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# OVERVIEW OF SPATIAL METHODS FOR ASSESSING ANTHROPOGENIC LAND COVER TRANSFORMATION

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## Abstract

Changes in land cover and land use are a space-time process generated by complex patterns and interactions between social, physical, and biological components. The assessment of anthropogenic transformation of landscapes is based on remote sensing data. As a key thematic layer for mapping modern landscapes, geodata on land cover (land cover), obtained as a result of processing satellite images from various survey vehicles and systems, are usually used. To quantify the transformation, formulas and a calculation scheme based on the values of the areas in different boundaries were developed. Databases on land cover and land use were analyzed for a certain time interval. This can be a 5, 10, 15, 20 year period. In 1970-1990, for a specific year (date), data was obtained by interpreting scanned images on the monitor screen (resolution 0.5 m x 0.5 m pixels) and ortho photos (resolution 2 m x 2 m pixels), respectively. More recent values (starting from 2014) are obtained using a combination of digital classification and interpretation of spot data. This paper is a review of methods for assessing land cover transformations. The authors were able to identify the main approaches to the quantitative assessment of changes and the evolution of approaches to the study of this topic since the 1990s.



*Keywords:* Land cover transformation, anthropogenic impact, spatial analysis

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## 1. Introduction

Over the past 50 years, the world's ecosystems have undergone significant changes. The most notable transformations include the loss of half of the world's forest cover, irreversible desertification, and the degradation of 30 % of ecosystems (www.millenniumassessment.org/en/index.aspx). Population growth (from one billion at the end of the 19th century to 6.5 billion at the beginning of the 21st century), combined with consumption rates, are patterns associated with these degradation processes. Where do land cover transformations occur, how large and how possible are the scenarios, are recurring and relevant questions for each country? This is crucial for those countries where, on the one hand, the greatest natural and cultural heritage is concentrated, as well as the highest rates of ecosystem loss and degradation (typical for the tropical zone). Lambin et al. (2003), believe that most of these issues are covered in the analysis of changes in soil cover and use (ACCUS). Vitousek et al. (1997) document that this type of analysis provides insight into the causes and consequences of trends in degradation, desertification, loss of biodiversity, and overall loss of natural and cultural capital. Thus, it becomes obvious that the databases on land cover and land use change are relevant for documenting the processes described above. Based on the analysis, models of the possible consequences of global changes can be created and land-use planning strategies can be justified. Land cover data is widely used in the world practice for mapping landscapes/ecosystems at global and regional scales. For example, the new European Landscape Classification LANMAP (Mücher et al., 2010) uses 10 generalized land cover categories based on the integration of CORINE, GLC2000 and PELCOM data. In 2014, a global map of Ecological Land Units with a resolution of 250 m was published, developed by the Association of American Geographers, the US Geological Survey, ESRI, and others (Sayre et al., 2014). In the mapping process, the GlobCover 2009 database was used with 23 categories of land cover, combined on the final map in 9 aggregated groupings. The generalized categories of land cover, according to the authors ' teams, give quite an adequate idea of the "land cover" layer, which, along with three other attribute layers (bioclimatic conditions, topography, surface sediments), is used for the complex characterization of the selected in the process (semi-surface).) automatic mapping of geosystems. However, all land cover categories are non-hierarchical in terms of their further classification (*Alekseeva* et al., 2017).

## 2. Problem Statement

The research is carried out within the framework of the state task of the research work «Analysis of regional geoecological problems under global environmental change». The purpose of the study is to develop and test new approaches and methods for assessing the state of the environment in regions of Russia and the world, as well as landscapes and their geoecological functions within urban, rural areas, zones of new economic development, in protected areas, in areas of intensive tourism and recreation, taking into account international experience, to make optimal decisions in the field of regional development. The relevance of research is determined by the increase in anthropogenic loads on the environment in Russia and the world to a scale that threatens the reproduction of natural resources, the heterogeneity of trends in the observed changes in the natural environment and the need to integrate the methods of geoecological assessments existing in world practice into the system of scientific and technological development of the Russian FederationCover and land use trends (CCUS) are spatial processes that follow stochastic behaviour

