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EVALUATION OF RECENT SEDIMENTATION RATES IN THE LAKES OF EAST LITHUANIA BASED ON RADIOISOTOPE DATING

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Introduction

Intensive sedimentation took place in the lakes in Holocene and continues till present (Общие…, 1986; Lietuvos…, 1991). It is especially intensive in the central parts of lakes where in about 10 000 years a 12–18 m thick layer of lake sediments has developed. Consecutive analysis of the sediment cores by radioisotope methods and supporting hydrometeorological data can be used as a tool revealing paleoclimatic and paleoecological changes that have taken place in the lakes catchment.

Studies of lake and marine sedimentation by the ^{210}Pb method have been carried out in many regions of the world (Krishnaswami et al., 1971; Koide, Bruland, Goldberg, 1973; Robbins, Edgington, 1975; Robbins, 1982; Bollhöfer et al., 1997; Mažeika, Dušauskienė-Duž, Radzevičius, 2004). This method is often combined with cesium-137 (^{137}Cs) and sometimes with radiocarbon (^{14}C) studies. The ^{210}Pb in lake sediments is of double origin. Part of ^{210}Pb forms *in situ* as a result of ^{226}Ra decay. This part (*supported*) is determined by radioactive equilibrium with ^{210}Pb parent isotopes – ^{214}Pb and ^{214}Bi. The other part of ^{210}Pb is non-equilibrium or unsupported (^{210}Pb excess – unsupported) and is used for dating. It forms while burning the fossil organic fuel and gets into water systems as a result of rapid atmospheric transport and deposition of ^{210}Pb originated from ^{226}Ra decay products. Two chronologically linked events predetermine the distribution of ^{137}Cs in lake sediments – deposition of ^{137}Cs after the accident in the Chernobyl NPP in 1986 and global fall-outs of ^{137}Cs (with their maximum in 1963–1964) as a result of nuclear bombs testing in the atmosphere.

Processes of sedimentation in the lakes Drūkšiai, Baltys, Lydekis, Glėbas, and Varėnis located in the eastern part of Lithuania (Baltic Upland) were investigated by radioisotope methods (Fig. 1).

Two of investigated lakes (Baltys and Glėbas) have no tributaries and are endoheic. They are fed by groundwater base flow from forested anthropogenically almost undisturbed catchments. Rivers with comparable catchments flow across the Varėnis and Lydekis lakes. Part of their catchments is used in agriculture. The Lake Drūkšiai catchment is also used in agriculture but the regulation of its runoff in the 20th century and operation of Ignalina NPP were the factors, which produced the greatest effect on it.

The results obtained by radioisotope dating have been compared with the average annual mass of sediments measured using sediment traps.

1. Geological, Hydrological and Environmental Settings

The Lake Drūkšiai is situated in the northeastern part of Lithuania, Utena County, 2 km south of the Lithuanian–Latvian border. Part of the lake is included into the territory of the Republic of Belarus. Lake Drūkšiai is the largest lake in Lithuania. The area of its water

surface is 49 km^2, the length is 14.3 km, and the width is 5.3 km (Таутвидас, Ласинскас, 1986). The annual atmospheric precipitation in the lake catchment amounts to 600 mm. There are 174 days with precipitation per year. The surface runoff is 154 mm. A greater part of Lake Drūkšiai catchment is occupied by forests (42 %). The farm lands account for

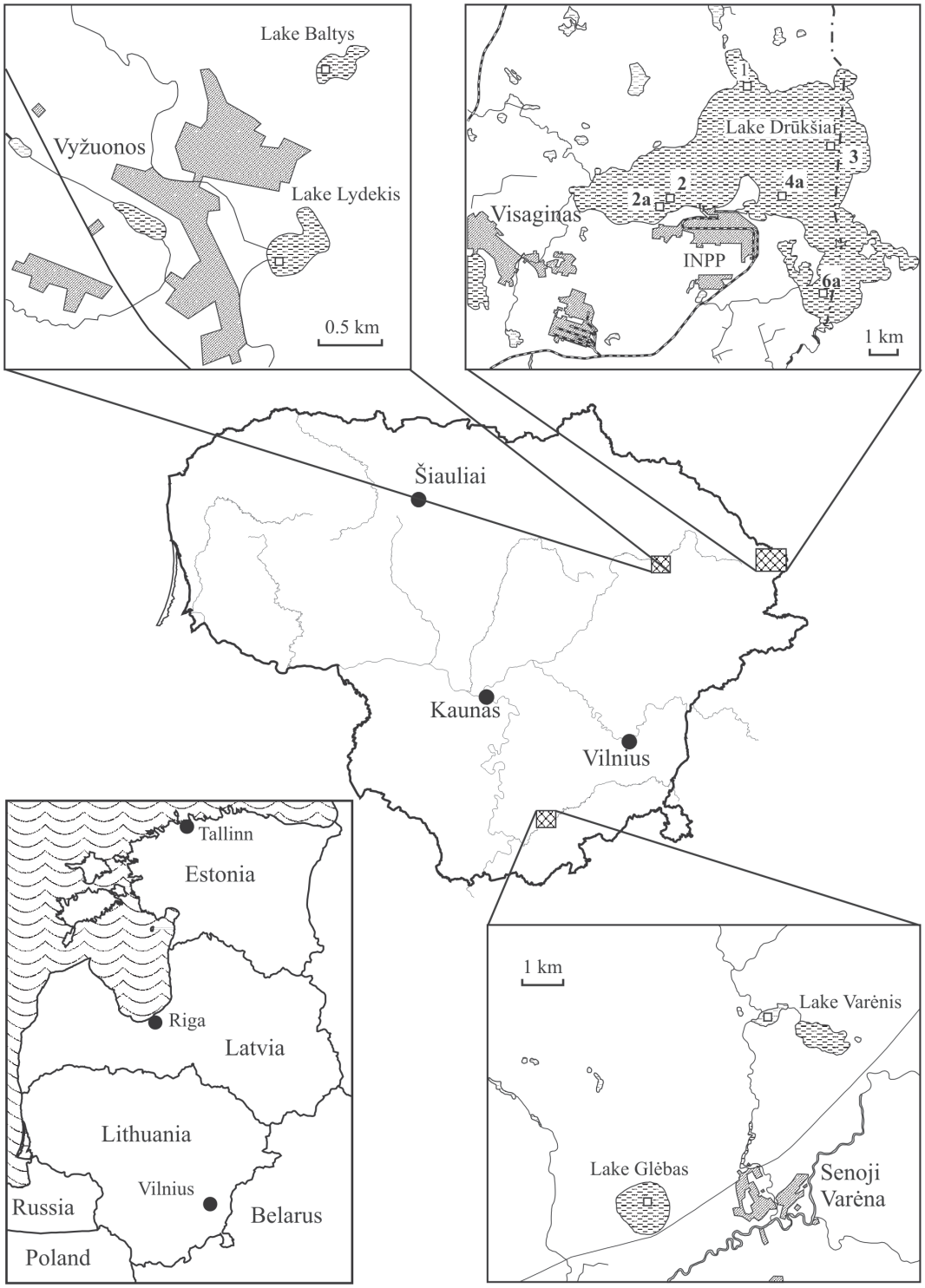

Fig. 1. Location scheme of studied lakes and stations where core samples were taken.

17 % including 10 % of arable land. Lakes account for 22.5 %, bogs – for 6.9 % and roads and other man-made covering – for 1.5 % of the basin area. A small Drūkša river used to flow from the south-eastern part of the lake before the beginning of the 20th century. A canal for water-mill between the Lake Drūkšiai and Lake Stavokas (the eastern promontory of the lake) was dug out in about 1912. Since then the lake water has been flowing through the new Prorva canal and through the old one. The runoff through the Drūkša river was blocked in 1953 when a hydroelectric power plant (HEPP) was built on the Prorva canal. The lake catchment area expanded by about 24 % after annexation of Apyvardė river catchment. Since then the Lake Drūkšiai has a few small tributaries with their summary average annual discharge of 3.0 m^3/s and one outflow. The HEPP was closed in 1982 but the hydrographic network has not been renaturalized. The Ignalina NPP was started up in 1984. High water level is maintained in the lake for cooling the NPP. Due to this, the annual water level fluctuation amplitude has reduced from 1 to 0.4 m. The Lake Drūkšiai is characterized by a high diversity of recent surface sediments (Гарункштис, 1975).

The lacustrine sediments of the surrounding territories have been less thoroughly investigated. The lakes Lydekis and Baltys are situated in the Utena District, in environs of Vyžuona settlement. Lydekis is drained by Vyžuona rivulet (Table 1).

Judging from geomorphologic signs, the depressions of both lakes are of thermokarst origin. The whole catchment of the Lake Baltys (about 1 km^2) is forested. The average annual precipitation in the catchments of Lakes Lydekis and Baltys is 620 mm. There are 168 days with precipitation per year on the average. The average temperature of the warmest (July) month is 17.1°C and of the coldest month (January) is -5.7°C. The average surface runoff of Lake Lydekis is 274 mm. Spring floods account for 36 % of the total annual runoff.

Table 1. Morphometric and hydrological features of the studied lakes.

Lake	Area, ha	Max. depth, m	Average depth, m	Number of tributaries	Number of outflows	Catchment area, km^2	Runoff, m^3/s
Drūkšiai	4900	33	8	11	Prorva	613	3.20
Varėnis	23	9	3.1	2	Varėnė	396	3.18
Lydekis	18	22	–	1	Vyžuona	381	3.31
Glėbas	135.9	10	–	0	No	6.1	–
Baltys	9.2	9	–	0	No	1	–

The Lakes Glėbas and Varėnis are situated in the Varėna District, in the environs of Senoji Varėna settlement. The Lake Varėnis is drained by Varėnė rivulet (Table 1). Glėbas is an enclosed lake without affluents or effluents. Its bottom is gradually inclining to the centre of the lake where the depth reaches 10 m. The lake depression is situated on the glaciofluvial terrace, which is sloping toward the valley of Merkys River. The depression of Lake Glėbas had been pressed down by a block of dead ice. The depression of Lake Varėnis is of thermokarstic origin. Its surrounding area is covered by glaciofluvial deposits. Sediments of Lake Varėnis are mainly represented by silty clay but they also include all types of lacustrine sediments from sand to lake marl. The sediments of the three other lakes have been poorly investigated.

