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LAND USE AND ITS INFLUENCE ON ECOLOGICAL STABILITY OF THE AREA: CASE STUDY IN LITHUANIA

Valciukiene Jolanta, Gasparavicius Arnoldas, Jukneliene Daiva, Atkoceviciene Virginija
Vytautas Magnus University Agriculture Academy, Lithuania

Abstract
Several decades ago, land use and ecology in general were not a very relevant topic, but with the beginning of particularly intensive urbanization and agricultural expansion, scientists began to pay increasing attention to ecology and the improvement of related factors. The aim of the article is to analyse the land use of selected areas and its impact on the ecological condition of the area. 3 (Ignalina, Molėtai and Zarasai) from 15 districts (which are characterized by considerable forest cover and exceptional recreational characteristics) of Lithuania were selected as the object of research. The largest part of the area of these districts (44-57%) consists of agricultural areas, a slightly smaller area (32-42%) is occupied by forests and other natural areas. Artificial covers occupy from 8 to 11 percent of the total area of districts. Analysing the change of these land cover areas over a period of 12 years, a practically stable (4-6%) decrease of agricultural areas and growth of forests and other natural areas (3-5%) as well as artificial covers (1%) in all three municipalities are observed. Taking into account the prevailing land cover structure in the districts in 2018, the estimated degree of polarization of all districts/ecological stability indicator of the area exceeded 0.67, i.e., areas have been found to be ecologically stable. However, after assessing the ecological stability of the surveyed areas using a multi-criteria analysis method and introducing more criteria influencing the ecological condition of the area, not only the land cover structure, it was found that the ecological condition of Molėtai district is still the worst according to the ranking indicators, while that of Zarasai and Ignalina districts is very similar. Such a negative multi-criteria assessment of the ecological condition of Molėtai district was influenced by all criteria: lower area of protected and natural territories, forests in the district, higher population density, road length, area of artificial covers and emissions (carbon monoxides, nitrogen oxides, etc.) quantity. Meanwhile, when assessing the ecological condition of Ignalina district, 4 criteria were favourable, namely: relatively low population density, road length, and lower emissions of gases and liquids, carbon monoxide, and for Zarasai district 7 criteria: higher areas of protected territories, forests and other natural, agricultural areas as well as artificial cover areas and lower population density, emissions of nitrogen oxides, gaseous and liquid substances. The results of the study unambiguously revealed that the ecological stability of the territory is influenced not only by the land use structure, but also by other environmental elements related to the area, therefore for full sustainable development, it is necessary to responsibly assess all possible factors influencing the ecological condition of the area.
Key words: land use, ecological stability, multi-criteria analysis, CORINE

Introduction
Recently, land use in the world and its impact on the ecological stability of the area has become a very complex and relevant process. Comparing land use with the pre-industrial period, the impact of anthropogenic factors on the ecological stability of areas and climate change is significantly intensifying - forest areas are decreasing, arable land and urban areas are expanding, atmospheric gas composition is changing rapidly, the greenhouse effect and soil pollution are increasing as well. (Rockstrom, 2009; Verburg et al. 2011; Berndes, 2011; Food Climate Research..., 2018; Organization for Economic..., 2012, 2018 a, b; Bai et al, 2018). A similar situation, except for the decrease of forest areas, is happening in Lithuania. Often urbanized areas are expanded by reducing green spaces or areas of agrarian territories (Valčiukienė, 2012). Irrational planning of infrastructure and development of built-up areas also worsens the quality of the local environment (Organization for Economic..., 2018 a, b). Various negative changes in the country's landscape due to active agriculture, forestry development and rapid urbanization are becoming relevant to the country's governing bodies, which are interested in the ecological stability of the place, and attract the attention of scientists. Therefore, works aimed at describing changes in land use and determining their connections with the ecological condition of the area are becoming more and more relevant for this purpose (Veteikis, Piškinytė, 2019).
The aim of this article is to analyse the land use of selected areas and its impact on the ecological stability of the area. As can be seen from the above review of literature sources, the natural environment, where the forest cover of the area plays an important role, is important for the ecological stability of the entire area. The new Lithuanian Master Plan 2030 identifies 15 municipalities with their own forest cover and exceptional recreational characteristics (Lithuanian Master Plan ..., 2020). From these municipalities, 3 municipalities were randomly selected for the survey - Ignalina, Molėtai and Zarasai districts, located

in the eastern and north-eastern part of Lithuania. Detailed indicators of land cover structure and ecological stability in these municipalities are analysed in the further “Results” section of this article.

