Land cover changes: regional verification of global trends with Australia and Argentina as a case study

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Abstract. Land cover change is considered to be one of the main factors of global changes, including climate change and biodiversity loss. This research devoted to an analysis of land cover transformation at regional level, in Australia and Argentina, aiming to verify the global trends of the beginning of XXI century. Basing on the MODIS data, we use rasters for the years 2001, 2012, and 2020, and detect transitions between land cover categories. For the key time period of 2001-2012 we identify land cover transformation processes, compare studied countries, and verify some of the global trends. Then, we discuss some of the natural and anthropogenic factors of land cover changes. One of the most significant process for both countries found out is shrub encroachment, which is a global trend. It is observed on up to hundreds of thousands of square kilometres, and takes 2-4% of the countries' areas. Besides this, the widespread processes are the degradation of woody vegetation with an increase in contribution from open spaces in non-forest zones (2-3% of each country area), and overgrowing of croplands (2-3%). In Australia, we detect the increase in contribution from tree vegetation (2% of country area). In Argentina – decline in the contribution from shrublands (2% of country area). The share of total areas of land cover transformation is about the same for the study regions and is estimated about 13-15% of the countries territories.

1 Introduction

As far as land cover transformation has such negative consequences as loss of habitat, fragmentation, degradation, the quantitative assessment of this transformation is very important for proper environmental management.

Land use and land cover (LULC) research are based mainly on the comprehensive analysis of remote sensing data, geospatial data (protected areas, river basins, climate reanalysis and others), statistical and analytical regional data (agricultural lands and livestock statistics, forestry, demographic statistics etc.), and field surveys (land cover

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monitoring, local population surveys) (fig. 1). The variety of methods is represented in reviewed papers regarding studied countries.

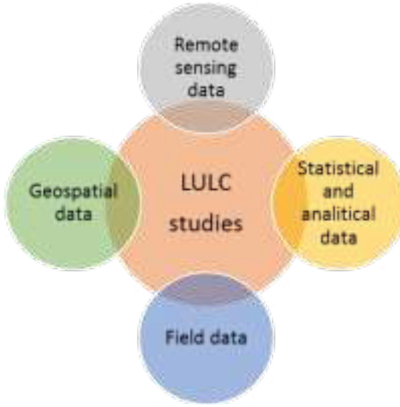

Fig. 1. Types of data for LULC research. *Source: compiled by authors*

In a paper of Calderón-Loor et al. [1] the land cover dynamics in Australia is analysed for the period over the 30 years, 1985-2015. The authors study the whole continent based on the large array of Landsat images. Ghahramani with colleagues investigates options of adaptation to climate change including land use change in southern Australia [2]. Sharp et al. conduct social research concerning local community values of LULC changes in Southeast Australia (New South Wales) [3]. Among papers in Russian, we would emphasize the studies of Nekrich [4] with the analysis of agricultural landscapes in Southeast Australia (Victoria state), and review of Baikin, Belichev, and Fedorov [5] where major issues of agriculture in Australia are discussed.

Considering research on Argentina, usually, authors discuss only a single issue of land cover change. For instance, approaches to modelling of land cover for biofuel production assessment [6]. Another example is the issue of economic policy and its influence on land cover dynamics [7]. Mostly the papers are devoted to regional research, Gran Chako and the Pampas. Gran Chako is famous because of the deforestation problems, which are investigated in the frame of LULC issues [8]. As for the Pampas, with the long agricultural development, it has such problems as land degradation and overusing. Modern research also consider ecological risks, connected with pesticides in agricultural techniques [9].

This paper is focused on identification and analysis of land cover transformation, including its natural and anthropogenic factors, in two countries and comparative analysis for Australia and Argentina. The conclusions of this research can contribute to understanding of the global and regional trends in land cover and present-day landscapes transformation.

2 Materials and Methods

This research is conducted basing on the scientific work of Klimanova with colleagues about the transformation of land use structure in the world “Land cover transformation at a global level during 2001–2012: mapping and analysis of changes” [10]. We applied the methodology developed by the authors to the regional case study. The aim of our research is an analysis of land cover transformation for the same time period, 11 years from 2001 to 2012, in Australia and Argentina. There are two stages of the research: 1) verification of the results, that our colleagues achieved for the global level [10], 2) analysis and comparison of trends in two countries. We also made a first step to land cover change estimation to the year of 2020 to understand if the vectors of the first decade transformation are changing in our days or not.