The average annual precipitation in the catchments of Lakes Glėbas and Varėnis equals to 620 mm. There are 169 days with precipitation on the average. The average temperature in July is 17.2°C and in January it is -5.8°C. The average surface runoff of Lake Varėnis is 258 m. Spring floods account for 28 % of the total annual runoff.

2. Sampling and Methods

The Niemistö gravity corer was used for taking five short (up to 70 cm in length) cores from Lake Drūkšiai. The same technique was used for cores taking from the central parts of the other lakes. The cores were sliced into 1 to 6 cm thick slices. The samples were dried in laboratory and examined for water content, dry bulk density and components of sedimentary matrix. After radiochemical pre-treatment the ^{210}Pb activity in cores taken from stations 1, 2 and 4a was measured at the Institute of Botany using beta-spectrometry (Душаускене-Дуж, 1981).

Development of high quality germanium detectors of gamma-radiation provides a non-destructive tool for direct measuring of ^{210}Pb activity using its week gamma-radiation. All cores were examined by the method of gamma-spectrometry. Standard methods were applied in the pre-treatment of samples for determination the activity of gamma-emitting radionuclides (Gudelis *et al.,* 2000). Activity of gamma-emitting radionuclides in the core samples was measured by germanium detector GWL-170230-S manufactured by 'EG&G Ortec'. In the upper part of some cores ^{60}Co activity (along with ^{210}Pb and ^{137}Cs) was also detected.

3. Results and Discussion

The data on the ^{210}Pb activity were interpreted on the basis of constant rate of supply (CRS) model (Koide, Bruland, Goldberg, 1973). The activity of ^{210}Pb exponentially reduces with depth in the interval of accumulation of unsupported ^{210}Pb. The ^{210}Pb activity below this interval is in equilibrium with the ^{226}Ra. In this case the unsupported activity of ^{210}Pb $\mathrm{Act}\left(^{210}Pb_{xs}\right)$ is derived using formula:

$$Act\left(^{210}Pb_{xs}\right) = Act\left(^{210}Pb_{tot}\right) - Act\left(^{210}Pb_{sup}\right), \qquad (1)$$

where $Act\left(^{210}Pb_{tot}\right)$ – measured activity of ^{210}Pb; $Act\left(^{210}Pb_{\sup}\right)$ – supported activity of ^{210}Pb in equilibrium with ^{226}Ra (the activity is expressed in Bq/kg of dry weight).

The sediment dry mass accumulation rate (mean) R_m is calculated using formula:

$$R_m = \frac{G_j \times \lambda}{\ln Act(^{210}Pb_{xs(0)}) - \ln Act(^{210}Pb_{xs(Gj)})}, \qquad (2)$$

where $Act(^{210}Pb_{xs(0)})$ – according to exponential function approximated activity of ^{210}Pb in the surface of sediments (depth – 0), $Act(^{210}Pb_{xs(Gj)})$ – according to exponential function approximated activity of ^{210}Pb in sediments at a depth G_j; λ – radioactive decay rate (for ^{210}Pb it is 0.031 1/year); G_j – compaction corrected depth; $G_j = \sum_{i=1}^{i=j} \rho_i \times d_i$ where ρ_i – dry bulk density; d_i – sample thickness in the core.

The time of sediment layer accumulation T is derived from the ratio:

$$T = \frac{G_j}{R_m}. \qquad (3)$$

The probable (or partial) sedimentation rate for each slice of core is derived from the deviation of unsupported ^{210}Pb from exponential function:

$$R_p = \frac{R_m \times Act(^{210}Pb_{xs(Gj)})}{Act(^{210}Pb_{xs(i)})}, \quad (4)$$

assuming that decreased unsupported activity of ^{210}Pb shows dilution of atmospheric lead-210 by detritus (higher sedimentation rates compared to mean value), increased unsupported activity of ^{210}Pb – lover sedimentation rates.

The sediment dry mass accumulation rate for stations 1, 2a and 4a in the Lake Drūkšiai estimated by ^{210}Pb method are 0.12–0.16, 0.08 and 0.11 g/cm^2/year respectively (Fig. 2).

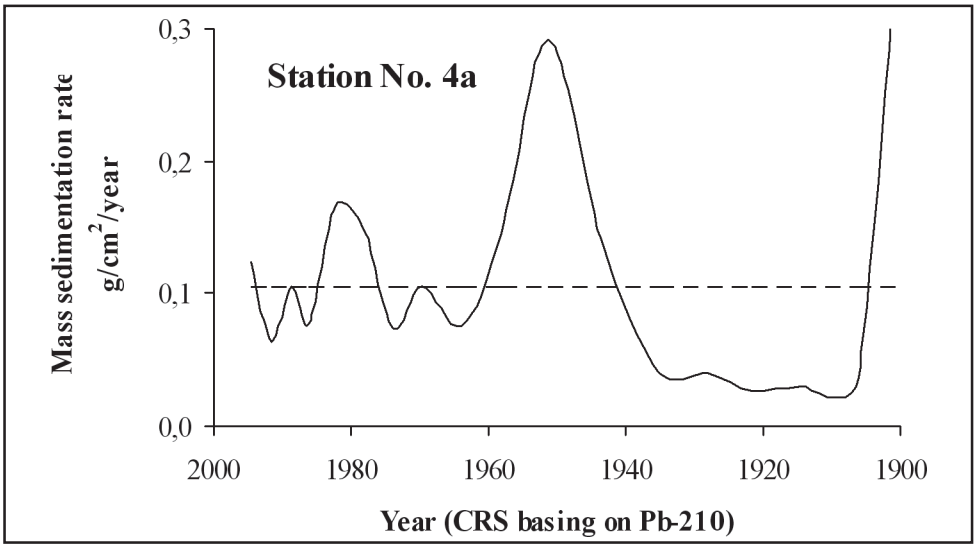

Fig. 2. Variations of sedimentation rates in the Lake Drūkšiai based on CRS age model for gravity cores (solid line – mean, dotted line - partial).

The 70 cm thick layer of recent lake sediments has accumulated in the zones of stations during 85 and 95 years respectively. More pronounced time differences (in comparison with the rates of sedimentation) occur due to dissimilarity of the density of sediments, which, in its turn, depends on the composition and compaction of sediments. Comparison of deviation of sedimentation rates in the stations showed no definite variation tendencies of sedimentation rates over the lake. The even sedimentation in station 2a in the 20th century might have been predetermined by the unique morphometric and hydrodynamic conditions in this part of the lake (the greatest depth of the lake is in its comparatively narrow western bay). Whereas two or three peaks of higher sedimentation rates can be distinguished for stations 1 and 2 (Fig. 2).

Higher sedimentation rate in the area of station 1 occurred in the time frame 1920–1940 and after 1980. Noticeable variations of sedimentation rate were also recorded for station 4a, which is situated closest to the zone of hydrographical transformations entailed by building hydrotechnical constructions in the last century. Three periods of higher sedimentation have been distinguished there: after 1900 (building of the canal and direction of water flow through Prorva; changes of water level in the lake), after 1940–1960 (direction of the water of Apyvardė rivulet to the lake for the needs of HEPP, expansion of the catchment) and after 1980 (building of NPP, digging of canals for technical water discharges and changes of water level in the lake). The rates of sedimentation could have also been predetermined by greater amounts of precipitation in the indicated time frames.

Before starting the Ignalina NPP in 1980–1981 (construction period) sedimentation rates were measured by means of sediment traps in stations 1, 2a and 3 of Lake Drūkšiai (Fig. 1). The sediment dry mass accumulation rate for station 1 and 3 was 0.17 g/cm^2/year and for station 2a – 0.29 g/cm^2/year. The proportion of mineral material in stations 1 and 3 amounted to 70 % and in station 2a – to 64 % (Тамошайтис, 1989).

The sediment dry mass accumulation rates determined by the method ^{137}Cs in the same zones were 0.13, 0.11 and 0.12 g/cm^2/year respectively (Table 2).

Table 2. Recent sedimentation rates in Drūkšiai, Baltys, Lydekis, Glėbas, and Varėnis lakes.

Lake	No of sampling station	Lake depth at the sampling station, m	Lake sediment types	Range of dry bulk density in the core, g/cm^3	Mean sediment dry mass accumulation rate, g/cm^2/year	
					Method ^{210}Pb	Method ^{137}Cs
Drūkšiai	1	18	Silty clay	0.06–0.22	0.12-0.16	0.13
	2	14	Sandy silt	0.1–0.7	n/m	0.07
	2a	12	Sandy silt	0.06–0.16	0.08	0.11
	4a	6	Clayey silt	0.1–0.6	0.11	0.12
	6a	5	Silt	0.1–0.18	n/m	0.12
Baltys	1	6.8	Gyttja	0.02–0.08	0.05	0.07
Lydekis	1	19.5	Silty clay	0.04–0.12	n/m	>0.5
Glėbas	1	8	Gyttja	0.03–0.05	n/m	0.05
Varėnis	1	4	Silty clay	0.12–0.35	n/m	>0.5

These values are slightly higher than the ones determined by the ^{210}Pb method what implies higher mobility of ^{137}Cs than ^{210}Pb in the lake sediments (Fig. 3).