Methodology of research and materials

Research data and methods. The main data used in the study - the CORINE dataset was downloaded from the Lithuanian spatial information portal www.geoportal.lt. The information in this dataset on land cover in the survey areas in 2006 and 2018 was processed by ArcMap software. With the help of this software, *a comparative analysis of the data* was performed, during which the program filtered and compared detailed data on the land cover of the studied areas in 2006 and 2018 (artificial cover, agricultural areas, forests and other natural areas, wetlands and water bodies) and their areas occupied. After collecting and summarizing the land cover data, *the degrees of polarization* for 2006 and 2018, also known as *ecological stability coefficients*, were calculated for each district. There is no unified methodology for calculating this coefficient, there are several formulas. In this work, the formula was chosen, which was used by the staff of the Institute of Ecology of Vilnius University when preparing the report of the Lithuanian CORINE land cover project 2006 (Vaitkuvienė, Dagys, 2008) (1).

$$P_K = \sum_{i=1}^{n} \frac{d_1 S_1}{S} \tag{1}$$

where, P_K – the degree of polarization of the landscape;
d_i – naturalness index for the *i*-th cover type;
S_1 – area of the *i*-th land cover type of the area;
S – the area of the whole territory.

This formula makes it possible to calculate the ecological stability coefficient also for such areas that do not have a relatively large number of natural or artificial lands, as the result depends only on the value of the naturalness index (Table 1).

Table 1

Naturalness indices (Vaitkuvienė, Dagys, 2008)

CORINE land cover class	Naturalness index
Continuous construction	0.05
Discontinuous construction	0.15
Industrial or commercial objects	0.05
Road and rail network and associated land	0.05
Port areas	0.05
Airports	0.15
Mining sites	0.25
Landfills	0.15
Construction areas	0.05
Green urban areas	0.65
Sports and recreation areas	0.45
Non-irrigated arable land	0.35
Fruit and berry plantations	0.45
Pasture	0.45
Complex agricultural areas	0.55
Areas of arable land with inclusions of natural vegetation	0.65
Deciduous forest	0.95
Coniferous forest	0.95
Mixed forest	0.95
Natural meadows	0.95
Wilderness and heaths	0.75
Transitional forest stages and shrubs	0.85
Beach, dunes, sand dunes	0.95
Areas with poor vegetation cover	0.75
Fireplaces	0.75
Continental wetlands	0.95
Peatlands	0.85
Water flows	0.95
Water bodies	0.85
Coastal lagoons	0.95

The general values of the naturalness index were not singled out in the report of the Lithuanian CORINE land cover project 2006 prepared by the staff of the Institute of Ecology of Vilnius University, therefore the methodology developed by P. Aleknavičius (2008) was chosen to assess the general values of ecological stability coefficients (Table 2).

Table 2

Polarization coefficient/ecological stability value indices (Aleknavičius, 2008)

Coefficient values	**Ecological condition of the area**
≥ 0,67	Stable
0,51 – 0,66	Moderately stable
0,34 – 0,50	Not stable
≤ 0,33	Unstable

Since in this case the degree of polarization/ecological stability coefficient of the area only assesses the impact of the landscape on the ecological condition of the area, a multi-criteria analysis was performed to assess not only the impact of the landscape on ecological stability but also the impact of certain environmental elements on the ecological condition of the area identifying which of the study areas has the best ecological condition.

Table 3

Chosen criteria for multi-criteria analysis using PROMETHEE software (Source: compiled by the authors)

No	**Criteria**	**Justification of the criteria**
1	Protected areas (percentage of occupied area in the district)	Biodiversity conservation may be considered on the basis of protected areas such as nature reserves, sanctuaries and others. Therefore, the larger the area of these areas in the district, the more ecologically strong the district is likely
2	Forests and other natural areas (percentage of occupied area in the district)	Forests tend to be highly diverse and provide many ecosystem functions, including habitat supply, carbon sequestration, water regulation, and erosion prevention. Therefore, it is considered that the more forests there are in the area, the ecologically stronger the area
3	Agricultural area (percentage of occupied area in the district)	The biodiversity crisis is caused by factors such as agricultural development and logging, so growing agricultural land has a partial negative impact on the ecological condition of the district
4	Population density (population 1 sq. km)	Higher population concentrations are usually associated with higher energy consumption, which is one of the main drivers of greenhouse gases, especially carbon dioxide emissions
5	Artificial covers (percentage of occupied area in the district)	Urban development is another major driver of land cover change. The construction of buildings and other artificial surfaces contributes to the loss of sensitive ecosystems and the degradation of natural habitats
6	Road length (km)	Many factors contribute to greenhouse gas emissions. One of them is transport. For this reason, the developed road infrastructure has a negative impact on the local ecological status
7	Gaseous and liquid substances emitted into the ambient air from stationary pollution sources (tons)	The release of substances or mixtures into the environment has a negative impact on natural ecosystems and the ecological condition of the area in general
8	Carbon monoxide emitted into the ambient air from stationary sources (tons)	
9	Nitrogen oxides emitted into the ambient air from stationary pollution sources (tons)	

PROMETHEE software was chosen for *the multi-criteria analysis* by introducing certain environmental elements that may affect the ecological condition of the areas.

Taking into account the analysis of various scientific sources, 9 criteria were selected for multi-criteria analysis with the help of PROMETHEE software, which include not only certain elements of the landscape, but also assess certain elements of the environment (Table 3).

