EVALUATION OF LANDSCAPE ECOLOGICAL POLARIZATION AND ITS APPLICATION FOR STRATEGICAL TERRITORIAL PLANNING

AINAVAS EKOLOĢISKĀS POLARIZĀCIJAS NOVĒRTĒŠANA UN TĀS PIELIETOŠANA TERITORIJAS STRATĒĢISKAJĀ PLĀNOŠANĀ

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Abstract. *To avoid antagonism in system nature-economy-society the concept of state territory management has to be based on the principles of sustainable and balanced development. The strategy of economy development should follow not only the criteria of economical effectiveness, but also the indexes of ecological stability of the territory.*

The extent of ecological polarization (measure of landscape stability) is conditioned by the combination of (1) landscape geochemical sensitivity and (2) technogeochemical pressure defined in respective territorial units. With respect to self-cleaning features of landscapes 7 levels of geosystem sensitivity were distinguished and mapped in Lithuania territory. The largest part of the territory is occupied by averagely and more than averagely sensitive geosystems, the least area is taken by relatively insensitive and extremely sensitive geosystems. The technogeochemical pressure was evaluated through the detailed analysis of landscape technomorphological structure. Using the GIS data bases, in the technotopes distinguished the technogeochemical pressure was evaluated according to the area of industrial and built-up territories, agricultural lands, road net density (adjusted by traffic intensity), and dosmestic pollution (assessed according to the population density). Each of the agents was given different weight coefficients in regard to its pollution emissions. The layer superposition of the geosystem sensitivity and technogeochemical pressure gave the emergence of cartoscheme revealing the distribution of areas with different ecological polarization, divided into 5 tension levels. In order to distinguish the priority territories of land management and optimization the polarization area net and the natural frame of Lithuania were superposed.

Knowledge of the ecological polarization areas allows the rendering of recommendations to economy units for their economical activity organization that should be developed considering the means of landscape ecological stability maintenance like increase of forest percentage, formation of geochemical barriers, proper distribution of land use.

Keywords: *ecological polarization, landscape geochemical sensitivity, technogeochemical pressure, territorial planning.*

Introduction

In the contemporary conditions of the intense use of natural resources and technogenic pollution the security of landscape ecological stability is especially important, because landscape is a complex whole of inter-systemic links the functioning of which determine the sustainability of man's living environment.

In order to motivate the strategy of environment protection and rational use, it is important to evaluate not only the actual extent of anthropogenic load but also natural-ecological landscape potential (geopotential), that is determined by the landscape genetic possibilities to resist the technogenic load without noticeable changes [1-3]. There are many theories explaining this mechanism of landscape stability and self-cleaning, based on reversible negative links, stopping the chain impulse conduction reactions by biogeoceonosis species composition, microorganisms activity, hydrothermal factors [4-9] and the other indexes ensuring the landscape stability [9-11]. According to some scientists [12, 13], the highest self-cleaning ability is the mark to the landscape territorial complexes that are characterized by the high intensity of matter circulation, that strongly barrier or buffer the fluxes of pollutants or have dominance of dispersive fluxes. The territories that accumulate pollutants, have weak barriers and slow biogeochemical circulation are described by weak self-cleaning ability. These are the territories of low ecological stability, sensitive to anthropogenic activity.

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The purpose of this work was to evaluate the ecological stability of Lithuanian territory by distinguishing the areas of different ecological polarization, based on the ratio of landscape technogeochemical pressure and sensitivity to chemical pollution.

Materials and methods

Ecological polarization in landscape systems was estimated in three stages: (1) evaluated the sensitivity of landscape systems to chemical impact, (2) determined the territorial distribution of technogeochemical pressure, and (3) based on the result of the first two stages the classes of ecological polarization in landscape systems distinguished and their distribution mapped. Bellow is shortly presented methodology of all the stages.