The presence of the so-called 'corrosive' radionuclide ^{60}Co makes easier the identification of the peak in 1986 because the discharges of ^{60}Co into the lake occurred only after the start of the Ignalina NPP in 1983. Sediment dry mass accumulation rate in stations 2 and 6a were 0.07 and 0.12 g/cm^2/year respectively. The highest sedimentation rate has been recorded in the deepest lake area (station 1) and in most eutrophicated part of the lake (station 6a), i.e., in the zones of sedimentation of fine-grained terrigenous and organic material.

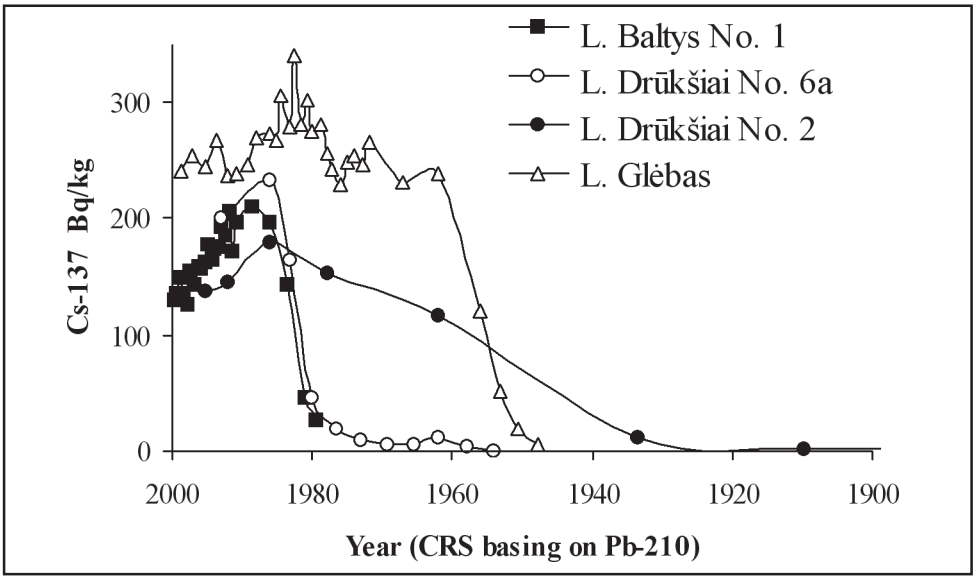

Fig. 3. ^{137}Cs in sediments versus calendar years.

Sedimentation rates determined by ^{137}Cs method for the small and enclosed Baltys and Glлbas lakes were 0.07 and 0.05 g/cm^2/year respectively. For the Lake Baltys comparative values of the measured parameter were obtained by both – ^{137}Cs and ^{210}Pb – methods (Fig. 4). The sedimentation rates measured using sediment traps for other Lithuanian lakes of similar type (Balsis, Akmena, Glūkas) were from 0.03 to 0.21 g/cm^2/year. No distinctive peaks of ^{137}Cs activity were distinguished in the core samples of drained Lydekis and Varėnis lakes.

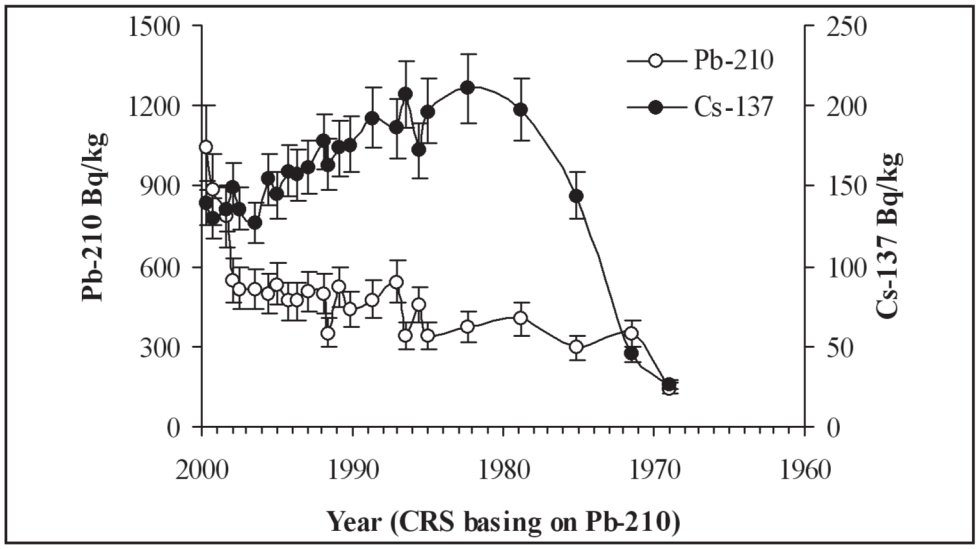

Fig. 4. ^{137}Cs and ^{210}Pb in sediments from Lake Baltys versus calendar years.

This is probably predetermined by active terrigenous sedimentation and turbulence of sediments. The 70 cm thick layer of sediments turned out to be insufficient for analysis. Assuming that the maximal activity of ^{137}Cs occurs in deeper zones we may assume that sedimentation rates in these lakes exceed 0.5 g/cm^2/year. These data have been obtained for the Lake Varėnis (using sediment traps) where the rate of sedimentation reached 1.0 g/cm^2/year.

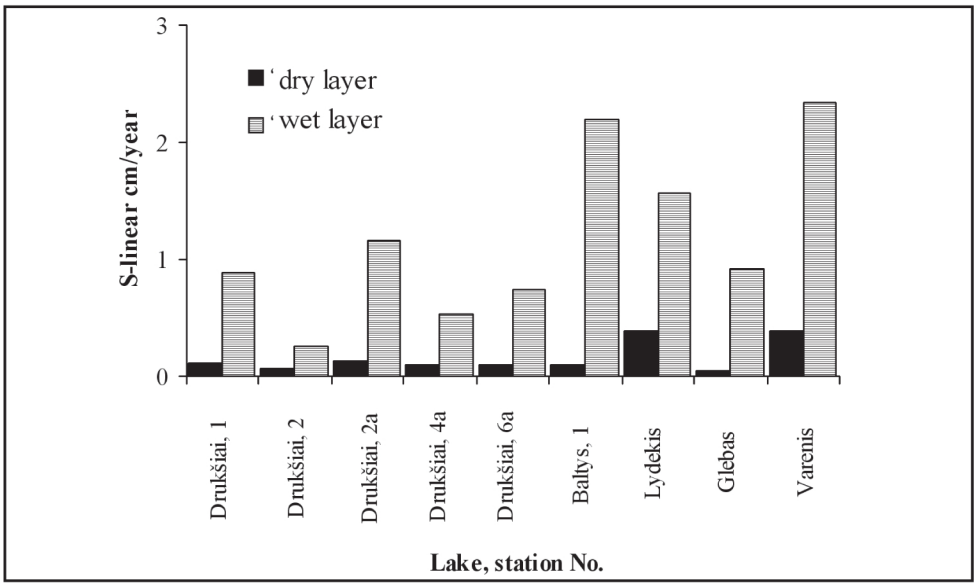

Fig. 5. Mean sedimentation rates in the studied lakes.

The lowest rates of sedimentation have been recorded in the Lake Glėbas where they are predetermined by geomorphology of lake environs contributing to slow input of dominant organic material. Parameters of sedimentation before and after 1986 differed but little – 0.05 and 0.04 g/cm^2/year respectively.

Depending on the composition and post-sedimentary transformations of primary material layers of different thickness can develop at the same average rate of sedimentation (Fig. 5). Thus, at the rate of 0.07 g/cm^2/year a layer of 2.2 cm in thickness accumulates in the Lake Baltys in a year whereas in the Lake Drūkšiai (station 2) – only 0.26 cm (at the same rate value). Both parameters are informative about the processes of sedimentation. The first one shows the physical intensity of sedimentation and the second one is more vivid for spatial perception of the process. It is also necessary to bear in mind that in the course of geological evolution organic material is subject to transformations and can be carried out by and used in biogeochemical processes.

The input of allochthonous particulate sediments with the surface runoff depends on precipitation as well. It has been determined that high water periods recur cyclically – in about 23–33 years. The data of annual precipitation from the Vilnius meteorological station (Fig. 6) show that four high water cycles can be distinguished in the 20th century.

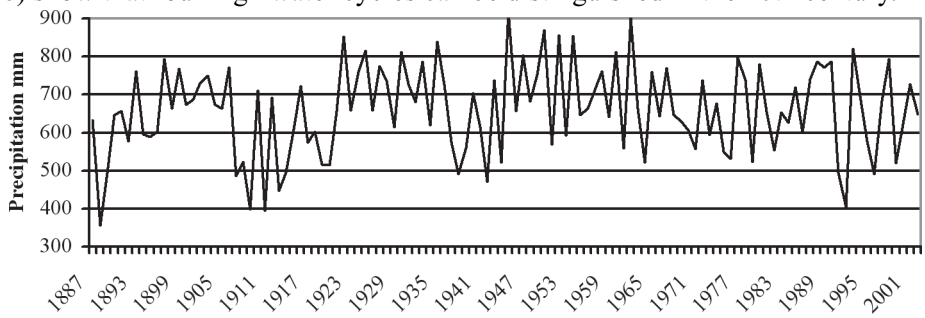

Fig. 6. Annual dynamics of atmospheric precipitation in Vilnius.

The first occurred at the end of the 19th–the beginning of the 20th century. It is, probably, responsible for higher rates of sedimentation in station 4a. The second high water cycle of 1925–1940 could have left its traces in the sediments of station 1. The traces of the third high water cycle (1950–1978), are, presumably, seen in station 4a and the traces of the fourth high water cycle (in about 1990) – only in station 1. Due to complicated configuration of Lake Drūkšiai depression, runoff regulation in the 20th century and large amounts of water taken for cooling the Ignalina NPP close to station 2a and heated water discharge close to station 4a the direction and velocity of currents, amount of particulate material and intensity of re-suspension have been periodically changing. This may account for the differences of the sedimentation rates in the studied areas.

