Use of GIS Technologies in Order to Assess the Degree of Transformation of the Land Cover Structure

D A Tretyachenko[1], Y S Greenfieldt[1], O A Klimanova[1], N N Alekseeva[1], M A Arshinova[1], E Y Kolbowsky[1]

[1]Faculty of Geography, Lomonosov Moscow State University, Russia, 119991, Moscow, GSP-1, 1 Leninskiye Gory

E-mail: daria.trt@gmail.com, y.greenfeldt@gmail.com, oxkl@yandex.ru, nalex01@mail.ru, amari_geo@mail.ru, kolbowsky@mail.ru

Abstract. The main purpose of this study was to identify global trends in the transformation of land cover structure for 2001-2012, that have significantly affected the structure and dynamics of modern landscapes.

1. Introduction

In the world practices of scientific research geo-spatial data bases Land Cover Change are wildly used to assess the Degree of Transformation of the Land Cover Structure. They are generated on the basis of spectral radiometer MODIS (Moderate-resolution Imaging Spectroradiometer). Data of the Land Cover Change are the secondary images obtained after processing of MODIS data in certain zones and are distributed in free access in Internet network [4]. These data contain information on spatial distribution of vegetation types of natural and anthropogenic geneses, urban and built-up areas, territories free of vegetation (waste grounds, glaciers, etc.), water bodies, water streams, and over moistened areas [1].

The object of the Land Cover Change analysis is the category of land cover, which in reality is only relatively connected to belt-zone specifics. For instance, the grassland category can be met both in Arctic and sub-Equator latitudes, Mixed Forest category exist within the moderate, subtropical and tropical zones. Therefore, to interpret results on the basis of landscape approach, it is necessary to use independent operational territory landscape units, according which the analysis and assessment of measurements could be conducted. The most applicable for such territory unit seems to be the natural zones with the uniform of hydrothermal, soil-geographic and geo-botanic characteristics.

2. Material and methods

As mentioned above, as a data source on land cover conditions for 2001-2012 is publically available data of Land Cover Change [4]. As a media for analysis the GIS package ArcGIS for Desktop Extension Spatial Analyst is used.

To assess the degree of transformation of the land cover structure, the aggregated global data with horizontal resolution 5'x5' in geographical coordinate system WGS-84 (World Geodetic System – 1984 were used. Considering that the main goal of the analysis was the calculation of area variations in land cover structure over the globe, the data were projected into Cylindrical Equal Area projection. The projection was carried out with the basic complectation of the ArcGIS for Desktop Basic. The cell

size of output raster was determined as 1000, firstly for conformity of further calculations of the areas of land cover variations, and secondly, since it provides the optimal raster dimension and does not allow losing the data metallization.

For raster data preprocessed with the method mentioned above the instrument Combine of ArcGIS for Desktop Spatial Analyst was used. Each combination of input data of two rasters was distinguished as a unique zone. For each zone the number of included cells was calculated, which in this case is 1 km ^{2}, since the resolution of analysed rasters is equal to 1000 m. The tables obtained were supplemented with the text description of the land surface (Join Field instrument), also the percent of existed changes within the initial zone (from the zone in 2001) was calculated.

The legend for Land Cover Change includes 17 classes (from 0 to 16), corresponding to classification of International Geosphere Biosphere Programme (IGBP): 0 is for the class of Water,1 is for Evergreen Needleleaf Forest, 2 is for Evergreen Broadleaf Forest, 3 is for Deciduous Needleleaf forest, 4 is for Deciduous Broadleaf Forest, 5 is for Mixed Forest, 6 is for Closed Shrublands, 7 is for Open Shrublands, 8 is for Woody Savannas, 9 is for Savannas, 10 is for Grasslands, 11 is for Permanent Wetlands, 12 is for Croplands, 13 is for Urban and Built-up, 14 is for Cropland and Natural Vegetation Mosaic, 15 is for Snow and ice, 16 is for Barren or Sparsely Vegetated.