The same with [10] materials are used in this research: the Global Land Cover Facility (GLCF) project with MODIS database (Retrieved from https://geog.umd.edu/feature/global-land-cover-facility-%28glcf%29) – which is considered as the most relevant in global and macro-regional surveys and suits better for such research [11]. The land cover categories are selected out from a classification of the International Geosphere-Biosphere Programme that includes 17 classes [12]. Data resolution is 5´x5´ and it is analyzed in ArcGIS Desktop software.

There are some similar nature and social-economic characteristics between Australia and Argentina. Both countries have vast semi-arid and arid landscapes, tropical and sub-tropical deserts, grasslands, shrubs, and woodlands. The similar social-economic features are related to European expansion in the past, which led to landscape degradation such as deforestation and cattle breeding. Both countries have a high percentage of agricultural lands in their current land use structure (around 55% in both countries), large-scale land ownership, the important role of agriculture in GDP, and exports. Therefore, we chose Australia and Argentina to conduct a comparative study focusing on their similarities mentioned above, and to discover their trajectories in land use and land cover change.

The research has the following algorithm for each country. We detect transitions between land cover categories, comparing rasters of the years 2001 and 2012, and get a table with attributes of areas (square kilometres for each type of transition as grasslands to open shrubs, grasslands to open savannas or grasslands to croplands, etc.). Then, all types of transitions we classify to transformation processes, according to the approach from [10]. We compare the trends between study countries, and with global trends, published in [10].

3 Results

The data regarding transformation processes in Australia and Argentina are presented below. The research revealed 12 processes in Australia and 14 in Argentina (see Table 1, Fig. 1).

Table 1. The processes of land cover transformation in Australia and Argentina, 2001-2012

The process of transformation (*code*)	Area of transformation (sq. km)	
	Australia	Argentina
Increase in areas occupied by permanent snow *(P-1)*	-	2.136
Increase in areas of the active layer in polar zones *(P-2)*	-	172
Increase in contribution from tree vegetation (from 10-30% to 30-60%) in natural zones of all types *(P-3)*	**168.218**	22.250
Decline in the contribution from shrublands (from 10–60 to < 10%) in unforested zones *(P-4)*	63.727	**60.792**
Overgrowing of barren and sparsely vegetated lands (in natural zones of all types) *(P-5)*	**126.458**	25.155
Shrub encroachment *(P-6)*	**325.807**	**57.359**
Increase in contribution from forest vegetation from 30–60 to > 60%, in forest zones *(P-7)*	15.288	**31.090**
Degradation of woody vegetation with an increase in contribution from open spaces in unforested zones *(P-8)*	**141.020**	**80.611**
Plowing *(P-9)*	24.331	23.489
Overgrowing of regularly cultivated lands (in some cases, a change of cultivated crops is possible) *(P-10)*	**112.169**	**94.078**
Desertification *(P-11)*	1.130	4.724

Savannization *(P-12)*	5.982	1.207
Flooding *(P-13)*	3.890	1.328
Draining *(P-14)*	5.709	6.878

Source: data is calculated by authors, basing on MODIS data («The Global Land…», n.d.); classification of the processes is given according to [10], with minor changes ; bold font shows that process that identified on the territory more than 1% of the country area.