Conclusions

The possibilities of evaluation of recent sedimentation parameters by radioisotope methods are shown on the example of a few Lithuanian lakes. Positive results have been obtained by a few methods: ^{137}Cs, ^{210}Pb and even ^{60}Co. Enclosed lakes among the small ones are more suitable for such investigations than the drained ones.

The mean sediment dry mass accumulation rate in studied lakes ranged in the 20th century from 0.05 to 0.16 g/cm^2/year. The deviations from the mean values were related with the major climatic and hydrological events and hydrographic changes in the catchments of relevant rivers.

The divergence of results obtained by different methods may be related with the noticeable diffusive downward (in rarer cases upward) transport of radioisotopes, their remobilization to the water and, sometimes, with the representativeness of samples (difference of thickness) and their pre-treatment.

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References

Bollhöfer A., Mangini A., Lenhard A., Wessels M., Giovanoli F., Schwarz B. (1997). High-Resolution ^{210}Pb Dating of Lake Constance Sediments: Stable Lead in Lake Constance, *Environmental Geology*, Vol. 24, p. 267–274.

Gudelis A., Remeikis V., Plukis A., Lukauskas D. (2000). Efficiency Calibration of HPGe Detectors for Measuring Environmental Samples, *Environmental and Chemical Physics*, Vol. 22, No. 3–4, p. 117–125.

Krishnaswami S., Lal D., Martin J. M., Meybeck M. (1971). Geochronology of Lake Sediments, *Earth Planet Sci. Lett*., Vol. 11, p. 407–414.

Koide M., Bruland K. W., Goldberg E. D. (1973). Th-228/Th-232 and Pb-210 Geochronologies in Marine and Lake Sediments, *Geochim. Cosmochim. Acta*, Vol. 37, p. 1171–1187.

Lietuvos geologija (1991). A. Grigelis, V. Kadūnas (sud.), Vilnius: Mokslas.

Mažeika J., Dušauskienė-Duž R., Radzevičius R. (2004). Sedimentation in the Eastern Baltic Sea: Lead-210 Dating and Trace Element Data Implication, *Baltica*, Vol. 17, No. 2, p. 79-92.

Robbins J. A., Edgington D. N. (1975). Determination of Recent Sedimentation Rates in Lake Michigan using ^{210}Pb and ^{137}Cs, *Geochim. Cosmochim. Acta*, Vol. 39, p. 285–304.

Robbins J. A. (1982). Geochemical and Geophysical Applications of Radioactive Lead Isotopes. *Biogeochemistry of Lead*. J. O. Nriagu (Ed.), p. 285–393.

Гарункштис А. А. (1975). Седиментационные процессы в озерах Литвы, Вильнюс: Мокслас.

Душаускене-Дуж Р. (1981). Распределение свинца-210 в экосистеме Балтийского моря. *Гидробиологический журнал*, т. 17, вып. 2, с. 85–95.

Общие закономерности возникновения и развития озер (1986). *Сер.: История озер СССР: Методы изучения истории озер.* Д. В. Севастьянов (отв. ред.). Ленинград: Наука, Ленинградское отделение.

Тамошайтис Ю. (1989) Интенсивность современных седиментационных процессов. *Базовое гидрофизическое состояние озера Друкшяй*, Вильнюс: Мокслас, с. 134–145.

Таутвидас М., Ласинскас М. (1986). Физико-географическая характеристика водосбора оз. Друкшяй. *Сер.: Теплоэнергетика и окружающая среда*, Вильнюс: Мокслас, т. 5, с. 7–14.

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Rytų Lietuvos ežerų dabartinės sedimentacijos analizė radioizotopiniais metodais

Santrauka

Darbe pateikiami kelių Rytų Lietuvos ežerų (Drūkšių, Balčio, Lydekio, Glėbo ir Varėnio) dabartinės ir netolimos praeities sedimentacijos tyrimų rezultatai. Du tirti ežerai (Baltys ir Glėbas) neturi intakų ir yra nenuotakūs, juos maitina tik požeminis vanduo. Varėnio ir Lydekio ežerais prateka upės, kurių vidutinis metinis debitas atitinkamai – 3,18 ir 3,31 m^3/s. Dalyje šių upių baseinų ūkininkaujama. Drūkšių ežero baseinas taip pat naudojamas žemės ūkyje, tačiau didžiausią poveikį ežerui turėjo jo nuotėkio reguliavimas XX a. ir Ignalinos AE veikla.

Iki 50–70 cm ilgio nuosėdų kolonėlės buvo paimtos Niemisto gravitaciniu vamzdžiu, lauko sąlygomis jos buvo suskirstytos į įvairaus storio – nuo 1 iki 6 cm – sluoksnelius. Laboratorijoje išdžiovinti mėginiai buvo tiriami aukštos skiriamosios gebos gama spektrometrijos metodais, juose buvo nustatomi ^{210}Pb ir ^{137}Cs savitieji aktyvumai.

Tyrimų rezultatai interpretuoti pastovaus srauto modeliu, įvertinant vidutinį sedimentacijos greitį. Pagal ryškius ^{210}Pb aktyvumo nuokrypius nuo modelinių dydžių kai kuriais atvejais buvo įvertintos ir sedimentacijos greičio variacijos. Nustatyti šie parametrai: sausosios masės kaupimosi greitis ($g/cm^2/m.$), linijinis sausos ir drėgnos būsenos sluoksnio prieaugio greitis (cm/m.). Taip pat nagrinėti duomenys apie analogiškus parametrus, įvertintus ežeruose pastatytais nuosėdų gaudytuvais. Drūkšių ežere dabartinis sedimentacijos greitis, išmatuotas nuosėdų gaudytuvais, buvo nuo 0,17 iki 0,29 g/cm^2 per metus, Varėnio ežere – nuo 0,64 iki 1,0 g/cm^2 per metus. Tirtuosiuose ežeruose vidutinis sausosios masės kaupimosi greitis kito nuo 0,05 iki 0,16 $g/cm^2/m$. Kituose nepratakiuose ežeruose sedimentacijos greitis kito nuo 0,03 iki 0,19 $g/cm^2/m.$, o pratakiuose – nuo 0,15 iki 0,21 $g/cm^2/m$.

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THE PROBLEM OF LANDSCAPE RELATIVE ENTROPY EVALUATION AND ITS APPLICATION (ON THE EXAMPLE OF LITHUANIAN TERRITORY)

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Introduction

Today, the intensity of natural resources exploitation and technogenic pollution causes the remarkable ecological instability in the landscape system, which with all the whole of inter-systemic links and their proper functioning determines the sustainability of human 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 (Звонкова, 1985; Устойчивость…, 1983; Ландшафты…, 1990). 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 (Арманд, 1975; Арманд, 1988; Демек, 1977; Сочава, 1978; Naveh, Liebermann, 1994; Ланге, 1969) and the other indexes ensuring the landscape stability (Ланге, 1969; Pauliukevičius, Grabauskienė, 1993; Pauliukevičius, Kenstavičius, 1995). According to some scientists (Глазовская, 1988; Экогеохимия…, 1995), the highest self-cleaning ability is the mark of 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 and are described by a weak self-cleaning ability. These are the territories of low ecological stability, sensitive to anthropogenic influence.

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

1. Relative Entropy of Landscape

The entropy of landscape, as understood in this work, comprises the difference between the values of geosystem sensitivity and technogeochemical pressure (Fig. 1). It is assumed that the higher is the landscape system (i.e. a particular territory) sensitivity and the higher is the technogeochemical pressure on it, the greater is the value of landscape relative entropy. Entropy, as per its initial meaning, is the measure of the isolated thermodynamic system disorder, and landscape system (or a particular territory) with all its processes and elements, evolution, dynamics and functioning, energy emissions and other ways of energy loss is one of the examples of thermodynamic systems. However, what make it different from isolated systems is the sun radiation and the Earth inner energy that add a huge and more or less constant quantity of energy rising up the level of the inner energy of landscape. The biosphere organisms assimilate it, keep the energy balance, and landscape territorial organization at some constant level that is fluctuating responding mostly the human impact. As it will be

explained bellow, there is a great variety of systems sensitivity (system respond to the human activities impact) degrees and also the ways and quantities of technogeochemic pressure on to geosystems. As it is still too difficult to determine the absolute value of entropy or, to be more precise, the absolute change of entropy after the human intrusion into landscape systems, the term of relative entropy was introduced. The meaning of this term comprises the understanding that sensitive geosystems are subject to lose their primary or initial organisation (in structural and linkage sense) easily. The degree of technogeochemical pressure as one of the most hazardous and destructive impact factors for organisation of landscape system shows the possible risk or threat to the system of certain sensitivity.

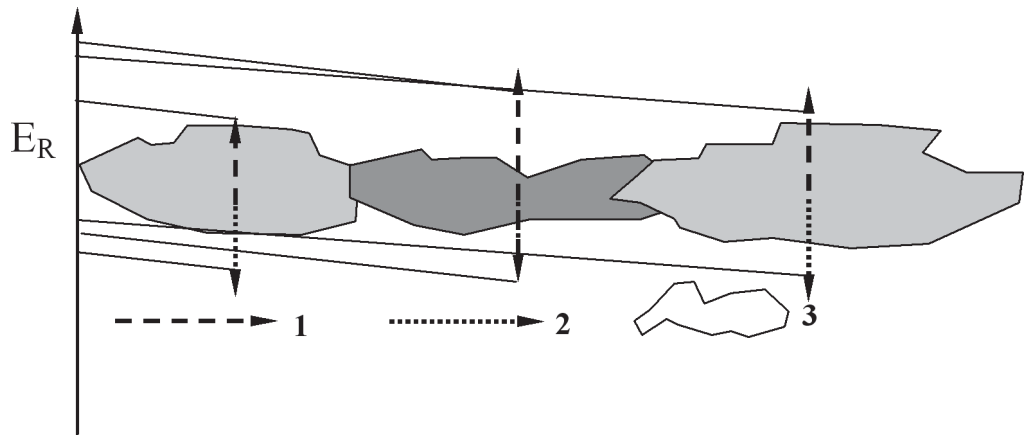

Fig. 1. The relative entropy (E_R) of landscape as the conditional distance between the sensitivity (1) and technogeochemical pressure (2) experienced by a particular geosystem (3).