Thus, the data for Land Cover of 2001 and 2012 were compared where the each cell which is characterized with corresponding numerical index from 0 to 16 according to the classification. With the change of the land cover class from 2012 in comparison with 2001 the change of numerical index is occurred. It allows segregating a sell (or the number of sells) as an area of certain types of changes. For example, index 12.5 means that the arable lands covered the cell in 2001 were replaced with mixed forest in 2012.
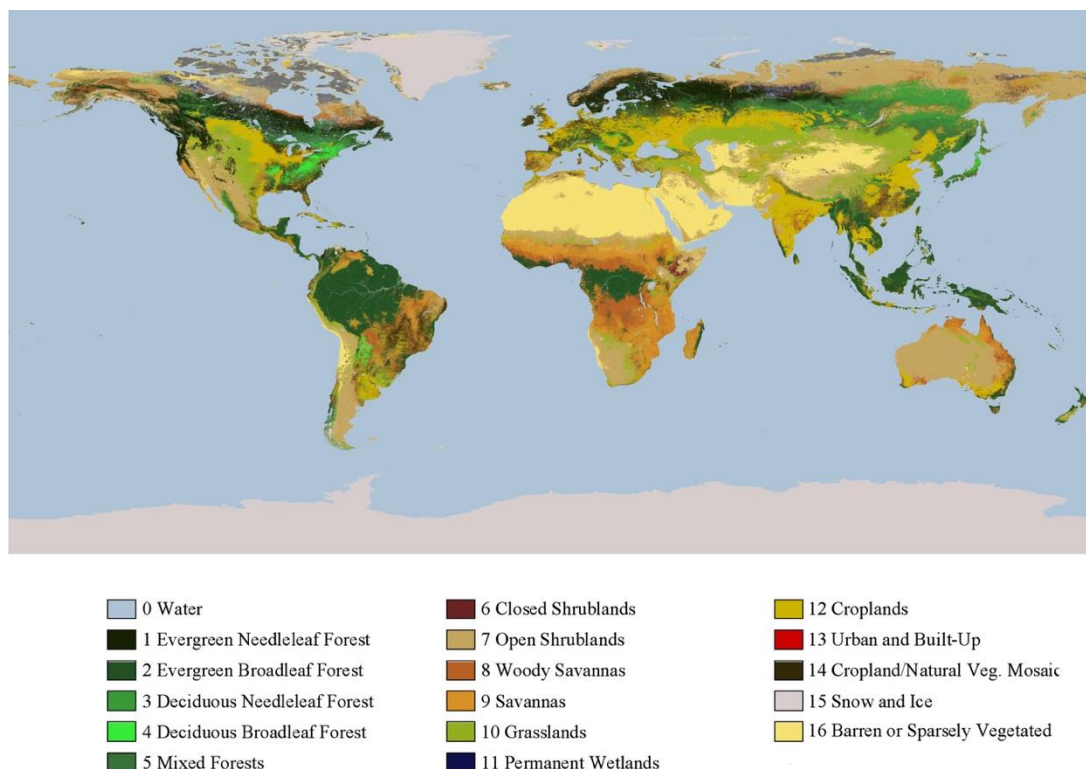

Figure 1. Global Mosaics of the standard MODIS land cover for 2012.

The generated data array allowed calculating the values of relative fractions of the classes of land cover for two time periods and determining the relative decrease/increase of the areas under consequent classes.

Analysis of the data demonstrates a contradictive tendency for different continents and not often corresponding to available statistical data. Among these processes variations of evergreen wide leaves forests in Eurasia and North America could be mentioned, while such forests areas declines in Africa and South America, what contradicts commonly accepted understanding of the process of forest decrease in tropical regions and increase of forested areas in the middle areas. Rarefied bush formations in Africa, South America and Australia demonstrate a tendency to shortening both in absolute and relative measures, which might be related to conditioning of desertification in these areas. Areas covered with permanent snow cover and glaciers all over the World (except for North America) are decreasing. In Africa such class of land cover is not presented at all. Elsewhere the increase of territories without vegetation is observed. The most significant share is observed in Africa. However, we should mention that the temporary changes are generally not high.

Additionally, the transfer between different classes, which let us to suggest that the most common classes and territories occupied by these classes are more or less stable, that in its turn suggests that transaction types for any continent and share of each class are remain stable.

The boundaries of natural zones subjected to analysis of land cover transformation at zonal level are obtained from the electronic atlas of the World "ArcAtlas: Our Earth" (1996) [2]. Along with this the initial map contains the boundaries of geographical bans of the zonal landscape types at the plain and the altitudinal landscape specters in the mountains and intrazonal landscapes (river values, mangroves, saline lands, glaciers, and marshlands). According to explanation note for the map the areas of the natural zones are characterized with the uniformity of hydrothermal, soil-geographic, geo-botanical characteristics, which make them the most appropriate operational-territory unit for conducting spatial-time analysis of land cover. In distinguish of land cover characteristics the natural zones have as an attribute adjunct belongings to a certain geographical belt. Totally 26 natural zones are marked out on the map; they are related to seven geographical belts.