Geosystem sensitivity to chemical impact. Evaluation of landscape resistance, based on the concept of geosystemic links, is very complicated. Therefore, for the environmental purposes in order to standardize the use of natural resources, it is enough to evaluate the partial index, i.e., the sensitivity (vulnerability), that is understood as a short-term geosystem reaction to the outer impact, estimated by the possible relative speed of structure degradation.

The determination of landscape system sensitivity to chemical impact was performed on the grounds of the regularities of the heavy metals and organic pollutants migration [14], evaluating (in grades) the potential geosystems possibilities to neutralize or in a relatively short time to remove the toxic substances. Two different models were offered for evaluation of sensitivity to chemical impact:

1. Landscape system sensitivity to soil pollution. In the process of this evaluation the soil genetic type was taken as the main factor: the least sensitive are gleysols, the most sensitive – arenosols. The sensitivity of soil in respect of granulo-metric composition rises in range from rough sand to clay. According to relief influence, the least sensitive are geosystems that disperse the pollutants – elevations, the most sensitive – concentrating pollutants – hollows, etc. Besides that, factors of geochemical background, ground water depth, its mineralization, annual precipitation, and soil temperature were taken into account.
2. Landscape system sensitivity to the pollution of ground water. In regard to granulo-metric composition influence to the ground water pollution, the sensitivity grades rise in the range from clays to sands (the lighter is the soil the higher is the sensitivity to ground water pollution). The evaluation grades in regard to soil genetic type distribute in the same range as in the evaluation of sensitivity to the soil pollution (the most sensitive are the least geochemically active soils). In respect to the ground water depth, the higher is the level of water, the higher is the sensitivity grades. The other evaluation factors were the intensity of run-off, ground water mineralization.

Combination of the above mentioned evaluations gave the evaluation of integrated landscape system sensitivity to chemical impact. It was corrected additionally (±30%) by coefficients considering the impact of local factors (stabilizing factor – forests, destabilizing factors – long-term industrial air pollution) [14]. As a result, with respect to self-cleaning features of landscapes, 7 levels of geosystem sensitivity were distinguished and mapped in Lithuania territory.

Evaluation of technogeochemical pressure. Technogeochemical pressure in landscape is caused by emissions from industry and power production, agriculture, transport, pollution of domestic waste. In order to evaluate the ecological polarization in landscape systems, it is important to know the territorial distribution of the mentioned pollution sources. To determine directly the actual pollution of each industrial plant, agricultural field or settlement is impossible at this time due to the shortage or imprecision of the data. Statistical data given in reports only for administrative districts and large cities is of insufficient preciseness to analyse the territorial distribution of pollution. Therefore the method was offered allowing to qualitatively evaluate the potential pollution in landscape using the term of so called technogeochemical pressure. In order to evaluate the strength of technogeochemical pressure the earlier published [15] methods was adapted. The technogeochemical pressure was evaluated in grades considering the total pressure

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being made by the mentioned pollution sources (industry and power supply, agriculture, transport, and domestic waste). Every pollution source was given (by expert analysis) the different maximum evaluation in grades, reflecting the relative weight of respective pollution source in technogeochemical pressure (to compare: the industry and power supply got maximum 40 grades evaluation range, agriculture – 30, transport – 20, domestic waste – 10).

Technogeochemical pressure from industry & power production and agriculture was evaluated according to their occupied part (in %) in the territory. Transport's technogeochemical pressure was evaluated according to the density of the main infrastructure elements (roads and railroads) also taking into account the type and category of these elements, because these determine the extent of pollution along the infrastructure lines. For evaluation of the technogeochemical pressure created by domestic waste the population density indirectly showed the extent of pollution. The main principle of evaluation was: the higher is the pollution source relative index (percentage, density), the higher meaning of technogeochemical pressure it was given in a respective territory. Finally the sum of all the pollution source evaluations made up the integrated technogeochemical pressure evaluation in the territory. The calculation of the mentioned relative dimensions was enabled by operations and analysis using various GIS data bases (©CORINE Land Cover Lithuania data base, European Commision, Phare Programme, 1998; Topographical information LTDBK50000-V ©State survey of land managing and geodesy, 1996; GDB200 ©GIS-CENTRAS, 1993-1999).

