased almost by 10%. In all states of this macroregion, large forest plantations were established (743.000 ha in Rio Grande do Sul, 489.000 ha in Santa Catarina and 221.000 ha in Paraná).

The Center-West macroregion faces prompt agricultural development of the Savanna areas, including both colonization of virgin lands and conversion of natural pastures. Therefore, a considerable increase of the area under seasonal crops is characteristic of all states of this macroregion: it grew by 8.5% of the total state area in Mato Grosso and

[1]Acronym, meaning the first letters from the names of four states: Maranhão, Tocantins, Piauí and Bahia.

almost by 5% in Mato Grosso do Sul and Goiás states. The area under sugar cane has also considerably expanded here. In all states of this macroregion large forest plantations were established, reaching those nearly 1 million ha in the state of Mato Grosso do Sul.

To conclude, agricultural colonization can be considered as the main driving force of the LULC changes in Brazil, being of continuous influence not only in 2001—2012, but also earlier. Half a century ago an attempt of agricultural development in Amazônia was made, which, however, didn't become as large-scale as it was thought (Naumov 1983). In the 1980s, colonization of the Savanna has started, mainly in the Center-West (Naumov 2010). This colonization campaign brought more notable results; according to the estimates, about 90 million ha, including 60 million ha of cropland, were developed (MMA, 2009). This campaign is still under way, mostly at the transition zone between Savanna and Amazon forest. At the same time, considerable changes occurred in agricultural specialization and land use in the previously developed Southeast and South macroregions (Naumov 2005; Naumov 2012). In general, the most considerable recent changes in agricultural land use in Brazil were almost everywhere caused by the expansion of soybean; during 2001—2012 its planted area in Brazil has doubled, reaching 28 million ha by 2012 (CONAB). Particularly noteworthy are the changes in the area under coffee plantations. By 2012, the coffee planted area in Brazil has dropped by 129.500 ha, or 6% compared with 2001. In the meantime, the main coffee plantations have shifted to Minas Gerais, increasing in this state by 137.300 ha during 2001—2012, and also have expanded in the Northeast, in Bahia. In the Amazon macroregion, in Rondônia state, coffee plantations area has dropped twice compared with 2001, when it was lager there, then in São Paulo, formerly main coffee producing state in Brazil. The area of rice cultivation changed considerably. In the South this crop is mostly planted in Rio Grande do Sul (more than 2/3 of the gross national harvest of this crop), being this subtropical region historically the area of irrigated rice cultivation (CONAB). In the 1980-s due to colonization of the Savanna the upland rice became a pioneer culture in the Center-West. However, in 2015 only 13% of the total planted area of this crop was located in the tropical part of Brazil, and even there 11% of the total area was under irrigated rice. This is a consequence of implementation after 2012 of nature protection laws, limiting the development of forests and declaring tropical rivers valleys as water protection zones (Acts 12.651 of May 25, 2012 and 12.727 of October 17, 2012 (Codico..., 2012). As a result, the acreage under rice decreased considerably nearly everywhere, except Rio Grande do Sul and Santa Catarina.

Unfortunately it was not possible to consider data on the area of pastures. The problem stems from the lack of available statistical data for the studied period, as the area of pastures by states is reported only during agricultural censuses, the latest one held in 2006. Another reason is considering pasturing as non-agricultural land use. The area of natural pastures in Brazil, meanwhile, permanently decreases. According to IBGE, after 2006 the area of improved in Brazil exceeded that of "natural" ones. The total area of the improved pastures, considered to appear "in good state" is estimated at 9.25 million ha, other 9.9 million ha are "degraded" improved pastures. Total area of "natural" pastures is estimated at 52.7 million ha, while 44 million ha were under seasonally cultivated croplands, 11 million ha under perennial plantations, 36 million ha under planted forests, and 51 million ha under nature protection areas and natural reserves (IBGE. Mudanças..., 2016).

FORESTRY

Processes related to forestry and other commercial and subsistence use of forests (the second ones still are important in Amazonia) play an essential role in LULC changes in Brazil (22 of 96 identified types of changes). According to national statistics, in 2012 Brazil ranked 2nd in the world by forest area amounting to 561 million ha, or about 60% of the national territory (IBGE 2002). Throughout the history of economic

[2] *In Brazil, soybean is considered as a grain crop.*

development forests were actively cleared in Brazil. Consequently, it is estimated in the Amazon biome between 15 and 18% loss of natural environments; in the Savanna, Pampas and Caatinga biomes 50% and in the Atlantic Forest 88% (GEO Brazil 2002; MMA 2012; UNEP 2016).