2. Methods

Relative entropy in landscape systems was estimated in three stages: (1) the sensitivity of landscape systems to chemical impact was evaluated, (2) the territorial distribution of technogeochemical pressure was determined, and (3) based on the result of the first two stages, the classes of relative entropy in landscape systems were distinguished and their distribution mapped. Bellow follows a brief description of 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), which 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 ground of the regularities of heavy metals and organic pollutants migration (Jankauskaitė, 1993), 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 with respect to 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. With regard to granulometric 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 with 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). With respect to the ground water depth, the higher is the level of water, the higher is the sensitivity grades. The intensity of run-off and ground water mineralization were the other evaluation factors

The evaluation of integrated landscape system sensitivity to chemical impact was derived from a combination of the above-mentioned evaluations. It was corrected additionally (±30%) by coefficients considering the impact of local factors (stabilizing factor – forests, destabilizing factors – long-term industrial air pollution) (Jankauskaitė, 1993). As a result, with respect to self-cleaning features of landscapes, 7 levels of geosystem sensitivity were distinguished and mapped in the territory of Lithuania.

Evaluation of technogeochemical pressure. Technogeochemical pressure on landscape is caused by emissions from industry and power production, agriculture, transport, pollution of domestic waste. In order to evaluate the relative entropy 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 qualitative evaluation of the potential pollution in a landscape using the term of so called technogeochemical pressure. In order to evaluate the strength of technogeochemical pressure the previously published (Jankauskaitė, 1998) methods was adapted. The technogeochemical pressure was evaluated in grades considering the total pressure 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. The technogeochemical pressure of transport 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 is: the higher is the pollution source relative index (percentage, density), the higher is the meaning of technogeochemical pressure it was given in a respective territory. Eventually, 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 (Veteikis, 2003). 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 the relative entropy classes. The above described information layers (sensitivity to chemical impact and technogeochemical pressure) were superposed using the GIS software and too many (5 × 7 = 35) relative entropy classes were extracted. To simplify this complicated relative entropy assessment, the relative entropy classification matrix was created allowing to reduce the 35 relative entropy variants into 5 classes from very low to very high relative entropy (Table).

3. Results and Discussion

The main three groups of results were obtained by the above methodology. 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 (a kind of soils) are dominant 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 the Seashore zone and the region of Saugai–Priekulė (sand with the lowest geochemical activity and influence of Klaipėda city).

The results show that territorially the largest part (two thirds of Lithuanian 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) occupy a small part of Lithuanian territory (1% each) (Fig. 2).

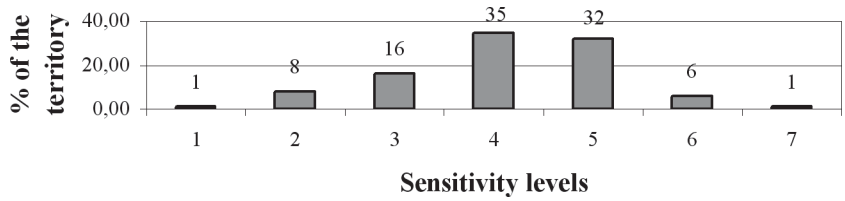

Fig 2. Percentage distribution of geosystems of different geochemical sensitivity in the territory of Lithuania: 1 – relatively insensitive, 2 – little sensitive, 3 – less than averagely sensitive, 4 – averagely sensitive, 5 – more than averagely sensitive, 6 – very sensitive, 7 – extremely sensitive.

With 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 the Middle Lithuania Plain), they are the most frequent (taking up 37% of the territory). The lowest grades were obtained for technotopes in the relatively natural South-eastern 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. 3). 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 relative entropy in landscape. The mapped distribution of 5 level relative entropy areas shows a very spotty situation in this regard (Fig. 4). With growing landscape relative entropy 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 relative entropy also shows the areas of unequal landscape stability.

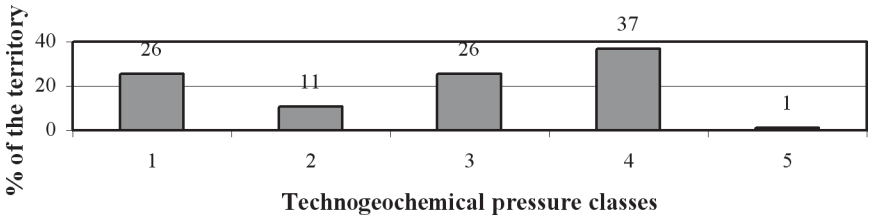

Fig 3. Percentage distribution of areas with different technogeochemical pressure in the territory of Lithuania: 1 – very low, 2 – low, 3 – medium, 4 – high, 5 – very high.

Table. Distinguishing the classes of relative entropy according to the combination of geosystem sensitivity (categories 1 to 7 see fig. 2 caption) and technogeochemical pressure degree (categories 1 to 5 see fig. 3 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 areas of the highest relative entropy, though occupying 4% of Lithuanian territory, are more or less scattered across the country. The highest concentration of relative entropy 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 relative entropy, 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).

Besides the mentioned large areas, there are several smaller spots with very high relative entropy worth to be mentioned: Klaipėda seaport, established in very sensitive seashore geosystems, Radviliškis town with railroad node and Panevėžys city creating very high technogeochemical pressure for sensitive geosystems, etc. Percentage of relative entropy classes distribution in Lithuanian territory is given in Fig. 5. Each of low, medium and high relative entropy classes occupy about one fourth of Lithuanian territory. Areas with very high relative entropy take up 4%, very low – 17% of Lithuanian territory.

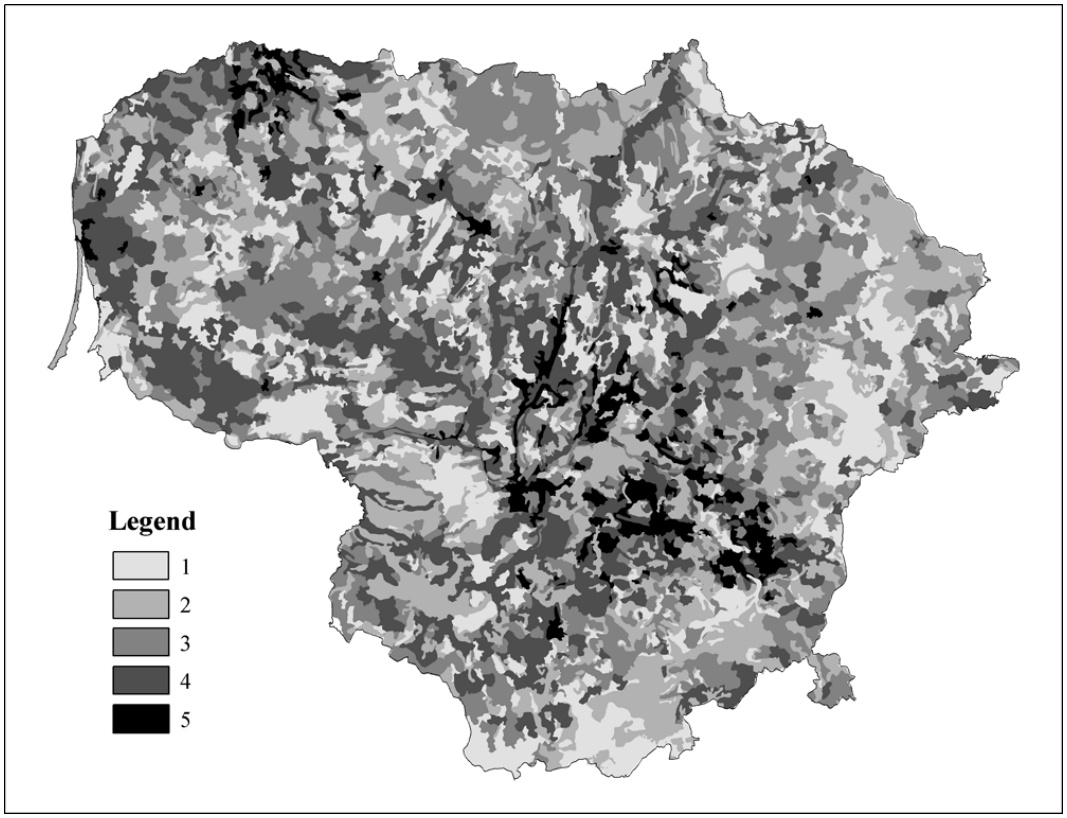

Fig. 4. Distribution of relative entropy in the Lithuanian landscape systems. Relative entropy: 1 – very low, 2 – low, 3 – medium, 4 – high, 5 – very high.

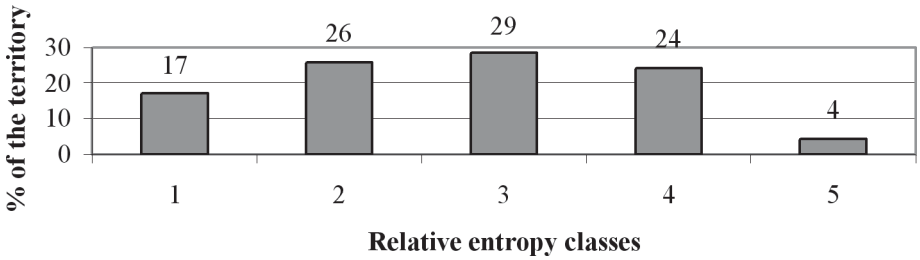

Fig. 5. Percental distribution of relative entropy classes in the Lithuanian territory. For class names see Fig. 4 caption.