The numerical data were obtained regarding the changes of soil cover categories from 2001 to 2012. All natural zones were divided into three groups. Changes in each group covered: 1) less than 10% zone area (total 6 zones); 2) from 10 to 20% (total 11 zones); 3) over 20% (total 9 zones). Among relatively stable (the first group) are zones occupying huge areas (i.e. tropical deserts) and relatively insignificant by square (i.e. steppes of chilly plateaus). The third zonal group (with maximum variations) includes five zones of subtropical band excluding deserts and semi-deserts, two forest and sparse forests, i.e. moderate climate (taiga) and Arctic tundra bands.

There are the processes of vegetation free land obliteration in the desert zones of moderate and tropical belts. In moderate climate band the square of this area in relation of the general band square is significantly higher (4,81%), than in tropics (1,15%). Semiarid areas of moderate and tropical bans show the similar process specters, i.e. vegetation free land obliteration and bush obliteration. However, semiarid areas of the moderate zone are combined with decrease of bush fraction and obliteration of cultivated lands (probably irrigated in the past). An opposite trend – shortening of projective vegetation cover, i.e. an activation of desertification process – is typical for semiarid areas. In the steppe-forest and steppe zones the dynamics is characterized by increase of plugging but at the same time areas of slinging of cultivated lands is fixed. In the forests of equatorial zone both processes – increase of forest vegetation and its degradation – are observed. In taiga zone and mixed and broad leaf forests the processes of forest vegetation and structural variations determine a role play in increasing of forest vegetation fracture and slinging of previously cultivated lands.

3. Results and discussion

The obtained results demonstrate first of all the inventory of the changes of land cover and need for further deeper analysis that requires additional information. Verification of data obtained in this study based on the key areas supported with the reliable statistical information on the land use and literature data. It is necessary to identify the factors determining the observed variations of the land cover including climatic and anthropogenic (demographic and socio-economic).

The results allowed compiling a preliminary classification of the land cover variations for the considered period and identifying the types of transformation processes at the global scale. Four types of the processes were identified for equatorial and sub-equatorial belts, two types were for tropical belt, six types were for forest and sparse forests of tropical belt, six types were for non-forested zones of subtropics, seven zones were for forested zones of subtropics, seven zones were for forested zones of moderate climate zone, six types were for non-forested areas of the moderate climate zone, three types were for natural zones of sub-polar belt, and three types were identified for polar zone.

The data allow discussing the main trends in land use during 2001–2012 on the global scale, which possibly can impact on the structure and dynamics of existing landscapes. In difference of similar studies [5, 6, 7] the defined transition types and differences cover the entire specter of land cover categories and transformation processes, and give the possibility to investigate the main trajectories of not only the anthropogenic-determined, but also a natural category of the land cover. The use of relatively short (10 years) time interval for changes analysis supplements previously done environmental system changes for 1700-2000 [3].

The identified changes of the certain types, which can be interpreted as a kind of trends of the global processes possible in predictable future, significantly change the state of biosphere. In light of determined regularities it seems reasonable to model certain natural and social factors (climate change, population, density of road network, environmental track, etc.), that impact on the trends and order of reversibility in the determined trends in the land cover transformation.

Acknowledgement

References
[1]   Alekseeva N, Klimanova O, Khazieva E 2017 Global land cover database and and prospects of their sage for modern landscapes mapping *Izvestia Russian Academy of Sciences, Geographical series* **1** 126-39
[2]   *Atlas ArcAtlas "Our Earth"* 1996
[3]   Ellis E C, Goldewijk K K, Siebert S, Lightman D, Ramankutty N 2010 Anthropogenic transformation of the biomes, 1700 to 2000 *Global Ecology and Biogeography* **19** 589–606
[4]   *MODIS Land Cover* URL: http://glcf.umd.edu/data/lc/ (Accessed 15.02.2017)
[5]   Milleniun Ecosystems Assessment 2005 *Ecosystems and Human Well-being: Synthesis* (Washington, DC, USA: Island Press) 153 p
[6]   Mucher C A, Klijn JA, Wascher DM, Schamine´e JHJ 2010 A new European Landscape Classification (LANMAP): A transparent, flexible and user-oriented methodology to distinguish landscapes *Ecological Indicators* **10** 87–103
[7]   Sayre R, Dangermond J, Frye C, et al. 2014 *A New Map of Global Ecological Land Units — An Ecophysiographic Stratification Approach* (Washington, DC: Association of American Geographers) 46 p