After 1970-s, when the large-scale colonization of Amazonia started, the problem of deforestation in Amazonia draw great attention of the world community. Nowadays, Brazilian government implemented public policies and environmental control which enabled reducing the deforestation of the Amazon (Laurance et al. 2002; Chazdon 2008; INPE 2015). In 2016, the Environmental Monitoring Program of the Brazilian Biomes was created by the Ministry of the Environment (MMA), whose purpose is to expand the mapping and monitoring of deforestation and land cover for all Brazilian biomes.

It is also important to stress, that regional differences in deforestation rates in Brazil depend on the nature protection legislation and public policies. Forest Code (BRASIL 2012) established a legal protection norm of 80% of total area of each rural land property for the Amazon forest biome, of 35% for the areas under Savanna, located in the so-called Legal Amazon region, and of 20% for the other areas under Savanna for the rest of biomes. Moreover, the protection of native vegetation in public reserves is consistently low outside the Amazon and below 5% for most biomes. As the largest part of area under native vegetation in each Brazilian biome is still found in private ownership, it is hard to control the accomplishing of the nature protection legislation (Ferreira et al. 2012), and to get the data for LULC analysis. In total, from 21 to 30 million ha is the estimated size of areas in Brazil, where natural vegetation should be restored and/or protected (Sparovek et al. 2010; Soares-Filho 2014)

The analysis of statistical data on protected areas of Brazil allows to evaluate their possible contribution, in particular, on reforestation processes (Protected Planet 2015). During 2002–2012, 17 natural reserves, 80 national parks, 205 managed natural areas, 83 protected areas with sustainable use of natural resources were established, mostly in the North and Southeast macroregions. However, the status of approximately 700 protected areas is not defined yet. We can assume, that the reforestation processes were driven mainly by expanding of protected areas in Amazonian states and in three states of the Northeast (Maranhão, Pernambuco, Piauí).

Forest plantations, created for production of commercial timber, cellulose and wood charcoal, which rapidly expands in Brazil, is another driving force of the LULC changes. In 2003 total national area of forest plantations in Brazil reached 1.6 million ha, 73.7% under eucalyptus and 25.3% under pine, with minor share of araucaria plantations (mostly in the state of Paraná) and acacia (in the state of Amapá) (BRASELPA 2003). By 2012, total area under plantations of eucalyptus and pines in Brazil reached 6.7 million ha (ABRAF 2013).

CONCLUSIONS AND FINAL REMARKS

The complex analysis of LULC changes in Brazil during 2001—2012 comprised land cover dynamics study based on satellite imagery data, and land use dynamics study, based on agricultural statistics data. For both approaches, the results were generalized at the regional level, being the states of Brazil basic units of research. Most of these states, surpass by area medium and even large European countries, which allowed to draw general conclusions on LULC changes and their driving forces. Nevertheless, we got reliable results, which can be discussed and developed in the further studies.

According to the data on conditions of land cover, in 2001—2012 the main processes of its transformation in the states of Brazil were driven by both natural and anthropogenic factors. Agriculture and, in large extent, deforestation are among the processes of anthropogenic origin, flooding and unwatering are the principal natural processes. Changes of vegetation cover on agricultural lands and reforestation are the processes of mixed natural and anthropogenic nature as they depend from both natural dynamics of vegetation, along with creation of forest plantations and conversion of pastures.

In general, the contribution of natural factors on LULC changes in Brazil is higher in the North (except Tocantins) and the Northeast (except Piauí and Pernambuco) macroregions. In Center-West and South macroregions anthropogenic factors make larger contribution. The latter are: development of agriculture, generally colonization as the country still has the considerable resources of undeveloped lands, and only 1/3 of its territory is used for cropping; conversion of pastures into agricultural lands; conversion of natural pastures into improved ones.

Comparison of the data on particular types of land cover changes and on the LULC transformation processes related with agricultural development shows for the most densely populated and developed states of Brazil the general correlation in trends, rather than the complete coincidence. According to the MODIS data, the areas with an increase of forest cover are larger by size, than statistics gives for forest plantations expansion. We assume that this is an evidence of the dualistic nature of this process, which depends from both natural and anthropogenic factors. Generally, the size of area of changes in the structure of cultivated lands is statistically less, than the area of transitions included in the "cultivation" category estimated assessed through the remote sensing data.