In order to do the analysis of the territorial distribution of technogeochemical pressure the specific system of territorial units – technotopes (relatively independent territorial units of landscape technogenic structure, characterized by specific techogenization type and landuse features) – was chosen. In the whole territory of Lithuania nearly 2000 technotopes were distinguished [16]. In the mentioned technotopes the relative measures of each pollution source were calculated, converted to grades and finally summed up. The technogeochemical pressure evaluation grades were classified into 5 levels from very low to very high technogeochemical pressure.

Distinguishing of ecological polarization classes. The above described information layers (sensitivity to chemical impact and technogeochemical pressure) were superposed using the GIS software and too many ($5 \times 7 = 35$) polarization classes were extracted. To simplify this complicated polarization assessment, the polarization classification matrix was created allowing to reduce the 35 polarization variants into 5 classes from very low to very high polarization (Table 1).

Results and discussion

The main three groups of results were obtained out the above methodology application. As mentioned, the landscape systems sensitivity to chemical impact of Lithuanian territory was determined. According to the landscape potential for self-cleaning 7 levels of geosystem sensitivity were distinguished and the map of their distribution in Lithuanian territory created (by M. Jankauskaitė). The largest area of extremely sensitive landscapes distinguished in Vilnius-Kaunas belt. Here, as in all the Eastern and South-eastern Lithuania the luvisols soils are dominating with a light mechanical composition, not having large buffer capacity. Long-term and very intensive atmospheric pollution in this zone have changed the background of soils with low geochemical activity. Much smaller areas of extremely sensitive geosystems are in the middle valley of the Venta river (light luvisols and the long-term impact of Mažeikiai oil-refinement plant). Extremely sensitive territories are also in Seashore zone and the region of Saugai-Priekulė (sand with the lowest geochemical activity and influence of Klaipėda city).

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Table 1.

Distinguishing the classes of ecological polarization according to the combination of geosystem sensitivity (categories 1 to 7 see fig. 1 caption) and technogeochemical pressure degree (categories 1 to 5 see fig. 2 caption): i – very low, ii – low, iii – medium, iv – high, v – very high

Sensitivity of geosystems	*Technogeochemical pressure*				
	1	2	3	4	5
1	*i*	*i*	*i*	*i*	*ii*
2	*i*	*i*	*ii*	*ii*	*ii*
3	*i*	*ii*	*ii*	*iii*	*iii*
4	*i*	*ii*	*iii*	*iv*	*iv*
5	*ii*	*ii*	*iii*	*iv*	*v*
6	*ii*	*iii*	*iv*	*v*	*v*
7	*ii*	*iii*	*v*	*v*	*v*

The results show that territorially the largest part (two thirds of Lithuania territory) is taken by averagely sensitive (35%) and more than averagely sensitive (32%) geosystems. Not so common is the level of less than averagely sensitive (16%), little sensitive (8%) and very sensitive (6%) geosystems. Extremes (relatively insensitive and extremely sensitive geosystems) ocupy small part of Lithuanian territory (1% each) (Fig. 1).

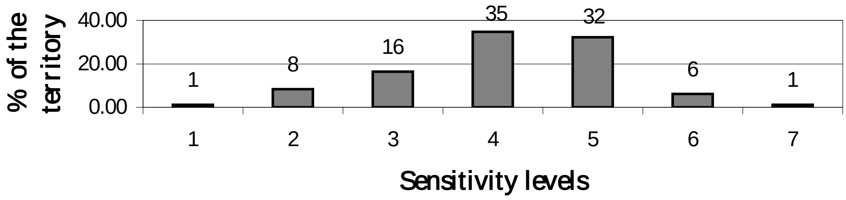

Fig. 1. **Percentage distribution of geosystems of different geochemical sensitivity in the territory of Lithuania: 1 – relatively insensitive, 2 – little sensitive, 3 – less than averagely sensitive, 4 – averagely sensitive, 5 – more than averagely sensitive, 6 – very sensitive, 7 – extremely sensitive**