In assessing the criteria, data were taken from the Department of Statistics of the Republic of Lithuania (https://www.stat.gov.lt/), the CORINE dataset and from the Lithuanian spatial information portal www.geoportal.lt .

When performing a multi-criteria analysis and determining in which of the studied areas the ecological condition can be the best, assessing not only the landscape but also the environmental elements, the directions of the criteria become a very important element. The criteria directions are selected taking into account the usefulness or uselessness of the criterion for the selected multi-criteria analysis objective. The directions of the criteria and the main data matrix used for the multi-criteria analysis performed with the help of PROMETHEE software are presented in Table 4.

Table 4

Multi-criteria analysis data matrix and criteria directions (Source: compiled by the authors)

	Part of protected areas in the district	**Part of forests and other natural areas in the district**	**Part of agricultural areas in the district**	**Population density pop. / 1 sq. km in 2020**	**Part of the artificial cover in the district**	**Road length, km**	**Gaseous and liquid substances, tons**	**Carbon monoxide, tons**	**Nitrogen oxides, tons**
	max	**max**	**min**	**min**	**min**	**min**	**min**	**min**	**min**
Ignalina district	34	39	50	10,07	0,0171	1501	124,70	66,75	16,41
Molėtai district	30	32	57	12,59	0,0187	1738	202,36	113,67	19,30
Zarasai district	40	42	44	11,21	0,0149	1708	129,73	107,43	13,65

Two different calculation methodologies were applied in the multi-criteria analysis, as the obtained results depend not only on the available criteria, but also on the selected functions and values in the program. First, the *usual* priority function was applied to all criteria. Later, the *linear* priority function was chosen for the calculations. When using the usual priority function, all that matters is that the value of one indicator is higher than the other, but the size of the difference is irrelevant. In this case, the program gives a coefficient equal to 1 to the criteria favourable for solving the multi-criteria analysis problem. Meanwhile, the linear priority function includes the state of identity Q and the strict priority value P, and there is a linear relationship between these thresholds (Q and P), therefore, in this case, it is not the fact that one indicator is higher than another that is important, but the value of the change between indicators, so the program gives coefficient values from 0.1 to 1 depending on the selected Q and P values (Figure 1).

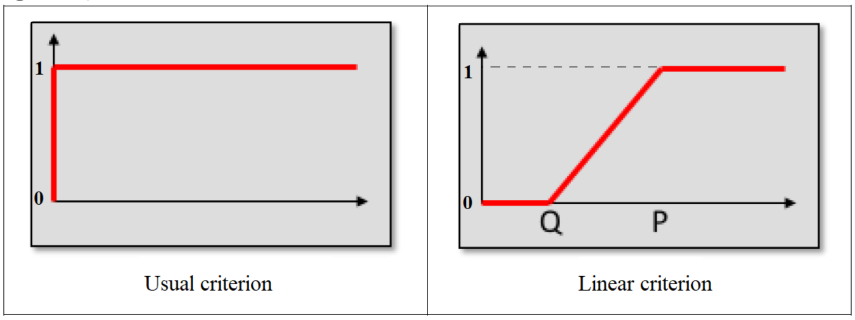


Fig. 1 Priority functions (Source: Mareschal, 2018)

The Q and P threshold values in the table below were used for the multi-criteria analysis (Table 5).

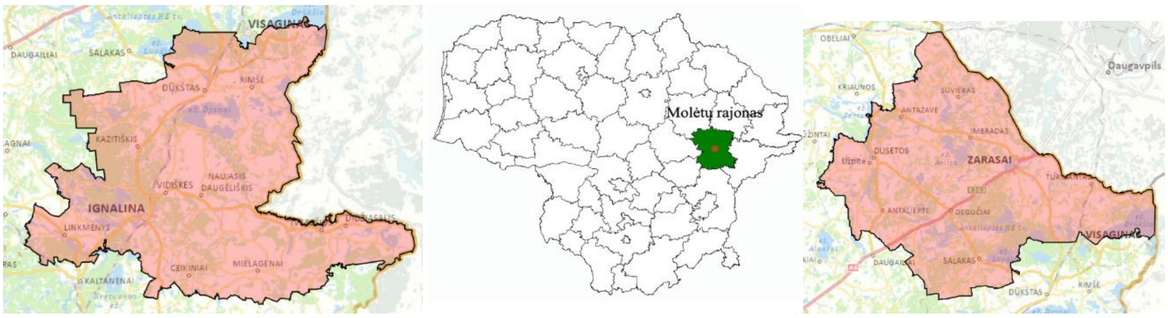
Table 5

Threshold values used in the multi-criteria analysis using the linear priority function (Source: compiled by the authors)

Thres hold values	Pro-tected areas	Forests and other natural areas	Agricultural areas	Popula-tion density	Artificial covers	Road length	Gaseous and liquid substances	Carbon mono-xide	Nitro-gen oxides
Q	0.02	0.03	0.03	0.60	0.0009	91.33	33.12	17.89	1.33
P	0.09	0.10	0.12	2.28	0.0035	249.33	84.89	49.17	5.10

Threshold data was generated based on suggestions from PROMETHEE software.