The suggested technique of comparative analysis of land use changes basing of the remote sensing data of medium spatial resolution and the data of agricultural statistics has shown its potential for identification of the main drivers of LULC transformation at the macro-regional level. Based of comprehensive geographical approach, it could be applied for different purposes, such as environmental assessment and territorial planning.

ACKNOWLEDGEMENTS

The research project was financially supported by the RFBR (Project 15-05-06186) and research project «Geographical problems of social and economic development of countries of the world» at the Faculty of Geography of MSU.

REFERENCES

Alekseeva N., Klimanova O., Hazieva E. (2017). Global databases on land cover and prospects of their application for the present-day landscape mapping. Izvestiya RAN. Seriya geograficheskaya, №1, pp. 126-139. (In Russian)

Associação Brasileira de Produtores de Florestas Plantadas (ABRAF) (2013). Anuário estatístico 2013 ano base 2012. ABRAF. – Brasília.

Barkmann, J., Helming, K., Muller, K., Wiggering, H. (2004) Multifunctional landscapes: towards an analytical framework for sustainability assessment of agriculture and forestry in Europe. Müncheberg: Centre for Agricultural Landscape and Land Use Research, 422 p.

Barten, F., Fustukian, S., Haan, S. (1996). The occupational Health Needs of Workers: The Need for a New International Approach. Social Justice, 23(4), pp. 152-163.

BRASELPA (2003). Asociaçao do Selvicultores do Brasil. Available at: http://www.braselpa.com [Accessed 20 Nov. 2017].

BRASIL (2012). LEI 12.651, DE 25 DE MAIO DE 2012. Diário Oficial da República Federativa do Brasil. Poder Legislativo, Brasília, DF: 28 de maio, 2012.

Channan, S., Collins K., Emanuel W. (2014). Global mosaics of the standard MODIS land cover type data. University of Maryland and the Pacific Northwest National Laboratory, College Park, Maryland, USA.

Chazdon, R. (2008). Beyond deforestation: restoring forests and ecosystems services on degraded lands. Science 320, 1458–1460. DOI: 10.1126/science.1155365.

Companhia Nacional de Abastecimento (CONAB). Available at: http://www.conab.gov.br/conteudos.php?a=533&t=2 [Accessed 20 Nov. 2017].

Departamento Intersindical de Estatística e Estudos Socioeconômicos (2011). DIEESE. Estatísticas do meio rural 2010-2011. 4.ed. / Departamento Intersindical de Estatística e Estudos Socioeconômicos; Núcleo de Estudos Agrários e Desenvolvimento Rural; Ministério do Desenvolvimento Agrário. -- São Paulo: DIEESE; NEAD; MDA.

Food and Agriculture Organization of the United Nations (2015). FAO. Statistical pocketbook-world food and agriculture. Rome: FAO. 231 p.

Ferreira C., Pardo R., Benites V., Polidoro J., Naumov A. (2009). Classificação semi-automática de imagens multitemporais Landsat-5 para análise do padrão de uso agrícola das terras do Sudoeste Goiano. In: XIV Simpósio Brasileiro de Sensoriamento Remoto, Natal. Anais XIV Simpósio Brasileiro de Sensoriamento Remoto. São José dos Campos: INPE, pp. 5781-5788.

Ferreira, J., Pardini, R.; M. J. P., Fonseca, C. , Pompeu, P. , Sparovek G., Louzada, J. (2012). Towards environmentally sustainable agriculture in Brazil: challenges and opportunities for applied ecological research. Journal of Applied Ecology, 49, pp. 535–541. DOI: 10.1111/j.1365-2664.2012.02145.x

Ferreira Manuel E., Ferreira J., Latrubesse E., Miziara F. (2013). Journal of Land Use Science: Considerations about the land use and conversion trends in the savanna environments of Central Brazil under a geomorphological perspective. DOI: 10.1080/1747423X.2013.845613

Ferreira, L. G., Sousa, S. B., Arantes, A.E. (2014). Radiografia das pastagens do Brasil. Goiânia: LAPIG/UFG. 214 p.

Foley, J., Ramankutty, N., Brauman, K., Cassidy, E., Gerber, J., Johnston, M., Mueller, N., O'Connell, C., Ray, D., West, P., Balzer, C., Bennett, E., Carpenter, S., Hill, J., Monfreda, C., Polasky, S., Rockstrom, J., Sheehan, J., Siebert, S., Tilman, D., ,Zaks, D. (2011) Solutions for cultivated planet. Nature, 478, pp. 337–342. DOI: 10.1038/nature10452

Global Land Cover Facility (GLCF). MODIS Land Cover. Available at: http://glcf.umd.edu/data/lc/ [Accessed 20 Nov. 2017].