In regard to technogeochemical pressure the highest grades belong to the technotopes with the largest part of industrial territories (technotopes comprising Vilnius, Kaunas, Klaipėda, and other large cities, some large industry and power plants). Such territories take up about 1% of Lithuanian area. High evaluation was given to agricultural technotopes (especially in Middle Lithuania plain), they are the most frequent (taking up 37% of the territory). The lowest grades were obtained for technotopes in relatively natural Southeast sandy plain and other woody territories (26% of the territory). Medium technogeochemical pressure values are applied to Žemaičių and Aukštaičių elevations, as they are averagely agriculturally cultivated (taking up 26%). Areas with low technogeochemical pressure occupy about 11% of Lithuanian territory (Fig. 2). These data show that Lithuanian landscape under the conditions of intensive exploitation experiences rather remarkable chemical load.

The third group of results reveals the distribution of the potential ecological polarization in landscape. The mapped distribution of 5 level ecological polarization areas shows a very spotty situation in this regard (Fig. 3). With growing landscape ecological polarization its stability diminishes due to the changes of the features upholding the landscape inter-systemic self-regulation potential and because of inability to keep the functioning equilibrium. Therefore the map of ecological polarization also shows the areas of unequal landscape stability.

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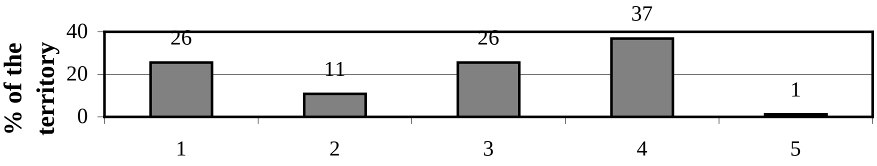

Fig. 2. **Percentage distribution of areas with different technogeochemical pressure in the territory of Lithuania: 1 – very low, 2 – low, 3 – medium, 4 – high, 5 – very high**