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 relative entropy map and Nature Frame scheme included into the National Plan of Lithuania (National…, 2003). 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 (National…, 2003; Kavaliauskas, 1992), most of them ranged from microregional to international level. The Nature Frame covers about 51% of Lithuanian territory (divides occupy 24%, corridors – 10%, stabilization nodes – 17%). The overlay operation with relative entropy map revealed that some of these territories fall into the areas of high and very high relative entropy (Fig. 6). Such territories (taking up 10% of

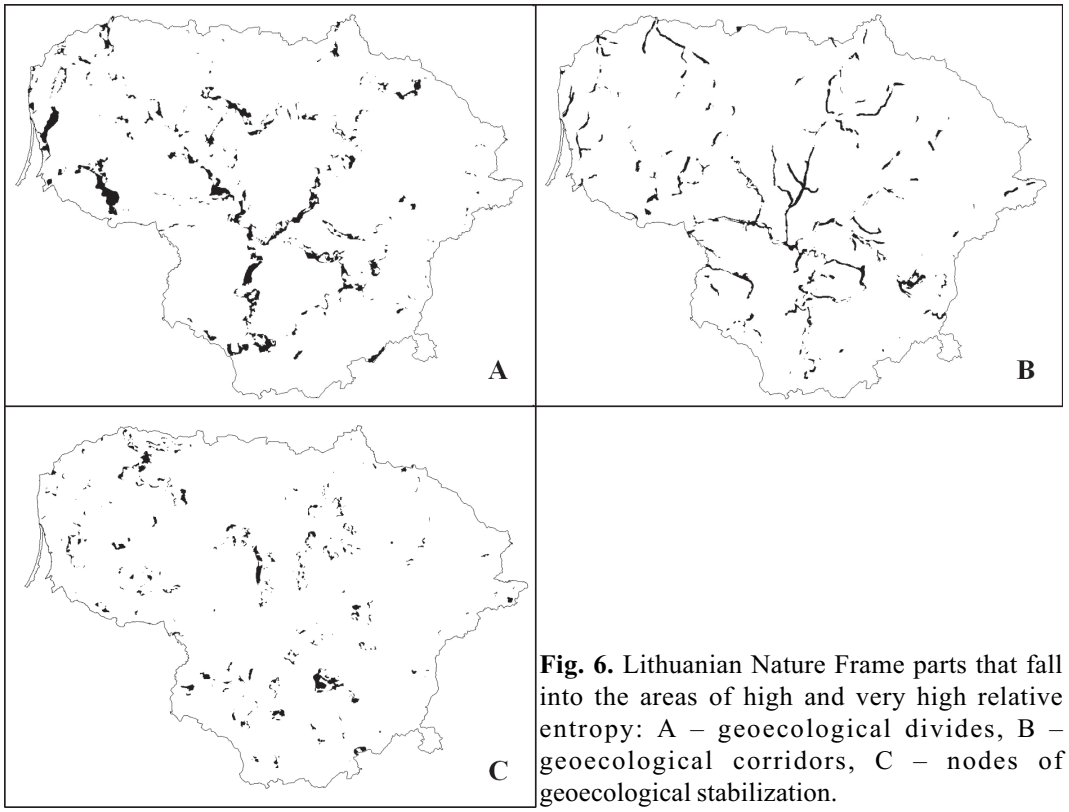

Fig. 6. Lithuanian Nature Frame parts that fall into the areas of high and very high relative entropy: A – geoecological divides, B – geoecological corridors, C – nodes of geoecological stabilization.

Lithuanian area and about 20% of Nature Frame) become the priority tasks for territorial planning and landscape optimisation.

Knowledge of the relative entropy 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 land use, 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 relative entropy. These areas should be associated with the primary installation of environment protection means. Some important results were obtained by application of methods evaluating the geosystems sensitivity and technogeochemical pressure, using the cartographic, statistical and field research data as well as GIS technologies; 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 relative entropy map of Lithuania.

2. The territory of Lithuania with 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 the north-western part of Lithuania (around Mažeikiai city).

3. Due to the vast 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 distinguishing large variety of relative entropy types, that were classified into 5 main classes and mapped. The cartographic view shows relatively high relative entropy of Lithuanian landscape. The highest relative entropy is characteristic to the triangle area of cities Vilnius–Kaunas–Kėdainiai and the region of Mažeikiai city. The areas of the lowest relative entropy, i.e. the areas of the most stable landscape, are determined in the largest forested territories (South, East, South-western Lithuania). Areas of very high relative entropy occupy about 4% of Lithuanian territory.

5. The example of the applications of presented results can be the overlay of the relative entropy 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 relative entropy. These territories should become the priority tasks of territorial planning and landscape optimisation.

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References

Jankauskaitė M. (1993). Geosistemų jautrumo cheminiam poveikiui nustatymas, *Geografija,* t. 29, p. 78–84.
Jankauskaitė M. (1998). Kraštovaizdžio cheminės apkrovos šaltiniai ir vertinimo problemos, *Geografijos metraštis*, t. 31, p. 284–293.
Kavaliauskas P. (1992). Methodological Fundamentals of Land Management, Vilnius: Academia.
National Plan of Lithuania (2003), Vilnius.
Naveh Z., Liebermann A. S. (1994). Landscape Ecology. Theory and Application, New York.
Pauliukevičius G., Grabauskienė I. (1993). Methods Forecasting the Resistance of Geosystems to Human Impact. *Structural, Dynamical and Functional Properties of the Lithuanian Landscape,* Vilnius, p. 149–171.
Pauliukevičius G., Kenstavičius J. (1995). Ekologiniai miškų teritorinio išdėstymo pagrindai, Vilnius.
Veteikis D. (2003). Technogeninė kraštovaizdžio morfostruktūra (Lietuvos teritorijos pavyzdžiu): Dr. disertacija, Vilnius.
Арманд А. Д. (1988). Самоорганизация и саморегулирование географических систем, Москва.
Арманд Д. Л. (1975). Наука о ландшафте, Москва.
Глазовская М. А. (1988). Геохимия природных и техногенных ландшафтов СССР, Москва.
Демек Я. (1977). Теория систем и изучение ландшафта, Москва.
Звонкова Т. В. (1985). Географическое обоснование экологических экспертиз, Москва.
Ланге О. (1969). Целое и развитие в свете кибернэтики. *Исследования по общей теории систем*, Москва, с. 181–251.
Ландшафты. Нагрузки. Нормы (1990), Москва.
Сочава В. Б. (1978). Введение в учение о геосистемах, Новосибирск.
Устойчивость геосистем (1983), Москва.
Экогеохимия городских дандшафтов (1995), Москва.

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Kraštovaizdžio santykinės entropijos įvertinimo ir jo pritaikymo problema (Lietuvos teritorijos pavyzdžiu)

Santrauka

Dabartinis intensyvus gamtinių išteklių naudojimas ir technogeninė tarša kelia didelę grėsmę kraštovaizdžio ekologiniam stabilumui, tad jo vertinimas darosi ypač aktualus. Kraštovaizdis – tai sistema, kurios funkcionavimo pusiausvyros palaikymas užtikrina žmogaus gyvenamosios aplinkos tvarumą. Tam tikslui svarbu pažinti esamą kraštovaizdžio būklę skirtingose teritorijose, pasižyminčiose nevienodu jautrumu cheminiam poveikiui ir egzistuojančio arba potencialaus technogeocheminio poveikio sąlygų įvairove. Galima teigti, kad cheminiam poveikiui jautrių geosistemų vidinė organizacija sutrinka greičiau dėl cheminio poveikio, kita vertus, augant išoriniam technikos sukeltam cheminiam poveikiui, taip pat išauga geosistemos dezorganizavimosi rizika. Taigi kraštovaizdžio sistemų vidinio dezorganizavimosi riziką, vartojant termodinamikos terminiją, galima vadinti santykine entropija. Siekiant įvertinti kraštovaizdžio sistemų santykinę entropiją, nustatyti technogeocheminės apkrovos veiksniai – pramonė, žemės ūkis, transportas, gyventojų sukeliama buitinė tarša. Šiame darbe pabandyta nustatyti santykinės entropijos pasiskirstymą skirtingose kraštovaizdžio sistemose Lietuvos teritorijoje. Santykinės entropijos dydį lemia technogeocheminio poveikio agresyvumo ir geosistemų jautrumo santykis (1 pav.).

Kraštovaizdžio sistemos Lietuvos teritorijoje pasižymi skirtingu jautrumu cheminiam poveikiui. Atsižvelgiant į kraštovaizdžio savivalos savybes išskirti 7 geosistemų jautrumo lygiai, sudarytas jų pasiskirstymo Lietuvos teritorijoje žemėlapis. Didžiausią ploto dalį užima vidutiniškai ir daugiau nei vidutiniškai jautrios geosistemos, mažiausiai (beveik po lygiai) yra santykinai nejautrių ir ypač jautrių geosistemų (2 pav.).