Research objects. As already mentioned, three districts in the east and north-east of Lithuania all belonging to Utena county were selected for the study: Ignalina, Molėtai and Zarasai. Ignalina district municipality is a resort area, which is often described as the capital of the recreation area of Eastern Lithuania due to excellent conditions for rest and sports at all times of the year. The area of the district occupies one-fifth of the total area of the county, i.e. 1447 km² (Figure 2).



a) Ignalina district b) Molėtai district c) Zarasai district

Fig. 2 Districts selected for the study (Source: www.geoportal.lt)

Molėtai district municipality is also often referred to as one of the summer tourism capitals. The area of the district is slightly smaller than the Ignalina district - 19 percent of the county area, i.e., 1368 km^2. Zarasai district municipality is located in the north-eastern part of Lithuania and occupies about 18 percent of the territory of Utena county, i.e., 1334 km². Thus, all districts are characterized not only by their exceptional recreational characteristics, but also by their considerable forest cover (from 32 to 42% of the total area), which in ecological terms has a significant impact on the ecological stability of the area, but still occupies a significant part of other, less ecologically stable areas. A detailed analysis of the land cover areas of the studied districts and their trends are presented in the following part of the results.

Discussions and results

The analysis of Ignalina district land cover revealed that in 2006 more than half (54%) of Ignalina district areas consisted of agricultural ones, the largest area of which was occupied by non-irrigated arable land (32% of total agricultural area) and complex agricultural areas (30% of agricultural land areas) (Figure 3).

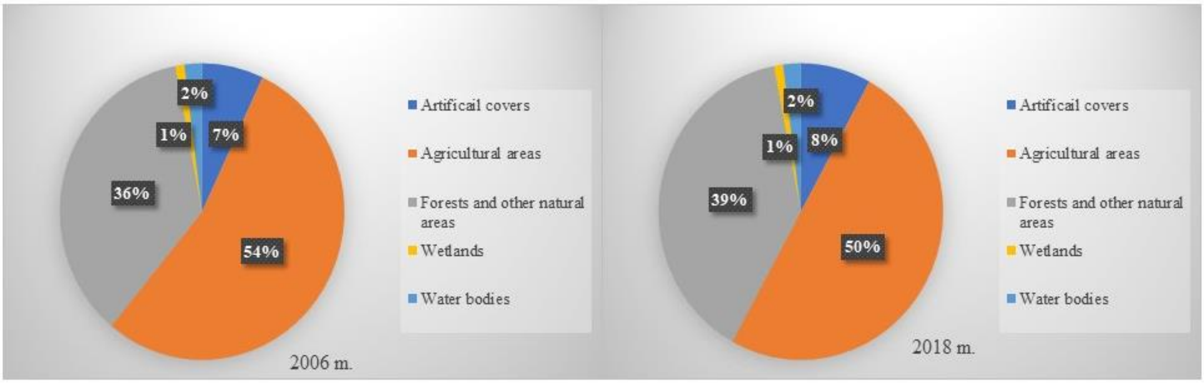


Fig. 3 Land cover in Ignalina district in 2006 and 2018
(Source: compiled by the authors based on the CORINE dataset)

In 2018, the structure of land cover in Ignalina district shows an obvious change in two cover areas: agricultural areas as well as forests and other natural areas. The decrease in agricultural areas (4858.69 ha, i.e., 4%) was mainly due to a quarter decrease in complex agricultural areas. Also, in 2018, compared to 2006, forests and other natural areas increased (4591.03 ha, i.e., 3%). The biggest impact on this change was the increase in the area of transitional forests and shrubs, which increased by as much as 89 percent in 12 years.
Meanwhile, in 2006, almost half (49%) of the area of Zarasai district consisted of agricultural areas, the largest area of which was occupied by arable land with natural vegetation inclusions (35% of agricultural area), complex agricultural areas (25% of agricultural area) and non-irrigated arable land (24% of agricultural area) (Figure 4).

