ANALYSIS ON THE OPTIMALITY OF LITHUANIAN LANDSCAPE STRUCTURE

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Abstract
The aim of this study was to perform an analysis of the optimality of the landscape structure of the Republic of Lithuania.
Various scientific methods were used in the study, namely: comparative, grouping, analytical, statistical data, graphical representation analysis. After calculating the formulas, the ratio of relatively natural and cultivated land in Lithuania and counties was determined, the relative deviation of the landscape structure from the optimal value of the ratio was estimated and the optimality class was determined.
The article presents an analysis of the changes in the natural, anthropogenized and anthropogenic landscape of the Republic of Lithuania during the time period between the years 2002 and 2020. It was found that in the analyzed period the area of natural landscape increased by 4.63%, that of anthropogenic – increased by 7.08%, that of anthropogenized - decreased by 36.34%. Assessing the structure of the country's landscape, it can be seen that in 2020 the largest part of the country's landscape was occupied by anthropogenized landscape (55.79%), the smallest – by anthropogenic landscape (5.65%), and the natural landscape accounted for 38.56% of Lithuania's territory.
Calculations were also performed, which established that the ratio of relatively natural land and cultivated land in Lithuania R_{ns} = 1.43. After estimating the relative deviation of the Republic of Lithuania from the optimal ratio value (D_r), it was obtained that D_r = -1.14, which means that the country's optimality class is B1.
Key words: landscape, components, optimal landscape, landscape structure.

Introduction

U. Walz (2011) describes the structure of a landscape as composition and arrangement, and the resulting spatial relationships between its individual elements can be described and quantified by means of landscape metrics.

R.H. Haines-Young (2009) notes that landscape structure means the pattern of a landscape, which is determined by its type of use, but also by its structure, for example, the size, shape, arrangement and distribution of individual landscape elements. For the delineation of these landscape elements, or so-called *patches*, often land use or land cover units are used. In this context, *land cover* refers to the physical surface characteristics of land (the vegetation found there or the presence of built structures), while *land use* describes the economic and social functions of that land.

Landscape is composed of a combination and mixture of disparate elements, habitats or land cover classes (Turner, Gardner, & O'Neill, 2003).

Landscape image comprises its spatial and structural parts, the formal visual and cultural aesthetic expression of the landscape. In accordance with this holistic image of the landscape, the manifestation of these special elements and visual functions is reflective of the natural and cultural coherence and beauty of long functioning natural and cultivated landscape systems (Krause, 2001).

The structure of near-natural landscapes may be referred to as *primary landscape structure*. Man intervenes more or less directly in biodiversity through land use. So, landscape structure resulting from anthropogenic uses can be referred to as *secondary landscape structure* (Walz & Syrbe, 2013).

Landscape pattern is more fragmented around city centres and along coastlines, where urbanization and human economic activities are more concentrated (Uemaa *et al.*, 2009).

R. Skorupskas and P. Kavaliauskas (2007) state that an integral, ecological approach combined with bio-psycho-socio-ecological and ergo-economical requirements to the environment currently becomes the main necessity of landscape optimization. An optimal landscape is instable in time. This is due to many factors, for example, ergo-economic suitability, geoecological determinativeness, social conventionality and perceptional comfortness. In the science article, the authors state that a set of anthropo-ecological criteria determines different interpretations or of the optimal horizontal structure of landscape: ecological, ergo-economical, socioecological perceptional.

Landscape structure reflects the results of policies and practices, and is well-suited as a target for management actions (Dramstad *et al*., 2001).

The object of article is the optimality of the Lithuanian landscape structure.

The aim is to perform an analysis of the optimality of the landscape structure of the Republic of Lithuania.

Tasks to be resolved:

1. To analyze the change of Lithuania's natural, anthropogenic and anthropogenized landscape in 2002–2020.

2. To calculate the ratio of relatively natural and cultivated land in Lithuania (R_{ns}).
3. To evaluate the optimality of the landscape of the Republic of Lithuania and counties as well as its classes.

Materials and Methods

First of all, during the research of determining the optimality of the Lithuanian landscape structure, the analysis of the articles published in scientific publications on the examined topic was performed.

The article presents a comparative analysis of the change in the area of the natural, anthropogenized and anthropogenic landscape in 2002–2020.