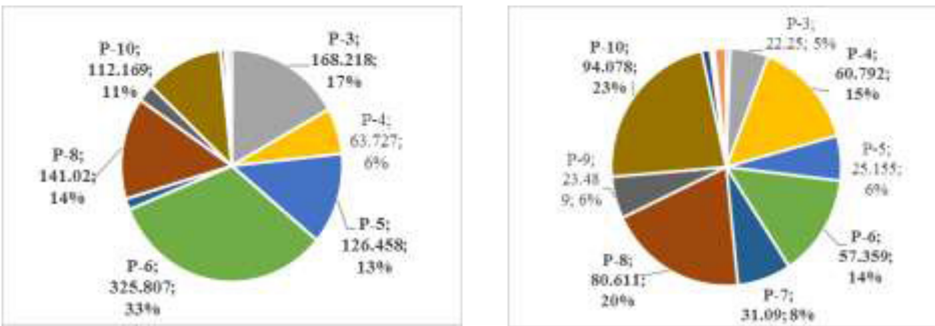

Fig. 2. Processes of land cover transformation in Argentina and Australia, codes see in Table 1 (thousands sq.km and share of each process from all territory under transformation, %). Bold font shows that process that identified on the territory more than 1% of the country area. *Source: calculated by authors, basing on the MODIS data, («The Global Land…», n.d.)*

3.1 Australia

Our results show that 13.5% of Australia area had land cover transformation in the period of 2001-2012. The dominant process here was *shrub encroachment* (Table 1, P-6). It is identified in the area of about 325.000 sq. km and associated mostly with the transformation of the grasslands to open shrublands. Such changes are be observed in the periphery of the tropics. These areas probably were pastures under the degradation processes, which is correlating with FAO statistic data (FAOStat. Land use. Retrieved from http://www.fao.org/faostat/en/#data/RL/visualize): decreasing of pasture area by 17% during 11 years in Australia.

Besides, in 2012 open scrublands grew up on the former barren and sparsely vegetated lands – mostly in the region of the Great Artesian Basin. The area of these changes is 125.000 sq. km – mostly in the basin of Kati Thanda –Lake Eyre, The Diamantina River and Cooper Creek. One of the factors of these changes might be climate dynamics: the amount of precipitation in 2000, 2001, 2010 and 2011 was higher than average across this region (according to data of Australian Government. Bureau of Meteorology retrieved from http://www.bom.gov.au/climate/history/rainfall/), which could probably contribute to the growth of shrubs formations.

We observe this process of shrubs encroachment on a wide area in Australia: around 6% of the country. This may confirm the findings at global scale level: the process of shrubs encroachment was classified by authors as widespread all over the world and observed in 11-13 natural zones in each geographical belt [10].

The second in the top list of widespread processes in Australia was *increase in contribution from tree vegetation (from 10-30% to 30-60%) in zones of all types* (Table 1, P-3). In total, it covered almost 170.000 sq. km or 2.2% of the continent.

We observe it across dispersed areas all over the continent within a few local examples: Cobar plateau, New South Wales, and some others. It is typical for the natural zone of woodlands, shrublands and savannas in the semi-arid sector of the tropics. Here, according to the remote sensing data we analyzed, savannas and woody savannas covered 50.000 sq. km to the year 2012. Such type of increase in contribution from tree vegetation is discovered also in subequatorial and subtropical belts, with the locations on the Cape York Peninsula and Arnhem Land.

Unfortunately, this process is problematic for interpretation. Despite the fact mentioned above, the savannas area in Australia had decreased by 3% from 2001 to 2012 due to the other processes (see below). The same with FAO statistics, it shows the plain dynamics in forestry of Australia. According to the climate data, there is no increasing trend in precipitations in Australia for these regions. Probably, afforestation works might explain some increase of woodlands area: around 7.000 sq. km for 11 years were replanted according to FAOStat. This might be typical for subtropical forests of the Great Dividing Range and at the Southwest part of the continent, close to Perth city.

The third place in the list of land cover transformation has the reverse process – the *degradation of woody vegetation in unforested zones* (Table 1, P-8), leading to increasing of open spaces. We observe this process in savannas, subequatorial and tropical belts (Arnhem Land and the northern part of the Great Dividing Range, where the density of tree cover is decreasing), covering around 140.000 sq. km in that regions (1.8% of Australia). Sometimes this process led to the total degradation of tree cover and its replacement by grasslands. It is observed in the regions of the Blue Mountains and Flinders River basin, where changes might be caused by anthropogenic factors – overgrazing (the valley is used as pasture for sheep and cattle).