Global Mapping of Agricultural Production Systems (2006). Pro-Poor Livestock Polity Initiative Meeting Report. Bangkok, 4–6 April 2006. Ed. by Robinson T., Thronton P. FAO, 2006. 79 p.

GEO Brazil (2002). Global Environment Outlook in Brazil. Brasilia, p.101

Instituto Nacional de Pesquisas Espacias (INPE) (2015). Monitoramento da Floresta Amazonica Brasileira por Satelite e Projeto Prodes. Instituto Nacional de Pesquisas Espaciais, Sao Jose dos Campos.
IBGE. (2016) Mudanças na cobertura e uso da terra do Brasil 2000 — 2010 — 2012 — 2014. Rio de Janeiro, 30 p.

Insituto Brasileiro de Geografia e Estadistica. (IBGE) (2002). Available at: www.ibge.br [Accessed 20 Nov. 2017].

Klimanova O., Tret'yachenko D., Alekseeva N., Arshinova M., Kolbovskij E., Grinfel'dt Yu. (2017) Changes of land cover on the continental and zonal levels: classification and mapping. Landshaftnye izmereniya ustojchivogo razvitiya: Issledovanie – Planirovanie – Upravlenie. — Tbilisskij gosudarstvennyj universitet Tbilisi. (In Russian)

Lapola, D., Martinelli, L., Peres, C., Ometto, J., Ferreira, M., Nobre, C., Aguiar, A., Bustamante, M., Cardoso, M., Costa, M., Joly, C., Leite, C., Moutinho, P., Sampaio, G., Strassburg, B., Vieira, I. (2014). Pervasive transition of the Brazilian land-use system. Nature Climate Change, v.4, pp. 27-35.

Laurance, W., Albernaz, A., Schroth, G., Fearnside, P., Bergen, S., Venticinque, E. (2002). Predictors of deforestation in the Brazilian Amazon. Journal of Biogeography, 29(56), 737-748. DOI:10.1046/j.1365-2699.2002.00721.x

Lewinsohn, T.; Prado P. (2005). How many species are there in Brazil? Conservation Biology, 19, pp. 619–624.

Loveland T., Reed B. , Brown J. , Ohlen D. , Zhu Z., Yang J L., Merchant W. (2000). Development of a global land cover characteristics database and IGBP DISCover from 1 km AVHRR data. International Journal of Remote Sensing. 216–7, pp. 1303–1330.

MMA (2009). Relatorio tecnico de monitoramento do desmatamento no bioma Cerrado, 2002 a 2008: dados revisados. Centro de sensoriamento remoto, IBAMA, Brasília.

Monfreda C., Ramankutty N., Foley J. A. (2008). Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000. Global Biogeochem. Cycles. V. 22. 19p. DOI:10.1029/2007GB002947

Millenium Ecosystem Assessment (MEA). Ecosystems and human well-being: Synthesis. Washington: Island Press, 2005. 155p.

Naumov A. (2005) Land use in Brazil: Major contemporary changes and their driving forces. Understanding Land-Use and Land-Cover Change in global and Regional Context. Ed. E.Milanova, J. Himiyama, I. Bičik. Enfield (NH), USA, Plymouth, UK. Pp. 208–223.

Naumov A. (2010).Spatial scenarios of the world agriculture development: the modern agricultural colonization in South America. Geografiya mirovogo razvitiya. Pod red. L. M. Sincerov, N. A. Sluka. T. 2. KMK Moskva, pp. 407–422. (In Russian)

Naumov A., Oliveira Ronaldo P., Pardo P., Turetta A. (2012). Balanced fertilization for sustainable development of agriculture in the savannas of South America: Towards a geographical approach. Geography, Environment, Sustainability. 5(4), pp. 84–95.

Naumov A. (1983). Agricultural development of Brazilian Amazonia. Latinskaya Amerika, №6, pp. 50-59. (In Russian)

Naumov A. (2013). Problems and prospects of the modern agricultural colonization in South America. Latinskaya Amerika. T. 466, № 7. pp. 36–49.(In Russian)

Richards, P. D., Walker, R. T., Arima, E. Y. (2014). Spatially complex land change: The Inderet Effect of Brazil's agricultural sector on land use un Amazonia. Global Environmental Change, Nov. 1; 29: 1-9. DOI: 10.1016/j.gloenvcha.2014.06.011.

Protected Planet. Available at: https://www.protectedplanet.net [Accessed 20 Nov. 2017].