Using the grouping method, the components belonging to the natural, anthropogenized and anthropogenic landscape are divided. The change in the areas of the analyzed landscape components was also examined. The data of the Land Fund of the Republic of Lithuania for 2002–2020 were used for the analysis. The percentage and hectare distribution of the country's landscape types in 2020 was estimated.

The analysis of the ratio of relatively natural and cultivated land in Lithuania was performed and the R_{ns} of the country and ten counties were calculated. The county data were compared and the county with the most optimal ratio of relatively natural and cultivated land was determined.

The relative deviation of the landscape structure of the Republic of Lithuania and counties from the optimal ratio value (D_r) was also calculated and the optimality class was estimated based on the table *Determination of the territory optimality class according to the distance of its natural and artificial land use* from the optimal value.

Thus, in writing the article, not only the above-mentioned methods were used, but also the methods of analytical and logical analysis. The article presents graphic representation methods (6 figures in total). Figures 5 and 6 were made using ArcGIS program.

Results and Discussion

Lithuanian natural landscape

A landscape covers all of the territory of the country including cities, towns, rural areas, forests and waters; it greatly influences the life and activities of society; it is the foundation of national identity and part of quality of life (Čiegis & Burgis, 2012).

The structure of the Lithuanian landscape, formed and shaped by natural and anthropogenic factors, is diverse and multi-layered.

Forests, water bodies and wetlands are components that make up the natural landscape.

The tendencies of changing the naturalness of the landscape are to some extent expressed by the development of the country's forest cover. In Lithuania, forest area covers 2,156,033.39 ha or 33.02%. Comparing 2002 with 2020, the forest area in Lithuania increased by 159,154.22 ha, i.e. 7.97%.

The forest area has developed due to participation in the Rural Development Program, the enforcement of the forest development program, etc.

Another component of the natural landscape is water bodies. In 2020, water bodies in the country occupied 266,532.84 ha and accounted for 4.08% of the territory of Lithuania. After the analysis of the change of water bodies in 2002–2020, it was established that their area increased by 4,368.39 ha or 1.67%.

Wetlands are one of the most natural components of the natural landscape. It is one of the most important parts not only of the natural landscape, but also of the whole Lithuanian landscape, these are territories of special ecological and aesthetic significance. Unfortunately, this natural component is the most ignored and endangered.

Wetlands in Lithuania in 2002 occupied 147,078.84 ha, in 2020 – 94,871.10 ha, which means that in 2002–2020 the area of wetlands decreased by as much as 52,207.74 ha or 35.50%.

The wetland area was shrinking due to human activities, climate change and natural processes.

The analysis of the components of the relatively natural landscape shows that the area of forests and water bodies increased between 2002 and 2020, but unfortunately the area of wetlands decreased.

Examining the change of the natural landscape, it was found that the area increased by 111,314.87 ha or 4.63% during the analyzed period (Figure 1).

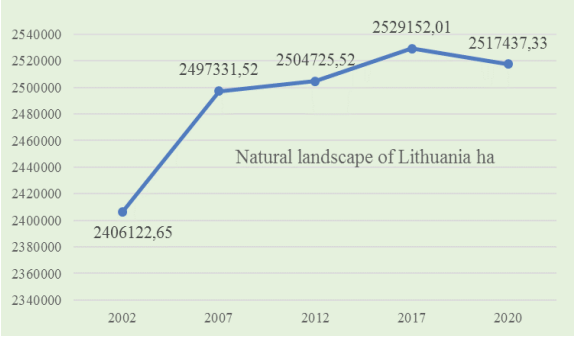

Figure 1. Natural landscape area change in hectares in Lithuania 2002–2020.

The natural landscape area has increased due to the development of forests and water bodies.

Anthropogenized landscape

The following components can be included in the anthropogenized landscape: agricultural land (arable land, orchards as well as meadows and natural pastures), tree and shrub plantations, unused land.

The area of agricultural land in Lithuania decreased by 88,053.11 ha or 2.53% in 2002–2020.

Human economic activity influences the change of land use, as the composition of land use changes with the change of purpose.

Greenery of trees and shrubs in the analyzed period increased as much as 117,643.34 ha or 138.91%. The reason for the increase of this land use is the development of green areas and the implementation of afforestation programs.