Atlikta detali kraštovaizdžio technomorfologinės struktūros analizė tapo kraštovaizdžio technogeocheminio spaudimo nustatymo pagrindu. Lietuvos teritorijoje išskirta apie 2000 įvairaus technogenizacijos laipsnio (pagal urbanizacijos lygį, kelių tankį, žemės naudojimo pobūdį ir kt.) technotopų – savarankiškų technogeninės kraštovaizdžio morfostruktūros dalių. Minėtuose technotopuose technogeocheminė apkrova buvo įvertinta pagal pramonės ir kitų užstatytų teritorijų, žemės ūkio naudmenų užimamą plotą, kelių tinklo tankį, pakoreguotą pagal eismo intensyvumą, ir buitinę taršą, įvertintą remiantis gyventojų tankumu naudojantis GIS duomenų bazėmis. Kiekvienam iš minėtų veiksnių suteikti skirtingi svorio koeficientai adaptuojant jau anksčiau pasiūlytą cheminės apkrovos kraštovaizdžiui vertinimo sistemą. Nustatytas skirtingo technogeocheminės apkrovos laipsnio teritorijų procentinis pasiskirstymas Lietuvos teritorijoje (3 pav.).

Perdengus geosistemų jautrumo cheminiam poveikiui ir technogeocheminės apkrovos žemėlapius gauta kartoschema, atskleidžianti santykinės entropijos Lietuvos kraštovaizdžio sistemose pasiskirstymą. Pažymėtini Vilniaus–Kauno–Kėdainių–Jonavos bei Mažeikių probleminiai didžiausios santykinės entropijos kraštovaizdžio sistemose arealai. Ekologiniu požiūriu stabiliausi (pasižymintys mažiausia santykine entropija) išlieka mažai technogenizuoti miškingi Pietryčių lygumos, Karšuvos ir Užnemunės arealai (4 pav.). Didžiausią Lietuvos teritorijos dalį beveik po lygiai užima vidutinės (29%), mažos (26%) ir didelės (24%) santykinės entropijos arealai, tuo tarpu labai mažos santykinės entropijos arealams tenka 17%, labai didelės – 4% Lietuvos teritorijos.

Pateiktas ir santykinės entropijos įvertinimo kraštovaizdžio sistemose pritaikymo pavyzdys, kai kartografinis santykinės entropijos pasiskirstymo Lietuvos teritorijoje vaizdas perdengtas su *Lietuvos bendrajame plane* pateikta gamtinio karkaso kartoschema. Apskaičiuota, kad apie 20% gamtinio karkaso teritorijų patenka į didelės ir labai didelės santykinės entropijos arealus (6 pav.). Tai teritorijos, kurioms būtina taikyti tinkamą aplinkosauginių priemonių planavimą, užtikrinantį kraštovaizdžio ekologinės pusiausvyros palaikymą.

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MORPHOLOGY OF LANDSCAPE BIOTA TERRITORIAL STRUCTURE (ON THE EXAMPLE OF LITHUANIAN TERRITORY)

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Introduction

One of the most relevant problems of modern times is the fragmentation of living organism habitats under the impact of human activity, which is directly influencing the decline of the landscape biotic[1] component variety both on the regional and on the global levels (Saunders and others, 1991). On the other hand, total suspension of human activity affects the formation of landscape biota territorial structure in the level of degradation, which is often perceived as the disappearance of landscape and biological diversity.

All natural protected areas and other ecologically valuable or relatively natural areas which underpin the general landscape stability in Lithuania are linked into a land management system of geoecological compensation zones – a Nature Frame, the idea of which was raised and approved two decades ago – in the year 1983. Since that time Lithuanian landscape has been transformed by political and economic changes. The "kolkhoz" system collapsed thirteen years ago – the vast stretches of land were sub–divided and the ecological mosaic thus increased (considerable number of works analyzing the changes of land use were written: J. Milius, F. Kavoliutė, G. Ribokas, G. Godienė and others). Still a part of meadows and pastures, infertile but very valuable in the view of landscape biological diversity, was abandoned; scrubs, bushes and trees of little value grew over it. In the same way a total restriction of human economic activities near the water resources has contributed to the formation of Lithuanian zonal-type communities of broad-leaved–coniferous forests. They accelerate the evolution (oligotrophy–eutrophy) processes of the water habitats, important in the view of landscape diversity. All these factors contributed to the territorial changes of landscape biota.

Consequently, if we want to keep the balance in our environment and to organize sustainable development of landscape, we have to know the contemporary state of Lithuanian landscape biostructure. This requires quantitative and qualitative assessment of landscape biota territorial structure, which allows revealing the consistent patterns of spatial distribution of structural elements and discerning the most characteristic territorial complexes, distinguished by different physiognomy, and vertical and horizontal structure of biotic cover.

A lot of works of Lithuanian botanists, zoologists, ecologists are devoted to the research of biota structure as the living organism communities with species differentiated according to the niches (J. Balevičienė, V. Rašomavičius, J. Naujalis, Z. Sinkevičienė, D. Patalauskaitė, J. Tupčiauskaitė, Ž. Lazdauskaitė, M. Žalakevičius, P. Kurlavičius, L. Balčiauskas, R. Baleišis, P. Bluzma, A. Ulevičius, L. Raudonikis). However, there is lack of research works that view biota from the point of landscape morphology and there is no geographical model of landscape biota territorial structure in the Lithuanian landscape science.

[1] The term *biotic* in this work is used, as an antonym to the concept *abiotic*, which is for conveyence of natural characteristics of investigated landscape components – are they alive or not alive.

Therefore, the main aim of this work is to reveal the current Lithuanian landscape biota territorial structure as well as the consistent patterns of spatial distribution of this structural territorial complexes, having in mind that one of the main goals (Lietuvos..., 2004) of the landscape policy of the Republic of Lithuania is: "to determine the structural diversity of our country."

1. The Concept of Landscape Biota Territorial Structure

The term *landscape biota* is perceived as a sum of biocomponents (vegetation, fungi and animals) in this work. They influence the particularities of landscape morphology. All living organisms as an integral part of ecosystems are understood by this term in the classical concept of ecosystem (Tansley, 1935; Одум, 1986). Nowadays ecosystem is treated as cartographical object in the landscape ecology science in North America and Western Europe (Forman, Godron, 1981; Godron, Forman 1983; Forman, 1995). According to this concept ecosystems (forest, meadow etc.) are referred to as *landscape biota territorial structure elements (BTSE)* in this work. The organization of ecosystems on the Earth surface forms ***the landscape biota territorial structure*** *(BTS)*.

Broad-leaved–coniferous forests represent the main zonal type of vegetation in Lithuania (*Ass. Querco-Piceetum*). Thus, the natural change trends of the biotic cover of our country are related with succession and the formation of stable climax communities – forests. There are also natural landscape BTSE – wetlands and alluvial meadows in Lithuania. Therefore the first feature, according to which the types of landscape biota territorial structure elements are classified is their **physiognomy**: *subnatural* (the initial succession is prevailing) or *anthropogenic* (the natural succession is interrupted by the human activities) (Table 1). Actually, since the human activity is not a constant factor, the scrub and trees growth can be observed in the extensively used territories and the *renaturalized* habitats are formed (the secondary succession is taking place).

The feature, which allows discerning the second classification stage (BTSE classes), is **the vertical arrangement** of the habitat constituents ***(their height and form)*** that is characteristic of all terraneous ecosystems: forest, meadow, wetland and others. For the urbanized territories a specific vertical structure of biocenosis is typical, but the more detailed research scale must be used for its analysis to compare the one used in this work (M 1:200 000). Thus the urboecosystems will not be analysed in this work.

Horizontal mosaic is the feature, according to which the landscape biota territorial structure elements are classified in the third stage (BTSE subclasses). All ecosystems can be treated as areal and linear elements. According to their form, distribution and the area, all surface of the land consists of the matrix, patches and migrational corridors. American and French scientists R.T. Forman and M. Godron (Forman, Godron, 1981, 1986) were the first who proposed these terms. These three territorial structural element types of biota are visually discerned on the map: *1. Matrix* is a BTSE characterized by its continuity and maximal unity; *2. Patches* are the areal, small and chaotically distributed different from the matrix BTSE; *3. Corridors* are the linear elements that connect other BTSE. Water flow ecosystems that are discerned with the scale 1: 200 000 are considered as corridors in this work.

2. Research Methods

Various methods were used in this work: logical methods (analysis of facts, formulation of concepts, classification, induction, hypothesis and analogy), mathematical methods (factor analysis, calculation of landscape indices) cartographical methods (analysis and preparation of maps), and regionalization methodological principles.

Table 1. Classification of landscape biota territorial structure elements (BTSE).

Height		Physiognomy					
		Subnatural		Anthropogenic		Renaturalized	
		BTSE	Form characteristics	BTSE	Form characteristics	BTSE	Form characteristics
High		Forests	High woody plants	Urbo complexes	Complexes of territories with buildings of various height with their own infrastructure		
Average		Wetlands	Low herbaceous plants, woody bushes, single trees	Agro complexes	Small height cultures with the patches of woody vegetation (for example, fruit tree gardens)	Shrub and/or grass vegetation	Low herbaceous plants, woody bushes
Small	Ecosystems with continuous vegetation cover	Meadows	Low herbaceous plans	Pastures	Low herbaceous plants		
	Ecosystems with discontinuous vegetation cover	Sands	Land with sparse embryonic plant cover or completely without it	Ruderal communities	Land with sparse herbaceous cover, but mostly without it		
Underwater layers		Lakes, rivers, the sea, Curronian lagoon	Compact volume objects or linear prolonged volume objects located on depressed surfaces, lower places.	Ponds, canalized river beads	Compact volume objects or linear prolonged volume objects located on depressed surfaces, lower places.		

Based on logical analysis and synthesis, the research works on the subject of this work in Lithuania and abroad were analysed, the landscape biota territorial structure and its territorial unit concepts were formulated.

Mathematical landscape analysis in the view of biotic component was performed employing the following digitalized cartographical material:

1) CORINE–2000 Lithuanian Earth surface digital database (© Lithuanian Environmental Protection Agency under the Ministry of Environment; European Environmental Agency, 2005) was used for the analysis of landscape biota territorial structure element (BTSE) spatial distribution and for analytical landscape indices calculation.