The results regarding *overgrowing of croplands* and *plowing* are a bit contradictory and should be verified more. According to the MODIS data, we can see the replacement of croplands by grasslands or open shrublands (around 90.000 sq. km). At the global level, it is considered as degradation of croplands [10]. So far, the decreasing of croplands area showed the trend minus 16% (16% of decreasing). However, we assume that these processes are the consequences of the mixed crop-livestock farming system in Australia [13, 2]. This management is practising in Riverina valley, Murrumbidgee valley, Murray valley, Darling Downs region. Potentially possible to assume that the mentioned processes are part of this management system and do not demonstrate trends of overgrowing of croplands or plowing. At the same time, FAO statistical data shows the increase of croplands area by 12%. There is one more aspect here. Some researchers highlight that in some regions plowing process and replacing brigalow scrubs (*Acacia harpophylla*) with croplands or cultural pastures is happen, and it might cause environmental problems, such as degradation of water quality and increasing concentrations of phosphates and nitrates [14].

To the year 2020 the main types of transitions are defined as following changes (comparing with 2001): sparse vegetation to grasslands and vice versa (180 thousands km^2, and 70 thousands km^2), grasslands to mosaic cover (trees, shrubs and herbaceous cover (12 thousands km^2), sparse vegetation to mosaic cover (10 thousands km^2).

3.2 Argentina

As for Argentina, 14.7% of the land had a transformation from 2001 through 2012. According to the remote sensing data, the most significant process for that time was *overgrowing of croplands* – we register it on 3.4% of the territory. During 11 years, it exceeded 90.000 sq. km, mostly in the Pampas – the main agricultural region of the country. It could be caused by several factors. Partly overusing and soil depletion and further – changing croplands to pastures (according to: Ministerio de Agroindustria - República Argentina. Retrieved from https://www.agroindustria.gob.ar). Partly – management features and crop rotation, the similar situation with Australia.

The process of *degradation of woody vegetation with an increase in contribution from open spaces* (P-8) is widely demonstrated in the Gran Chako region. Here cutting down the quebracho (especially rich for tannins *Schinopsis lorentzii* and *Aspidosperma quebracho* species) led to replacement savannas and woody savannas by grasslands or shrubs. Such changes were typical for riverside landscapes. According to the data of Gran Chako Monitoring System (retrieved from http://monitoreodesmonte.com.ar), for the period 2001-2012, the cutting down of quebracho is estimated at around 220-475 ha per year. As a result, the deforestation area reached 36850 sq. km. Currently, the deforestation trend is slightly decreased. From 2012 to 2019 Gran Chako had lost 12.000 sq. km. Along with Gran Chako, the second region with the same processes is the Region Mesopotamica, where the area of agricultural lands was expanding. In total, the area with the process of degradation of woody vegetation was 80.000 sq. km.

We have found a *decline in the contribution from shrublands* (from 10-60% to less than 10%) in non-forests zones (P-4) in wide areas. It can be observed the replacement of shrubs with grasslands. Typical territories are the Region Mesopotamica (the Province of Corrientes), the Pampas (partly), the Gran Chako (east part), the Northwest (mountain regions), and Cuyo. The total area of the process was 60.000 sq. km. The process can be related to overgrazing and degradation of Histosols.

Analysis of MODIS data shows *shrub encroachment* as well (60.000 sq. km). It is registered fragmentarily all over the country: on the south of Patagonia (the area of traditional cattle breeding), in the Pampas, in the Northwest of Argentina, in the Andes. It is worth to mention, that areas with the process of scrub encroachment are mostly coinciding with the areas of desertification [15].

The analysis of data for the year 2020 shows that the main types of transitions are following : tree cover to shrublands and vice versa (35 thousands km^2 and 6 thousands km^2), shrublands to tree cover, tree cover to mosaic, tree cover and shrublands to herbaceous cover (about 5 thousands km^2 for each).

4 Discussion

Comparing findings from Australia and Argentina, we have found out similar trajectories in land cover change (Fig. 1). There are processes with a significant area (more than 1% from the country area) in both countries:

- Degradation of woody vegetation with an increase in contribution from open spaces in unforested zones (P-8);
- Shrub encroachment (P-6);
- Overgrowing of regularly cultivated lands (in some cases, a change of cultivated crops) (P-10).