In 2002–2020, the areas of unused land in Lithuania decreased by 166,692.67 ha or 80.36%.

The analysis of the change in the areas of the components of the anthropogenized landscape shows that in the Republic of Lithuania in 2002–2020 the areas of agricultural land and unused land decreased, and the areas occupied by trees and shrubs increased.

Between 2002 and 2020, the area of the anthropogenized landscape decreased by 137,102.44 ha or 36.34%. (Figure 2).

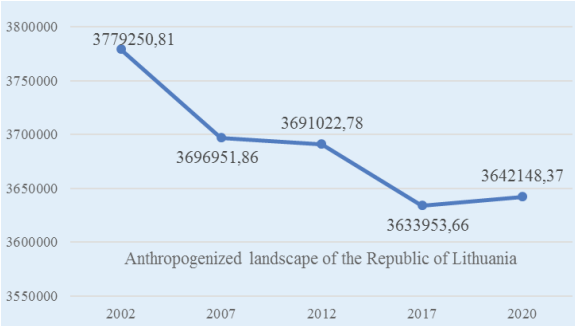

Figure 2. Anthropogenized landscape change in Lithuania in hectares during the period between the years 2002 and 2020.

The reason for the decrease in the area of anthropogenized landscape is the decrease in the area of agricultural land (2.53%) and unused land (80.36%).

Anthropogenic landscape.

Anthropogenic landscape includes: built-up areas, roads and damaged land.

Urbanization as a process is characterized by many factors or measurable variables, such as urban development, population growth in urban areas, consolidation of the urban network, or other socio-demographic shifts in society (Sillence, 2007).

In the period of 2002–2020, the area of built-up territories in Lithuania increased by 51,373.81 ha or 27.32%, and in 2020 it occupied 239,421.21 ha.

Based on the data of the Land Fund of the Republic of Lithuania (Nacionalinė, 2002–2020), it was established that in 2002–2020 the road area in the country decreased by 26,199.14 ha or 19.91%. In 2020, the road area covered 105,401.82 ha.

It can be said that this decrease in road area is conditional, because until 2007 the data of theoretical calculations of road area were provided, which were inaccurate, and in the following years cadastral measurements were started, during which data on road area are constantly updated every year. At present, more than 50% of cadastral measurements of road areas have been performed in Lithuania.

In 2002–2020, the area of damaged land in the Republic of Lithuania decreased by 762.12 ha or 3.05%.

The area of damaged land decreased due to the closure of non-compliant landfills and the disposal of illegal landfills, as well as the reclamation of quarries.

After analyzing the change in the area of the Lithuanian anthropogenic landscape in 2002–2020, it was established that the above area increased by 24,412.55 ha or 7.08%. (Figure 3).

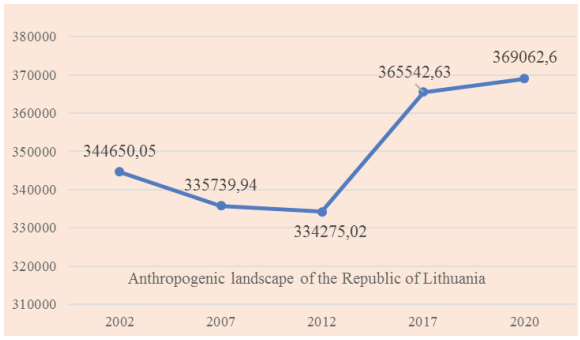

Figure 3. Anthropogenic landscape change in Lithuania in hectares during the period between the years 2002 and 2020.

The reason for the increase in the area of anthropogenic landscape is the development of built-up areas (27.32%).

After the analysis of the landscape of the Republic of Lithuania, it was established that in 2020 the anthropogenized landscape occupied the largest part of the country's landscape (55.79% or 3,642,148.37 ha), the smallest part of the landscape was occupied by anthropogenic one (5.65% or 369,062.60 ha). The natural landscape in Lithuania occupied 2,517,437.33 ha and accounted for 38.56% of the country's territory (Figure 4).