Ramankutty N., Evan A. T., Monfreda C., Foley J. (2008). Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000. Global Biogeochem. Cycles. V. 22. 19 p. DOI:10.1029/2007GB002952

Stallman, H. R. Ecosystem services in agriculture: Determining suitability for provision by collective management. Ecological Economics, Vol. 71, 2011, pp. 131-139. DOI: 10.1016/j.ecolecon.2011.08.016

Sparovek, G., Berndes, G., Klug, I.L.F., Barretto, A.G.O.P. (2010) Brazilian agriculture and environmental legislation: status and future challenges. Environmental Science and Technology, v.44, pp. 6046–6053. DOI: 10.1021/es1007824

Soares-Filho, B., Rajao, R., Macedo, M., Carneiro, A., Costa, W., Coe, M., Rodrigues, H., Alencar, A. (2014) Cracking Brazil's Forest Code. Science, v. 344, pp. 363-364. DOI: 10.1126/science.1246663

Uhling A., Goldemberg J., Coelho S.T. (2008) O uso de Carvalho vegetal na indústria brasileira e o impacto sobre as mudancas climáticas. Revista Brasileira de Energía, 14(2), pp. 67—85.

UNEP (2016). GEO-6 Regional Assessment for Latin America and the Caribbean. United Nations Environment Programme, Nairobi, Kenya.

World Programme for the Census of Agriculture. Available at: http://www.fao.org/economic/ess/ess-wca/ru/ [Accessed 20 Nov. 2017].

Received on November 18th, 2017 Accepted on November 22nd, 2017

Yulia Greenfieldt is Senior Scientist at the Department of World Physical Geography and Geoecology, Faculty of Geography, Lomonosov Moscow State University. She received her Ph.D. in Geography from Lomonosov Moscow State University in 2005. Her research work deals with ecological problems, transformation of land cover and natural environment, geoecological assessment of land changes at regional and local levels, land-use planning in South America.

Oksana Klimanova is Associate Professor at the Department of World Physical Geography and Geoecology of Lomonosov Moscow State University, lecturer for courses "Physical Geography of World", "Geoecology", "Urban ecology and sustainable cities". Her research interests focus on spatial aspects of man-nature interactions at different spatial levels, regional environmental assessment, cultural landscapes and urban a planning. Main publications: Environmental Challenges for Tropical Areas (2012, with Alexeeva N.), Regional Environmental Studies: Natural and Anthropogenic Factors of Regionalization (2014), Multiscale Dimensions of Cultural Landscapes: mapping and typology at different levels (2015, with Kolbowsky E.), Global Land Cover Databases and its use for Present-day Landscapes Mapping (2017, with co-authors).

Alexey Naumov was graduated from the Faculty of Geography of Lomonosov Moscow State University (MSU), where in 1990 he also got his Ph.D degree. Dr. Naumov is Associate Professor and Head of Department of Social and Economic Geography of Foreign Countries at the Faculty of Geography of MSU, lecturer for courses "Geography of World Agriculture" and "Social and Economic Geography of Latin America". In 2001-2011 he also served as Coordinator of programs of the International Potash Institute in Latin America. His research interests focus on spatial aspects of land use, agricultural development, and modeling of agricultural systems. Main publications: Land Use in Brazil: Major Contemporary Changes and Their Driving Forces (2005), Agricultural geography of the world (2004), Spatial scenarios of world agriculture development: contemporary agricultural colonization in South America (2010), Balanced fertilization for sustainable development of agriculture in the savannas of South America: Towards a geographical approach (2012, with co-authors), Problems and prospects of the modern agricultural colonization in South America (2013).

Rachel Bardy Prado is graduated in Biological Sciences from the Federal University of São Carlos, has master and doctor degree in Science in Environmental Engineering from the University of São Paulo, specializing in Planning and Water Management from the Federal University of the Amazon (Brazil). She is currently a researcher at Embrapa Soils since 2003 and has been working in monitoring and planning of ecosystem services, especially water resources. She leads the Ecosystem Service Embrapa Research Network. Currently she is accredited in the Post-Graduation in Engineering of Biosystems of the Fluminense Federal University in Rio de Janeiro, Brazil.

Darya Tretyachenko graduated in 2001 from the Faculty of Geography of the Lomonosov Moscow State University (MSU). She is a GIS-specialist at the Department of World Physical Geography and Geoecology, Faculty of Geography, Lomonosov Moscow State University. Her research interests focus on GIS-mapping and spatial analysis of land-use/land cover patterns at global and regional level.