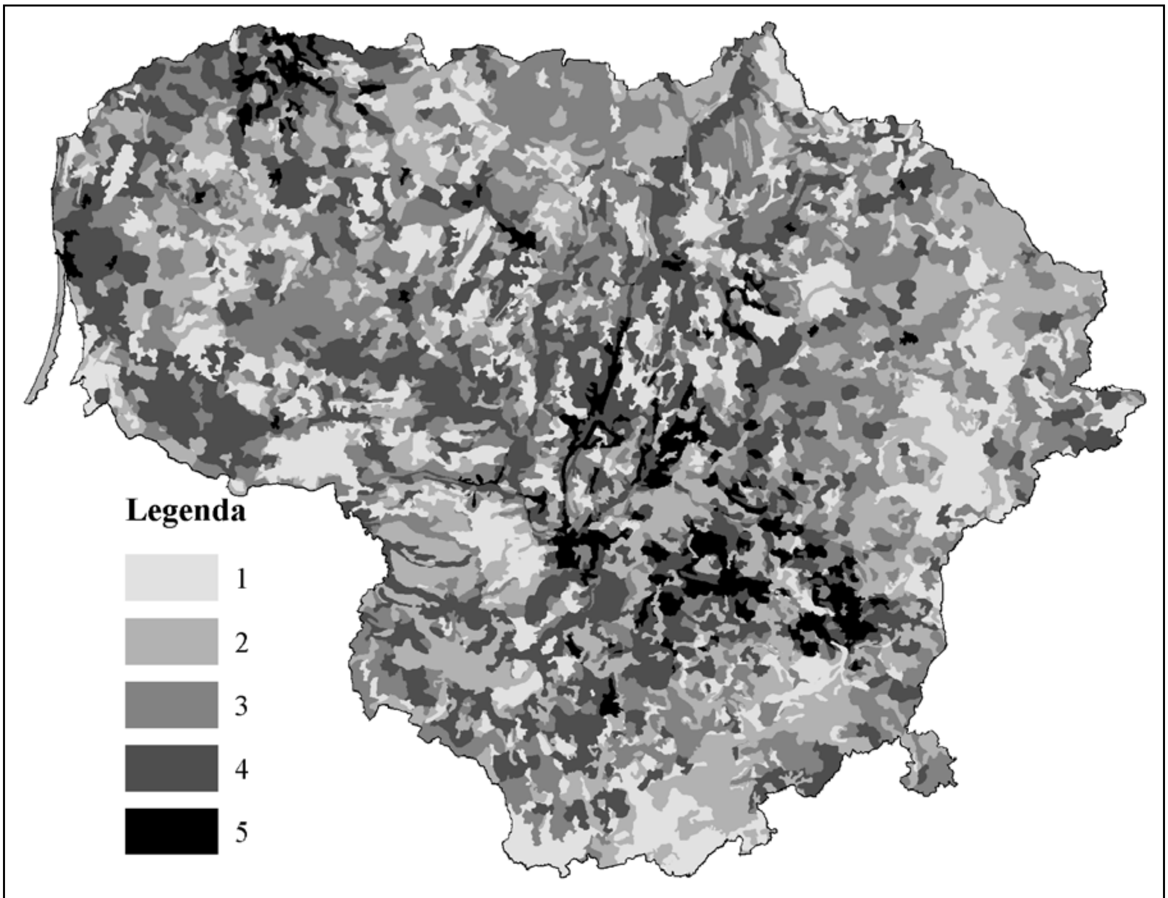

Fig. 3. **Distribution of ecological polarization in the Lithuanian landscape systems. Ecological tensions: 1 – very low, 2 – low, 3 – medium, 4 – high, 5 – very high**

The areas of the highest ecological polarization, though occupying 4% of Lithuanian territory, are more or less scattered across the whole country. The highest concentration of such a polarization spots is located in the triangle of Vilnius-Kaunas-Kėdainiai cities. This is the area of the most sensitive geosystems and highest, longest-lasting technogenization. The causes of such a situation are the proximity of the largest two cities (Vilnius and Kaunas), the arterial road connecting them, large industrial and power enterprises. In North-western Lithuania the area of very high ecological polarization, determined by extremely sensitive geosystems experiencing high technogeochemical pressure, covers the city of Mažeikiai and its surroundings (some parts of the Venta valley, oil refinement plant and railroad territories).

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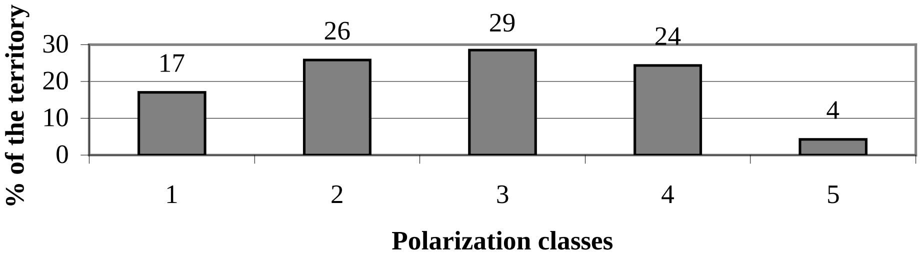

Fig. 4. **Percental distribution of ecological polarization classes in the Lithuanian territory. Class names see in Fig. 3 caption**