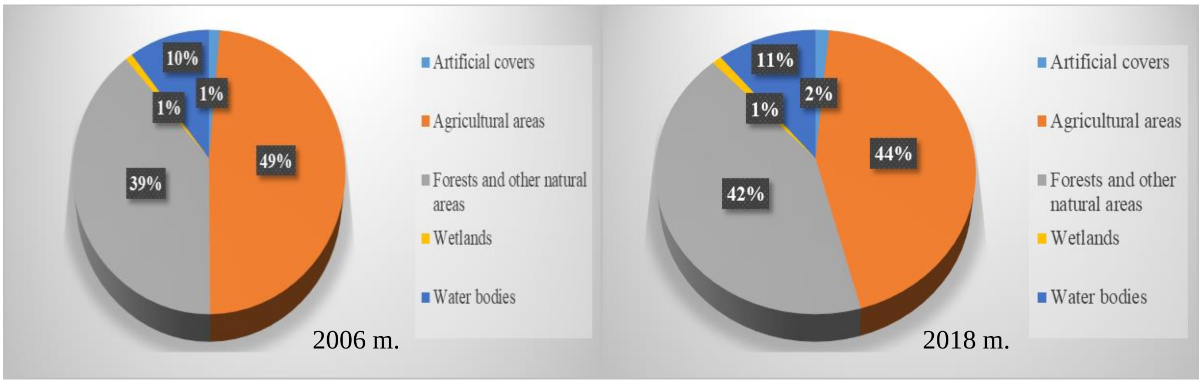


Fig. 4 Land cover in Zarasai district in 2006 and 2018
(Source: compiled by the authors based on the CORINE dataset)

In 2018, in the land cover structure of Zarasai district, it can be noticed that during 12 years the area of forests and other natural areas (4434.01 ha, i.e. 3%), water bodies (729.16 ha, i.e. 1%) and artificial cover (131.73 ha, i.e. 1%) increased. The change in the artificial cover was determined by the increased area of discontinuous construction. Forest area alone has grown by 3 percent (compared to 2006) due to increased transitional forest stage and shrub areas. It is also noticeable that the area of agriculture has decreased (5503.03 ha, i.e., 5%). The decrease in agricultural areas was mainly due to the halving of non-irrigated arable land.
Meanwhile, in 2006, almost two thirds (slightly less than 63%) of the territory of Molėtai district was occupied by agricultural areas (Figure 5). It consisted of non-irrigated arable land (29 percent), complex agricultural areas (33 percent) and arable land with natural vegetation inclusions (38 percent).

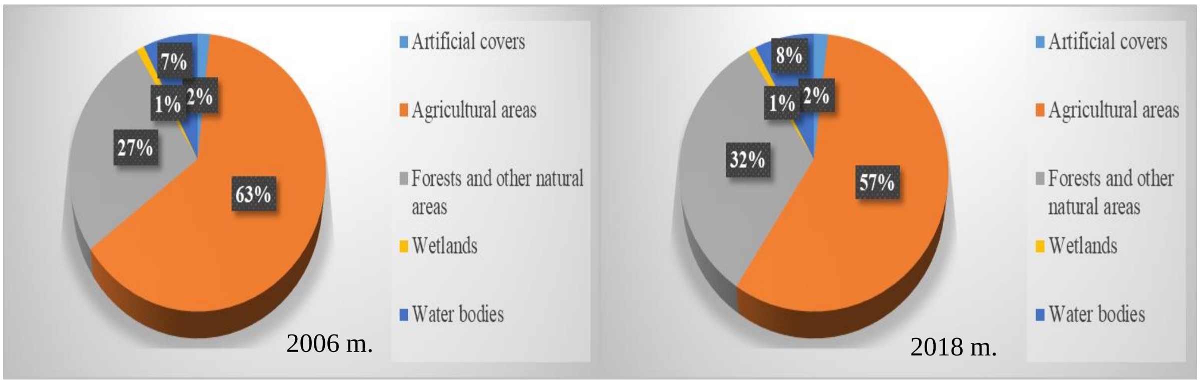


Fig. 5 Land cover in Molėtai district in 2006 and 2018
(Source: compiled by the authors based on the CORINE dataset)

Over 12 years, in the structure of the land cover of Molėtai district significantly decreased the agricultural area (7990.50 ha, i.e., 6%), increased the area of forests and other natural areas (7286.24 ha, i.e., 5%) a well as the area of artificial covers (341.81 ha, i.e. 1%). The decrease in agricultural areas was mainly due to a decrease of more than a third in non-irrigated arable land. Also, in 2018 compared to 2006 forests and other natural areas have grown strongly. This change was mainly due to the doubling of transitional forest stage and shrub areas.

Summarizing the structure of land covers in the districts and the tendencies of their change, it can be stated that the largest part of the area of all three districts (from 44% in Zarasai, 50% in Ignalina to 57% in Molėtai municipality) consists of other natural areas, respectively 42% – in Zarasai, 39% – in Ignalina and 32% in Molėtai municipality and artificial covers (8% each in Ignalina and Molėtai and 11% in Zarasai district municipality). Over a 12-year period (from 2006 to 2018) there is a practically steady (4-6%) decrease in agricultural areas and growth of forests and other natural areas (3-5%) as well as artificial covers (1%) in all three municipalities.

Using the analysed land cover data of the districts for 2006 and 2018, the calculated ecological stability coefficients for each of the analysed districts at the respective time period are presented in Figure 6.