Degradation of woody vegetation is associated with deforestation in savanna zones (the Gran Chako, Arnhem Land).

Shrub encroachment is observed 1) in the periphery of tropics (the Great Artesian Basin, Gran Chako) and 2) in subtropics and temperate zone (the Pampas and Patagonia). The factors of this process vary from climate dynamics (in Australia shrubs replaced grasslands on the period of increase average annual precipitation) to succession (in the Gran Chako shrubs grow in the deforestation zones) or overgrazing on pastures (in Patagonia shrubs replaced grasslands).

Overgrowing of croplands (by shrubs or grasses) might be a stage of crop rotation (change of cultivated crops), which is typical for study areas. There is no reduction of croplands area, according to the statistical data.

In addition to the main processes of land transformation mentioned above, several others are observed in both countries as well; however, they take place only limitedly. These processes include (1) Increase in contribution from tree vegetation (from 10-30% to 30-60%) in zones of all types (P-3); (2) Decline in the contribution from shrublands (from 10–60 to < 10%) in unforested zones (P-4); (3) Overgrowing of barren and sparsely vegetated lands (in zones of all types) (P-5).

Findings on land cover transformation in Australia and Argentina partly confirm the results, published previously. For example, Calderón-Loor with colleagues noted the following processes: degradation of woody vegetation with increasing of open areas in non-forest zones; overgrowing of croplands; and partly decreasing of shrub formations (from 10-60% to less than 10%) in non-forest zones [1]. This corresponds with our findings. On the other hand, the authors declared the increase in the grasslands area as well. However, our data demonstrate decreasing in the area of this land cover type (by 80.000 sq. km in 2012). As for our understanding, this discrepancy might be explained by difficulties in the term of “grasslands”, which can be interpreted in different ways.

According to the [10], shrub encroachment is defined as widely observed all over the world. Our findings regarding Australia and Argentina confirm this global trend. Moreover, in Australia shrub encroachment is considered as one of the factors of land degradation (along with a loss of fertile soil horizons and deflation), and to face this problem the government adopted a program on land neutrality [16].

The process named at the global level as “overgrowing of croplands” [10] in regional scales might have different aspects. According to our results considering Australia and Argentina, this process is one of the most widespread in both countries (observed on 3.5% area of Argentina and 1.5% - Australia), but cannot be verified as “overgrowing” by statistical data (Australian Government. Bureau of Meteorology. 121 years of Australian rainfall. retrieved from http://www.bom.gov.au/climate/history/rainfall/): croplands area in these countries have light positive dynamics for the study period. Thus, the process might be a change of cultivated crops in fact and should be discovered in further research.

5 Conclusion

In this research, the verification of some global trends was done, as well as regional trends were found out and compared in the studied countries.

In Australia and Argentina for the period of 11 years, land cover changes are observed on 15% of the counties area. The main processes of transformation are similar; there is degradation of woody vegetation with an increase in contribution from open spaces in unforested zones, shrub encroachment, overgrowing of croplands (which means in fact change of cultivated crops or the process of some agricultural transformations in general).

There are some differences in the studied countries. In Australia, increase in contribution from tree vegetation (from 10-30% to 30-60%) in zones of all types occurred in some areas. In Argentina, decline in the contribution from shrublands (from 10–60 to < 10%) in unforested zones, increase in contribution from forest vegetation (from 30–60 to > 60%) in forest zones, as well as plowing were observed.

In the context of natural zones, the most significant land cover changes are observed in the zones of woodlands and shrubs (tropics and subtropics). This is well corresponded with the Klimanova et al. findings at the global level. Along with this, Australian tropical deserts and semi-deserts have quite significant transformations as well (in contrast to the global trend): in 2012, we could see shrubs formations on the former barren and sparsely vegetated lands. This is perhaps the regional feature of Australia and the dynamics of the Kati Thanda–Lake Eyre and its surroundings.

The types of transitions for the period 2001-2020 defined in this research will be analyzed further as processes and compared with trends discussed above. The findings of this research will be useful for further investigations on regional environmental issues, including land cover change in other regions of the world.

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