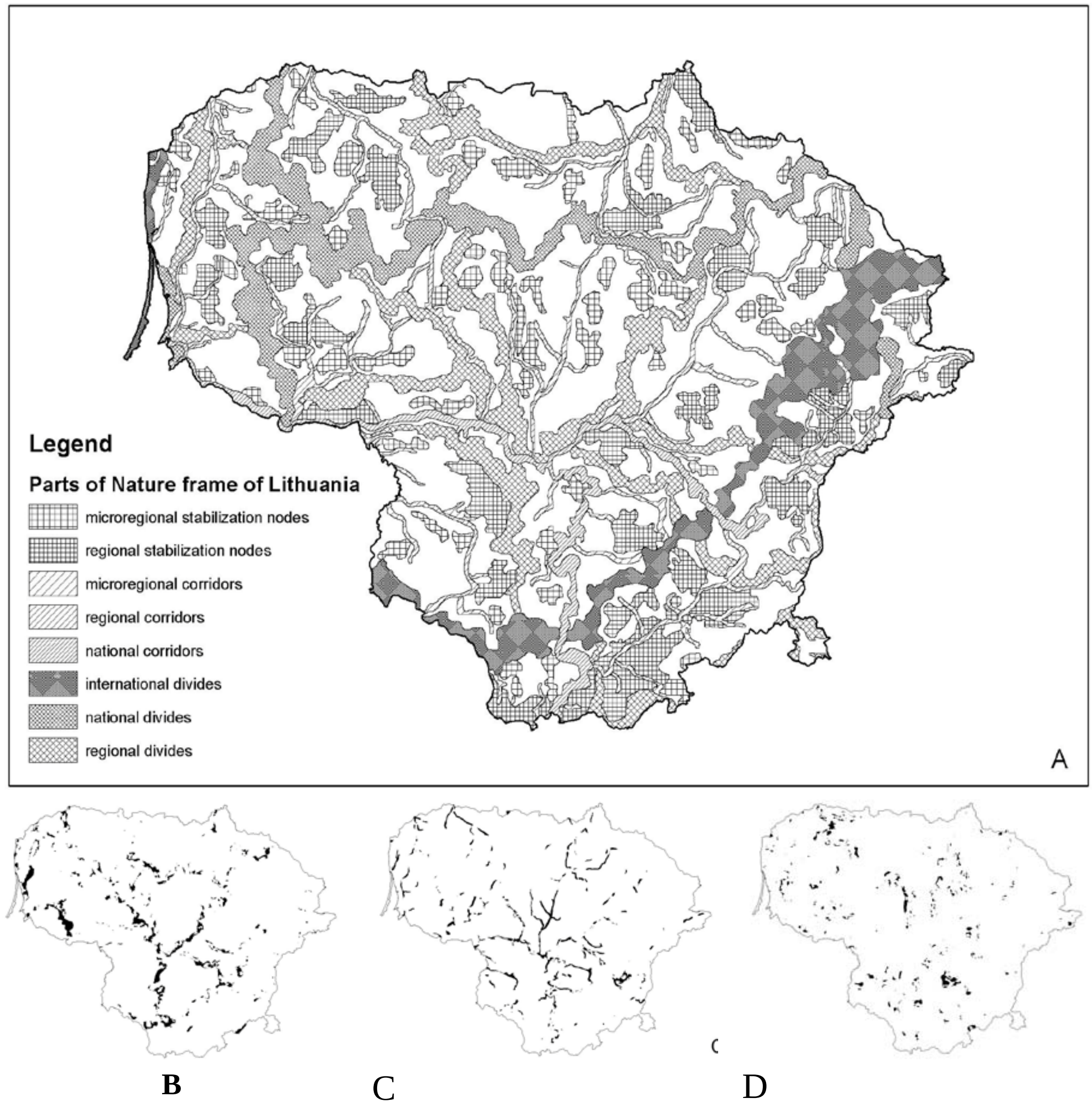

Fig. 5. **Nature frame of Lithuania (A) [17] and its parts that fall into the areas of high and very high polarization: B – geoecological divides, C – geoecological corridors, D – nodes of geoecological stabilization.**

Besides the mentioned large areas, there are several smaller spots with very high ecological polarization worthy to mention: Klaipėda sea port, established on very sensitive seashore geosystems, Radviliškis town with railroad node and Panevėžys city creating very high technogeochemical pressure for sensitive geosystems, etc. Percentage of polarization classes distribution in Lithuanian territory is given in Fig. 4. Each of low, medium and high polarization

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classes occupy about one fourth of Lithuanian territory. Areas with very high polarization take up 4%, very low – 17% of Lithuanian territory.