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and result from complex interactions between physical, biological, and social elements (Chu et al., 2010). In addition, they are the product of the synergistic action of a variety of endogenous and exogenous factors that interact with different organizational levels and are associated with technological and environmental change, economic development, population growth, and politics (Lambin et al., 2003). Changes in land cover in tropical regions are negative, and combined with this, deforestation is often underestimated. To understand the complexity of these transitions, it is important to monitor at different scales (temporal and spatial), as well as in dynamic social and institutional contexts. The transformations are nonlinear; they can be understood using the system concepts of complex adaptive, consisting of several interrelated elements that have the ability to change and adapt. They must be taken into account in a cycle where human decisions affect the landscape, ecological processes, and human livelihoods (Uriarte et al., 2010). The elimination of land cover, its degradation, and the transformation of land use patterns have a significant impact on biodiversity, as well as on the structure and functioning of ecosystems, which can contribute to the deterioration of soil fertility, water quality, and habitat loss (Peña-Cortes et al., 2011).

In the quantitative and statistical assessment of changes among international studies, the work of scientists from Mexico stands out. Over the past 10 years, articles and projects on regional problems have been prepared, where experts have calculated areal changes in administrative or natural boundaries. For the study of spatial changes, specific territories were selected on the scale of a natural area, state, province, or individual sea coast. The relevance of such studies is dictated by the increasing anthropogenic load associated with the development of cities, tourism, industry, deterioration of the epidemiological situation or sanitary conditions of the area. Scientists from Eastern Europe also conducted studies in the early 2000s to assess changes in land cover, the degree of anthropogenic impact on landscapes (Kupková, 2001; Michaeli et al., 2015). Changes in land cover/land use, in particular deforestation, make important contributions to biodiversity loss, greenhouse gas emissions and soil erosion. While developed countries are experiencing a net increase in forest area, most developing countries are experiencing forest losses, which are sometimes alarming. According to FAO (The state of food and agriculture, 2009), in Latin America, countries such as Brazil, Ecuador, El Salvador, Honduras, Paraguay and Venezuela had deforestation rates of between 0.6 and 3% per year between 2000 and 2005. In Mexico, the rate of deforestation has decreased over the past few years to less than 0.5% (The state of food and agriculture, 2009). However, this figure is higher in some regions, especially in tropical forests.

## 3. Research Questions

The review of methodological approaches to spatial-quantitative research is carried out on the example of some sites. It is based on the FAO Interdependent Interpretation method (1996). In this review, we present an analysis of the main scientific works. First, two basins of the Mexican Central Pacific, the Arroyo Seco Basin and the Maria Garcia Basin, are analyzed. Land cover classes are derived from field work, aerial photographs, reference literature, and prior knowledge of the study area. 16 types of land cover (landscapes) were identified. The typology of the land cover was determined in three years: 1971, 1996 and 2014. The databases of 1971 and 1996 were compiled on the basis of a photo interpretation. Including aerial photographs at a scale of 1: 20,000, digitized with a resolution of 0.5 m per pixel; digital orthophotos of 1996 with a spatial resolution of 2 m x 2 m per pixel. In 2014, a mixed photo-interpretation technique was

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used for SPOT 7 images with a spatial resolution of 10 m in multispectral and 0.5 m in panchromatic (Nene-Preciado et al., 2017). In the work of Jean-François Mas et al. (2009), the analysis of spatial changes is carried out according to the plan: to present an analysis of changes in land cover and use (ACCUS) based on a cartographic comparison of databases from 1976 and 1993 and cadastral data for forest areas for 2000. Another study analyzed the dynamics of land cover, using the example of a part of the Mesoamerican Biological Corridor (MBC-M) belonging to the state of Chiapas (MBC-Ch). MBC-Ch stands out for its high biodiversity, but also maintains the highest population density among the various parts of MBC-M (Ramírez-Mejía et al., 2017). The authors quantified the dynamics of land cover transformation, analyzed a set of spatial variables (altitude, slope, distance to rivers, distance to paved and unpaved roads, distance to rural settlements, and the presence of protected natural areas), correlated the amount of forest loss with some variables reflecting population density and economic activity, and developed potential scenarios for land use and further development of land cover in the Mesoamerican biological corridor of Chiapas.

## 4. Purpose of the Study

The purpose of this study is to review scientific developments on the spatial and quantitative assessment of changes in land (landscape cover) under the influence of anthropogenic influence (deforestation, land degradation, transformation of land use, etc.).