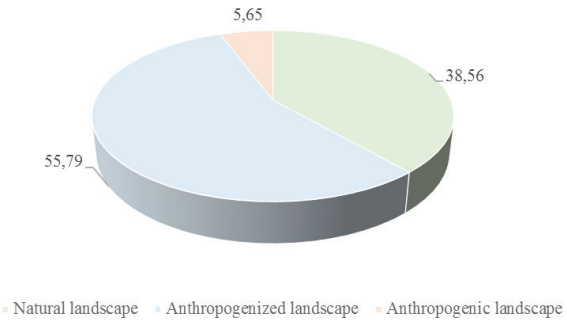

Figure 4. Distribution of Lithuania landscape in 2020, in percent.

Analysis of the ratio of relatively natural and cultivated land in Lithuania

The methodology of landscape formation (landscape benchmarks to be achieved) (Kavaliauskas *et al*., 2013) states that the optimal landscape structure of a country is assessed on the basis of geoecological compensation index, when the active part of anthropogenic (anthropogenized) land occupies 38%, passive part or natural (relatively natural) land occupies 625 (Skorupskas & Kavaliauskas, 2007).

Thus, the landscape cannot be considered optimal if the minimum percentage of natural areas required to compensate for anthropogenic impacts is not reached.

From the above analysis and Figure 4 it can be seen that in 2020, the natural areas of the Republic of Lithuania occupied 38.56%, while the anthropogenic together with the anthropogenized landscape accounted for 61.44%.

Taking into account the diversity of land uses, it is possible to calculate the ratio of relatively natural and cultivated land (R_{ns}) for any sufficiently large (regional level) area with specific boundaries using the formula:

$$R_{ns} = \frac{P+M+0.5\ A+0.8\ V}{U+T+0.5A+0.2\ V}, \quad (1)$$

where R_{ns} is the ratio of relatively natural land (fraction in the numerator) and relatively cultivated land (fraction in the denominator) of the land of the territory: P – wetlands; M – forests; A – agricultural land; U, T – urban and technological components; V – water bodies.

After performing the calculations according to the above formula, it was established that the ratio of relatively natural land and cultivated land (R_{ns}) of the Republic of Lithuania is equal to 1.43.

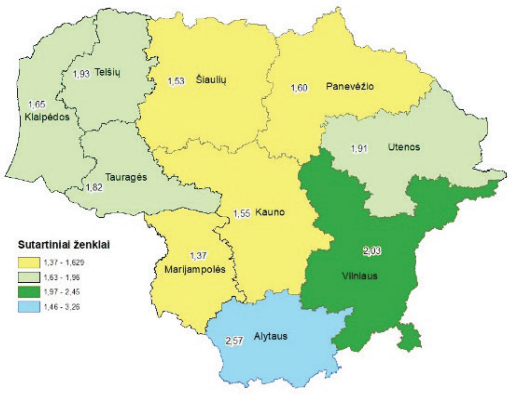

Figure 5. The ratio of relatively natural land and relatively cultivated land in the counties of the Republic of Lithuania.

The structure of the landscape is natural when $R_{ns} = R_o$. R_o is the optimal ratio value, which is equal to 1.63. There are ten counties in the territory of Lithuania. After analyzing the ratio of relatively natural land and relatively cultivated land, it was found that the optimal ratio of relatively natural land and relatively cultivated land is in Klaipėda county (R_{ns} = 1.65) (Figure 5). It can be stated that the optimal ratio of the mentioned land use is also in Tauragė (R_{ns} = 1.82), Utena (R_{ns} = 1.91) and Telšiai (R_{ns} = 1.93) counties.

The optimality of the landscape structure of the territories can be assessed by the following formulas:

$$Dr = \frac{R_{ns}}{Ro, \text{ when } R_{ns}>Ro} \quad (2)$$

or

$$Dr = \frac{Ro}{Rns, \text{ when } R_{ns}>Ro} \quad (3)$$

here D_r is the relative deviation from the optimal ratio value (R_o); R_{ns} - the ratio of relatively natural land and relatively cultivated land in the territory; R_o is the optimal value of the ratio.

After calculating D_r and based on Table 1, the landscape structure optimality class is determined.