Discussion may rise regarding the practical application of the research carried out. To prove the applicability of the results, the overlay operation was performed with the polarization map and Nature Frame scheme (included into the National Plan of Lithuania [17]). The Nature Frame of Lithuania (already acknowledged legally) distinguished according to the general geoecological principles, consists of geoecological divides (functioning as entering windows of circulating matter), migration corridors, and nodes of geoecological stabilization [18], most of them ranged from microregional to international level (Fig. 5, A). The Nature Frame covers about 51% of Lithuanian territory (divides occupy 24%, corridors – 10%, stabilization nodes - 17%). The overlay operation with ecological polarization map revealed that some of these territories fall into the areas of high and very high polarization (Fig. 5, B-D). Such territories (taking up 10% of Lithuanian area and about 20% of Nature Frame) become the priority tasks for territorial planning and landscape optimisation.

Knowledge of the ecological polarization areas allows the rendering of recommendations to economy units for their economical activity organization that should be developed considering the means of landscape ecological stability maintenance like increase of forest percentage, formation of geochemical barriers, proper distribution of land use. Besides that, the research results obtained can be interpreted in many other ways (like entropy, ecological planning, etc.) therefore they can be applied for the further analysis of landscape systems in Lithuanian territory.

Conclusions

1. In order to optimise the landscape destabilized by the contemporary intensive landuse, it is important to evaluate the sensitivity of landscape systems, their technogeochemical load, and by the ratio of the both to distinguish the problematical areas of potential ecological polarization. These areas should be associated with the primary installation of environment protection means. By application of methods evaluating the geosystems sensitivity and technogeochemical pressure, using the cartographic, statistical and field research data as well as GIS technologies, some important results were obtained: the cartographic models of landscape systems sensitivity to chemical impact and technogeochemical pressure in landscape technotopes; and finally, the overlay of the last mentioned two cartographic models enabled creating the landscape ecological polarization map of Lithuania.
2. The territory of Lithuania in regard to geosystem sensitivity to chemical impact is rather contrasting, having the dominance of averagely and more than averagely sensitive geosystems. Relativly insensitive and extremely sensitive geosystems cover a little part of Lithuania (each for about 1%). The most sensitive are the Baltic highlands, especially in the belt of Vilnius-Kaunas, characterized by intensive and long-term pollution, weakenning the natural landscape self-cleaning features. Besides that, the rather large area of very sensitive geosystems is located in North-western part of Lithuania (around Mažeikiai city).
3. Due to the broad agricultural areas in Lithuania the largest part of the country is occupied by the technotopes with high technogeochemical pressure sharing its part with less frequent technotopes experiencing low and medium technogeochemical pressure. Areas of very high technogeochemical pressure mostly are related with intensive industrial and residential built up and cover only about 1% of the territory.
4. Various combinations of geochemical sensitivity and technogeochemical pressure allowed to distinguish large variety of ecological polarization types, that were classified into 5 main classes and mapped. The cartographic view shows a relatively high polarization of Lithuanian landscape. The highest polarization is characteristic to the triangle area of cities Vilnius-Kaunas-Kėdainiai and the region of Mažeikiai city. The areas of the lowest ecological polarization, i.e. the areas of the most stable landscape, are determined in the

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largest forested territories (South, East, South-western Lithuania). Areas of very high ecological polarization occupy about 4% of Lithuanian territory.

5. The example of the applications of presented results can be the overlay of the polarization and Lithuanian Nature Frame maps. It was estimated that about 20% of the Nature Frame territories fall into the areas of high and very high ecological polarization. These territories should become the priority tasks of territorial planning and landscape optimisation. Besides that, the research results obtained can be interpreted in many other ways (like entropy, ecological planning, etc.) therefore they can be applied for the further analysis of landscape systems in Lithuanian territory.

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