## 5. Research Methods

The color compositions of the Landsat images were visually interpreted according to the interdependent classification method (State of the world forest, 1997). This method consists of updating the interpretation of the previous date with the image of the next date, which allows you to get a time series of maps than if it were obtained based on independent interpretations. The modelling process is based on the analysis of past changes, which allows us to estimate the rate of change between different types of cover/land use and the particular relationship between the localization of these changes and the variables that affect the spatial distribution of changes. Based on this analysis, you can identify the areas that are most susceptible to changes (probability maps of changes), and make forecast maps. The model based on the trend scenario uses the same change models as in the previous period. It is also possible to develop scenarios in which these models change due to changes in the socio-ecological environment (new agricultural or environmental policies, socio-economic changes in the simulated region. Finally, the simulated map can be evaluated by comparing it to an "observable" map, such as one obtained from satellite image analysis. Thus, the standard calculation of changes is as follows:

$$TC = [\left(\frac{S_2}{S_1}\right)\frac{1}{n} - 1]x100$$

*TC* is the exchange rate (%), *S1* is the area in the initial year (ha), *S2* the area in the final year (ha) and *n* the number of years of the analysis period.

The same data can be represented by the formula in a slightly different form:

$$t = 1 - \left(\frac{S_1 - S_2}{S_1}\right)\left(\frac{1}{n}\right) - 1$$

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For a mathematical assessment of the transformation of the land cover, a matrix of changes is also used, indicating the surface of each type of transition during the observation period (for a certain number of years). This change matrix can be transformed into a change probability matrix (Markov matrix), which indicates the probability of each transition occurring during the year and allows making forecasts on an annual basis (Soares-Filho et al., 2006):

$$P^t = HV^tH^{-1}$$

Where $P$ is the original transition matrix, $H$ is the eigenvector Matrix, $V$ A Matrix constructed based on eigenvalues, and $t$ is the number of years of the period corresponding to the original Matrix.

In order to identify the areas most prone to changes, the location of changes with respect to different explanatory variables mapped is compared cartographically for each transition. This comparison allows establishing a relationship between the potential for change and variables through different approaches such as multi-criterion analysis, regressions, weights of evidence or neural networks, among others.

## 6. Findings

Through the calculations made for the territories of Mexico, taken as an example, it was possible to obtain results and draw the following conclusions. Due to the growth of agricultural borders, the rainforest is one of the most affected vegetation covers on the coast of Jalisco, despite having planning tools such as environmental systems and watershed management plans. In 43 years, these forests decrease between 16 and 17%, which means a deforestation of between 4,000 and 7,100 hectares while agricultural use increased from 55% to 175% depending on the area.

## 7. Conclusion

There is a tendency to the recovery of tropical forests (transition to forests) accounts for one third of their losses, mainly due to agricultural use. There are two notable anthropogenic factors that have caused the transformation of land cover: road construction and Tourism Development have led to the loss of large areas of tropical forests, hydrophilic and halophilic vegetation. The Mesoamerican-Chiapas Biological Corridor has suffered a significant impact in terms of reducing the area covered by forests. MBC is likely to continue to play a key role in advancing development strategies in the region. Making more optimistic scenarios a reality requires an urgent series of integrated measures to reduce pressure on natural habitats. A key factor in these measures will be the use of an integrative approach to integrate biodiversity conservation and actions that have a positive impact on the social and economic well-being of local communities. Regions with high dynamics of change (mainly tropical areas) have significant changes in models and rates of change between the period used for model calibration and the simulation period. The trend model, which mimics the processes of rapid expansion of agricultural areas in patches of preserved forests, was the most flawed model, as it overestimated the number of changes and could not anticipate their location. The alternative model, which had a focus on reducing deforestation rates, was closer to reality. Knowledge-driven models are more suitable than data-driven models, which sometimes use techniques that allow for very accurate reproduction of period models. One of the advantages of the Markov

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methods program is that it allows you to manage both approaches or, rather, control the degree of expert intervention according to the interests of the user. The methods analyzed to estimate changes in land cover influenced by anthropogenic factors provide information on local problems, allow quantifying landscape transformation and also make an attempt to predict the dynamics of land use structure.

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