Table 1

Determination of the site optimality class according to the deviation of its natural and artificial land use ratio from the optimal value (Lietuvos Respublikos aplinkos..., 2015)

Ratio of natural and cultivated land (R_{ns})	R_{ns} deviation from optimal value (sometimes) (D_r)	Optimality classes
>78,25	>48,00	A6
13,37...78,24	8,01...48,00	A5
3,27...13,36	2,01...8,00	A4
2,46...3,26	1,51...2,00	A3
1,97...2,45	1,21...1,50	A2
1,631...1,96	1,00...1,20	A1
1,629...1,36	-1,00...-1,20	B1
1,35...1,09	-1,21...-1,50	B2
1,08...0,82	-1,51...-2,00	B3
0,81...0,20	-2,01...-8,00	B4
0,19...0,03	-8,01...-48,00	B5
<0,03	<-48,00	B6

After performing the calculations, it was obtained that the relative deviation of the Republic of Lithuania from the optimal value of the ratio is equal to -1.14, i.e. the country's optimality class is B1, indicating that there are more cultivated lands than natural ones in the country's landscape. As mentioned above, the Lithuanian natural landscape makes up 38.56%.

After calculating the counties D_r and determining the optimality classes, it can be seen that the optimal structure – A1 class was determined in Klaipėda, Tauragė, Telšiai and Utena counties (Figure 6).

Class B1 is an almost optimal structure, with a small predominance of cultivated land. This class is established for the whole territory of the country and for Marijampolė, Kaunas, Panevėžys and Šiauliai counties.

Optimality class A2 was determined for Vilnius county, and A3 – for Alytus county. Classes A2 and A3 show that the above-mentioned county landscape is dominated by natural components.

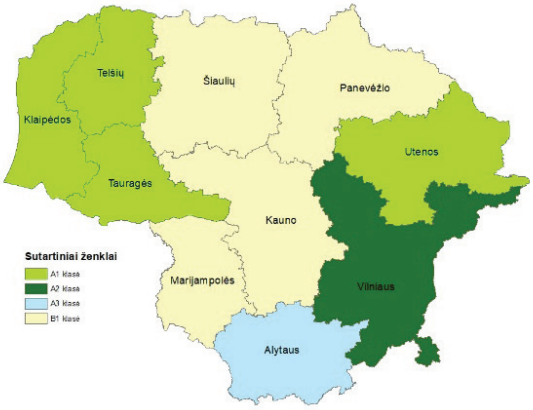

Figure 6. Optimality classes of landscape structure in counties of the Republic of Lithuania.

In 2020, the natural landscape in Alytus county occupied 55.85% of the county area, in Vilnius county – 48.08%. The value of the recommended indicator varies in individual regions of the country, which indicates the deviation of their geoecological structure from the optimal proportion. Regional differences in the optimality of the landscape structure provide guidelines for increasing the optimality of the landscape structure, i.e. for optimization to A1 or B1 classes.

The landscape optimality structure must be formed taking into account the general optimality of the land use structure of the whole country, territorial structures provided for in the General Plan of the Republic of Lithuania (natural framework, protected areas, functional priority areas, presuming the respective land use structure, etc.), ecological compensation.

Conclusions

1. After the analysis of landscape change in the Republic of Lithuania during the period between the years 2002 and 2020, it was established that the area of natural landscape increased by 111,314.87 ha or 4.63%, the area of anthropogenic landscape increased by 24,412.55 ha or 7.08%, the area of anthropogenized landscape decreased by 137,102.44 ha or 36.34%.
2. In 2020, the largest part of the country's landscape made up anthropogenized landscape (55.79% or 3,642,148.37 ha), the smallest - anthropogenic (5.65% or 369,062.60 ha). The natural landscape covered 2,517,437.33 ha and accounted for 38.56% of the country's territory.
3. After calculating the ratio of relatively natural land and cultivated land (R_{ns}) in the Republic of Lithuania in 2020, it was established that it is equal to 1.43. Out of ten counties of the Republic of Lithuania, the most optimal ratio of relatively natural land and relatively cultivated land is in Klaipėda county (R_{ns} = 1.65).
4. The relative deviation of the Republic of Lithuania from the optimal ratio value (D_r) is equal to -1.14, which means that the country's optimality class is B1, which indicates that there are more cultivated lands in the country's landscape than natural ones. Class B1 was set for Marijampolė, Kaunas, Panevėžys and Šiauliai counties, A2 optimality class was set for Vilnius county, and A3 – for Alytus county. The optimal structure - A1 class – was determined in Klaipėda, Tauragė, Telšiai and Utena counties.

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