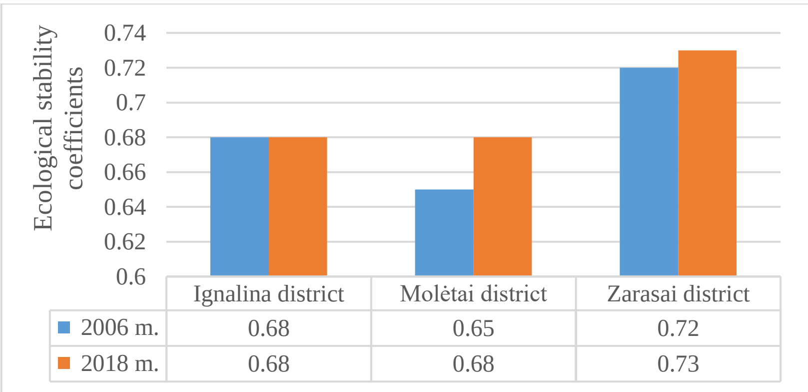


Fig. 6 Ecological stability coefficients of Ignalina, Molėtai and Zarasai districts

Based on the results presented on the obtained ecological stability indicators, it can be stated that when assessing the ecological stability of the area based on the structure of land cover throughout the analysed period, all areas are ecologically stable, i.e., all values of polarization coefficients exceed 0.67, except for the value of ecological stability coefficient of Molėtai district in 2006, which was 0.65. This value of the coefficient shows that the area in 2006 was moderately stable (Table 2), but in 2018 has already reached the ecologically stable area indicator (0.68). This was mainly due to a decrease (6%) in agricultural areas and a 5% increase in forests and other natural areas. Such trends in these areas have a positive effect on the ecological stability index of the area (Table 1).

However, as the analysis of scientific sources shows, the ecological stability of the area can be influenced by other criteria than the structure of the land cover (Table 3).

In a multi-criteria analysis using the PROMETHEE software ranking test, it was found that after choosing both the usual priority function and the linear priority function the order of the districts is the same, but the results obtained are not identical.

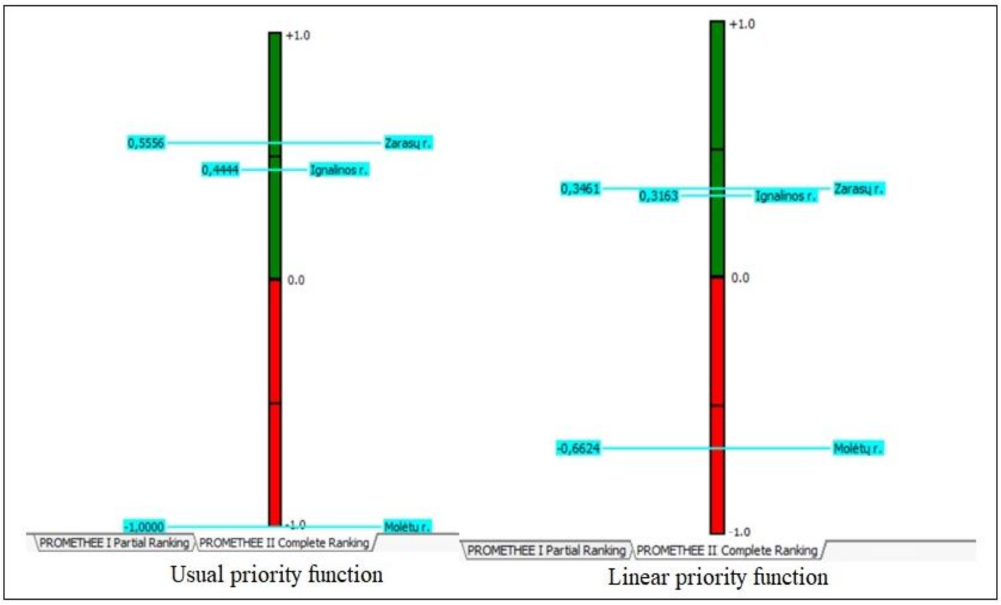


Fig. 7. PROMETHEE ranking test

After choosing the usual priority function, the best ecological condition is in Zarasai district, Ignalina district is in the second place, and Molėtai district is in the third place. Using the linear priority function and using the Q and P values recommended by the program, the ecological condition in both Zarasai and Ignalina districts is almost the same. The ranking coefficient of the ecological condition of Zarasai district is higher than the ranking coefficient of Ignalina district by only 0.03 points. As the difference is very small, it cannot be said that the ecological condition in Zarasai district is better due to possible errors in compiling and collecting statistics. Meanwhile, the analysis of both methods revealed that the ecological condition in Molėtai district is unambiguously the worst, despite the fact that using the linear priority function, the ecological condition ranking indicator of Molėtai district is slightly better (-0.66), and using the usual priority function (-1).

The most favourable indicators for the ecological condition of Ignalina district, i.e., those with the lowest values and a positive impact on the ecological stability of the area are presented in Figure 8, which shows the criteria for which the program assigns coefficients higher than 0.

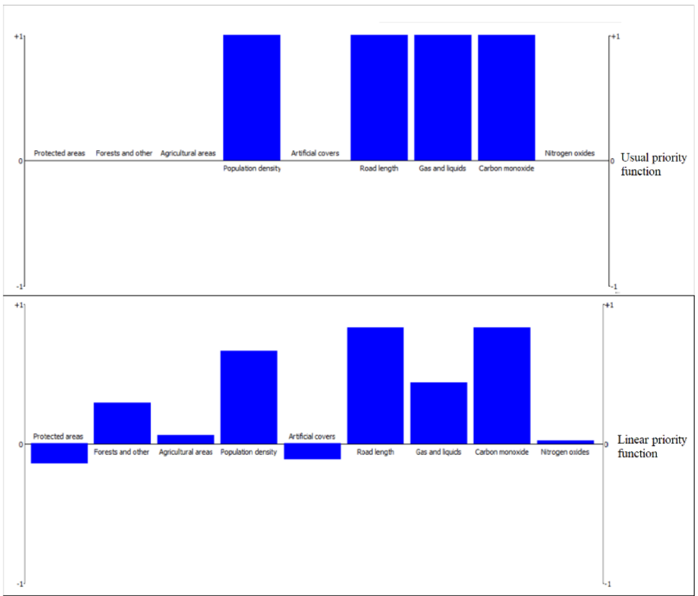


Fig. 8. Factors affecting the ecological condition of Ignalina district

As can be seen, the choice of the usual priority function revealed four criteria that are favourable to the ecological condition of the area: population density, road length, gaseous and liquid substances and carbon monoxide. Forests and other natural areas, agricultural areas and nitrogen oxides are also included in the favourable criteria using the linear priority function.
There are no favourable criteria for the ecological condition of Molėtai district using both calculation methods, but using the linear priority function the criteria ranking coefficients are slightly better than using the usual priority function, therefore the results obtained using different calculation methods are not the same (Figure 9).

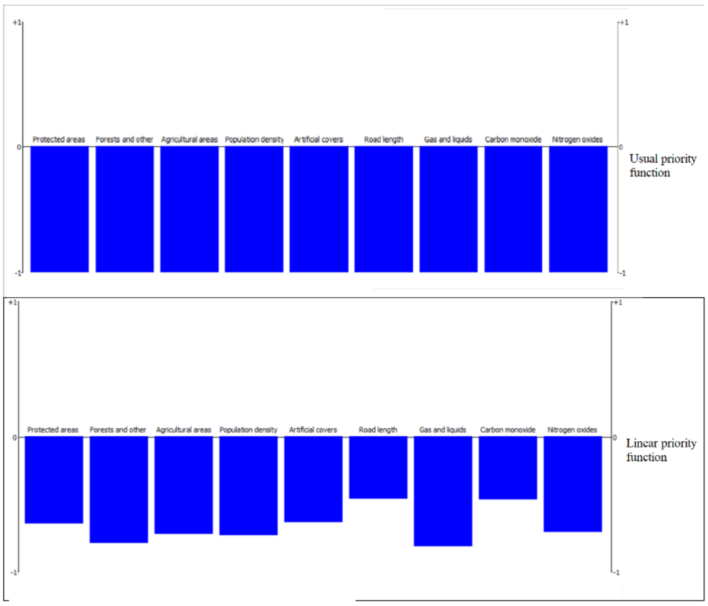


Fig. 9 Factors affecting the ecological condition of Molėtai district

Criteria favourable for the ecological condition of Zarasai district using different priority functions are presented in Figure 10.

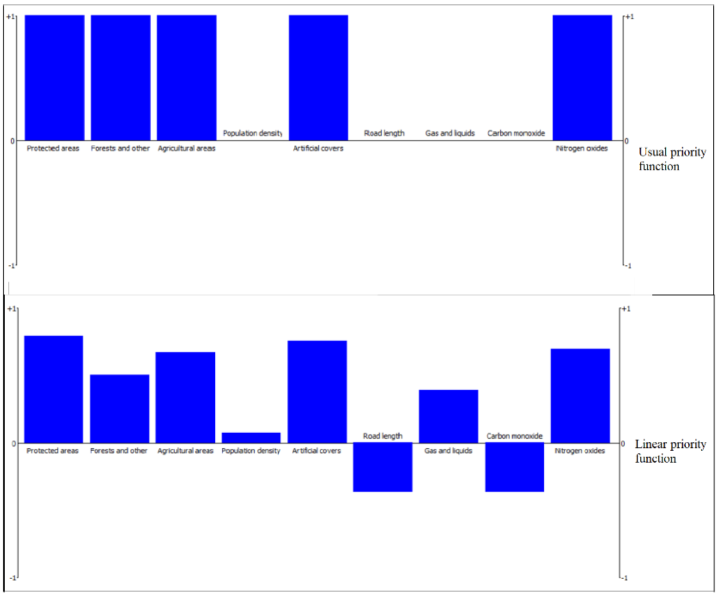


Fig. 10 Factors affecting the ecological condition of Zarasai district

The presented data show that when applying the usual priority function, 5 ecological conditions are favourable for the ecological condition of Zarasai district, namely: protected areas, forests and other natural areas, agricultural areas, artificial covers and nitrogen oxides, and linear priority function contributes population density, gas and liquids.

Thus, the assessment of the ecological stability of the districts using the multi-criteria method found that the ecological stability of the area is influenced not only by the land use, i.e. the structure of the cover of the area, but also other environmental elements related to the area, which, regardless of the positive ecological stability of it, may have a much opposite effect on the overall ecological stability of the area. As can be seen from the analysis, despite the sufficient area of forests and other natural areas as well as declining agricultural areas, which has a significant impact on the ecological stability of the area, other elements of the environment, such as emissions of gaseous and liquid substances, carbon monoxide and nitrogen oxides, or even the lowest possible population density and road network in the area, are equally important factors. Therefore, in order to achieve fully sustainable development of areas, in the planning and further management of them, which influences land use trends, it is necessary to responsibly assess as much as possible all possible factors influencing the ecological condition of the area.

Conclusions and proposals

1. In Ignalina, Molėtai and Zarasai districts, the largest part of the area (from 44 % in Zarasai, 50% in Ignalina to 57 % in Molėtai municipality) consists of agricultural areas, slightly smaller areas are occupied by forests and other natural areas, respectively 42 % - in Zarasai, 39 % - in Ignalina and 32 % in Molėtai municipality and artificial covers (8 % each in Ignalina and Molėtai and 11 % in Zarasai district municipality). Over a 12-year period, a practically even (4-6 %) decrease in agricultural areas and growth of forests and other natural areas (3-5 %) and artificial cover (1 %) were observed in all three surveyed municipalities.
2. Throughout the study period, depending on the structure of the land cover, the districts have positive ecological stability indicators, i.e., the values of the polarization coefficients exceed 0.67, except for the value of the ecological stability coefficient of Molėtai district in 2006, which was 0.65, i.e, the area was moderately ecologically stable. However, it is probable that due to the decrease in agriculture by the most -6 percent than in other districts and the increase in the area of forests and other natural areas by 5 percent, which have a positive impact on the ecological stability of the area, this area reached the ecologically stable area indicator in 2018 (0.68).
3. The multi-criteria analysis of the ecological stability of the districts showed that despite the positive ecological stability indicators when assessing the districts according to their land cover structure, the ecological condition of Molėtai district is still the worst according to the rating indicators (indicator values are -0.66 using linear priority function, using usual priority function - 1), while the ecological condition of Zarasai and Ignalina districts is very similar. Such a negative multi-criteria assessment of the ecological condition of Molėtai district was influenced by all criteria: lower area of protected territories, forests and natural areas in the district, higher population density, road length, area of artificial covers and emissions (carbon monoxides, nitrogen oxides, etc.) quantity. Meanwhile, when assessing the ecological condition of Ignalina district, 4 criteria were favourable, namely: relatively low population density, road length, and lower emissions of gases and liquids, carbon monoxide, and for Zarasai district 7 criteria: higher protected areas, forests and other natural, agricultural areas and artificial cover areas as well as lower population density and emissions of nitrogen oxides, gaseous and liquid substances.
4. The results of the study unequivocally revealed that the ecological stability of the area is influenced not only by land use, i.e., the structure of the area cover, but also other environmental elements related to the area, such as emissions of gaseous and liquid substances, carbon monoxide and nitrogen oxides, or even the lowest possible population density and road network in the area. Therefore, in order to achieve fully sustainable development of areas through territorial planning and further management, which also influences land use trends, it is necessary to responsibly assess all possible factors influencing the ecological condition of the area.

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Information about authors:

Jolanta, Valčiukienė, doctor of technology science, assoc. prof., Institute of Land Use Planning and Geomatics, Vytautas Magnus University Agriculture Academy. Address: Universiteto str. 10, LT-53361, Akademija, Kaunas district, +37037752372, jolanta.valciukiene@vdu.lt. Fields of interest: sustainable development of rural and urban areas, land use planning, land administration.

Arnoldas, Gasparavičius, master student, Institute of Land Use Planning and Geomatics, Vytautas Magnus University Agriculture Academy. Address: Universiteto str. 10, LT-53361, Akademija, Kaunas district, +37037752372, arnoldas.gasparavicius@gmail.com.

Daiva, Juknelienė, doctor of technology science, lecturer, Institute of Land Use Planning and Geomatics, Vytautas Magnus University Agriculture Academy. Address: Universiteto str. 10, LT-53361, Akademija, Kaunas district, +37037752372, daiva.jukneliene@vdu.lt. Fields of interest: sustainable development of rural and urban areas, land law.

Virginija, Atkocevičienė, Mg.sc.ing., lecturer, Institute of Land Use Planning and Geomatics, Vytautas Magnus University Agriculture Academy. Address: Universiteto str. 10, LT-53361, Akademija, Kaunas district, +37037752372, virginija.atkoceviciene@vdu.lt. Fields of interest: sustainable development of rural areas, land use planning.