2) Lithuanian geomorphologic map (1: 200 000; © Lithuanian Geological Survey, 2002); LR digital soil database (Lithuanian territory's 1:300000 digital soil map © National Land Service under the Ministry of Agriculture; © State Land Survey Institute, 1999); Lithuanian landscape morphologic map at a scale 1: 400 000 (© Ministry of Environment; © JSC Urbanistika, 2001); Lithuanian average annual precipitation quantity map (1: 1 750 000; © Centre for Cartography of Vilnius University, 2004); Lithuanian vegetation map (1:1 000 000; Brundza and others, 1981) was used for the evaluation of abiotic and biotic landscape components correlation (*factor analysis*) as well as for the discernment of landscape biota territorial structure complexes – *geobiocomplexes*.

3) GDB200 (© GIS-CENTRAS, 1993–1999) was used as the geographical basis for typological and individual regionalizations of Lithuanian territory.

The subject of *factor analysis* was the typological unit of potential vegetation based on Lithuanian vegetation map (Brundza, Pakalnis, Budriūnas, 1981). The variables examined are abiotical landscape components (parent materials, soils, the relief and the air), expressed in % points and relative distribution frequency (%) in every potential vegetation typological unit. The analysis of potential vegetation typological units was performed according to the classical factor analysis model (Čekanavičius, Murauskas, 2002, Девис, Радионов, 1977, Харман, 1972) by using a method of main components.

For making the interpretation of the acquired factors easier, the two initial variable characteristics were taken into account. They can determine some correlation tendency distortions – it is a ratio of every variable area in percents and its relative frequency. There are 4 types of factor interpretations (Table 2). The factor was named following the characteristics of the variables that comprise it.

Table 2. Types of factor interpretation according the ratio of variables area (%) and relative frequency in potential vegetation typological unit

Relative frequency, %	**Area, %**	
	≥20	**<20**
≥20	Main factors	Specification factors
<20	Supplementary factors	Controversial factors

Determination of territorial units (called geobiocomplexes) was based on the concept that all edaphic, topographic, climatic and anthropogenic factors are the basis to determine the type of irrigation of a territory, the amount of water infiltration, nutrient balance and the degree of inartificiality. This basis connects spatially close BTSE that are linked by the special energy and nutrient ties into one *geobiocomplex*. Inside of each geobiocomplex a special combination of BTSE develops.

Regionalization methodology was based on the logical rules of the set division (Pečkaitis, 2004). Traditional scale 1: 2 000 000 commonly used in natural geography was chosen for the individual landscape regionalization according to the biota territorial structure features.

Scale used – 1: 200 000. Software used: ArcGIS v.9.0 Desktop, ArcGIS v.9.0 Workstation, ArcView 3.2[a] programs and their extensions *Spatial analyst, vLATE1.1, Fragstats for Arcview, FragstatsArc.* With *SPSS 10.0 for Windows* program factor analysis was performed.

3. Research Results and Disscusion

Landscape biota territorial structure element distribution analysis. The human being and its impact upon our zonal vegetation type – forests is the main accelerator of contemporary biota territorial structure (BTS) formation. Landscape indices were used in order to highlight the different BTSE characteristics and analyze their distribution in the territory of Lithuania. There are the distribution characteristics of BTSE physiognomy, vertical and horizontal structure indices analysed in this work.

BTS physiognomy is determined and the territories of different anthropogenic impact are discerned, according to the whole range of forest spatial distribution metrics – forest patch size (a part of forest patches up to 2000 ha in the territory), geometric form (forest patch shape index) and connection (mean neighbourhood distance).

The average distance a_{vid} among forest patches was calculated for all Lithuania's territory (CORINE-2000 LŽD (© Lithuanian Environmental Protection Agency; European Environment Protection Agency) using the *mean neighbourhood distance* index. The average distance among all forest patches in Lithuania is 331,80 m. According to this value all Lithuanian forests were divided into separate clusters, where they are closer to each other than the average distance a_{vid}.

With reference to this, 924 areas of forests clusters were formed. Forest patches up to 2000 ha in each area of forest clusters are evaluated (from ~20% to ~96%) and show the fragmentation of forest cover. The average values of shape index (from 0,14 to 0,48) show the complexity of forest patch shape. The values of mean neighbourhood distance index (from ~61 m to ~673 m) show the peculiarities of connections between woody complexes. According to this the four types, describing different physiognomy of BTS (anthropogenic, anthropogenized, slightly anthropogenized and subnatural) were discerned (Fig. 1). The highest values of all indices are characteristic to the Central Lithuania Lowland, Baltic Upland, East Žemaičiai Plateau, Kuršas Uplands and Lithuanian coastal zone. The lowest values are typical of East Lithuania and Western Žemaičiai Plateau.

Edge contrast index of all BTSE was used to analyse the BTS vertical structure. The highest magnitude of edge contrast between adjacent BTSE types (>71%) is observed in East Lithuania and West Žemaičiai Plateau. The average contrast (31–70%) is typical to Central Lithuania BTSE (except for Užnemunė territory). The lowest contrast (<30%) – can be found in Aukštaičiai highland western sides, East Žemaičiai Plateau, and Užnemunė Lowland as well as in some parts of Pajūris Lowland BTSE.

The distribution of horizontal structure characteristics was analysed in the similar way. One of the indices is the ratio of BTSE area and number of neighbours. According to this index 7 horizontal structure types were distinguished (Table 3). Two types prevail in Lithuania. The first one is a type of small areas (<500 ha) with small number of neighbours (< 23 neighbours) (~ 44 %), occupying the vast territories in Žemaičiai, Baltic, Ašmena and Švenčioniai Uplands. The second type is characterized by large areas (> 2000 ha) with big number of neighbours (> 123 neighbours) (26 %) and is common to Central Lithuanian Plain, Southeastern sandy plain and West Žemaičiai Plateau.

Horizontal biota structure peculiarities were analysed according to the theory of graphs. The lines separating individual BTSE were treated as edges and their intersections as vertices. The more there are edges that meet in 1 vertex, the bigger is the variety of ecosystems.

Fig. 1. The distribution of biota territorial structure physiognomy types in Lithuania, determined by the values of forest patch size, shape and nearest neighbour indices.

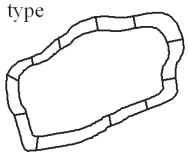
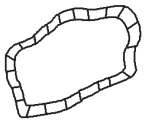
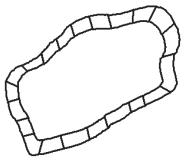
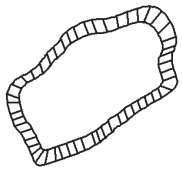
Three BTSE (CORINE 2000 3 level codes are 3.1.3., 2.1.1., 2.4.2., 2.4.3.) intersections prevail in the BTSE network of Lithuania. They are concentrated in the Baltic and Žemaičiai uplands and indicate an average variety of ecosystems. Central Lithuanian Lowland stands out as two BTSE (2.1.1. and 2.4.2.) intersections dominance area and the level of ecosystem variety is the lowest. At the same time four BTSE (2.1.1., 2.4.2., 2.4.3., 3.1.3., 2.3.1.) intersections are scattered throughout all Lithuania and do not form spots of bigger concentration.

Abiotic and biotic landscape component factor analysis results. Common feature of all potential vegetation typological units indicates that all factor types – main (together with the supplementary ones), specification and controversial factors explain approximately equal percent of variable dispersion. It means that all potential vegetation typological units are being formed on the mixed background *(controversial factors).* Therefore the types of potential vegetation influenced by edaphic components *(specification factors)* could be determined on the larger scale. Whereas the main factors (together with the supplementary ones), discerned by landscape component correlations, indicate the main forces, which have the major influence on the formation of the analyzed potential vegetation typological unit.

The climatic climax of south taiga shrubby spruce forests *(All. Piceion abietis*[2]*)* and the edaphic climax of pine forests dominated by green mosses (*All. Dicrano–Pinion)* as well as black-alder forests (*All. Alnion glutinosae, All. Salicion cinereae),* high moors of West Lithuania (*All. Sphagnion magellanici, All. Ledo–Pinion*) and transition moor communities (*All. Betulion pubescentis)* are characterized by the most obvious determinism

[2] All equivalents of vegetation units according J. Braun–Blanquet (1964) hierarchical synaxon system are taken from Балявичене, 1991; Dierssen, 1996; Matuszkiewicz, 2002; Navasaitis ir kt., 2003.

Table 3. Horizontal structure types based on the ratio of BTSE area (ha) and number of neighbours surrounding 1 BTSE.

	Area, ha		
	Small (0–500 ha)	**Average (500–2000 ha)**	**Big (> 2000 ha)**
Small (up to 23 units)	1 type 	3 type 	5 type 
Average (23–123 units)	2 type 	4 type 	6 type 
Big (> 123 units)	–	–	7 type 

of abiotic landscape components. However, mixed edaphic–topographic–climatic complex of factors characterize the abiotic structure of broad-leaved–spruce forests *(All. Piceion abietis, All. Carpinion betuli, All. Alnion incanae),* broad–leaved forests *(All. Carpinion betuli, Alnion incanae)* as well as alternative communities (*All. Piceion abietis, All. Carpinion betuli, All. Alnion incanae succession and regeneration stages*). Therefore, in order to highlight the differences of potential vegetation in the regional level, the edaphic peculiarities must be taken into consideration.

Specification factors explaining the similarly variable dispersion percentage, as the main ones are mostly associated with edaphic characteristics in each potential vegetation typological unit. Therefore, it is necessary to discern the vegetation types, reflecting the abiotic conditions of the peat, the sand and the valley before the usage of this vegetation map in a larger scale.

The percentage of the controversial factors existing in each potential vegetation typological unit reflects the huge amount of small landscape components and the formation of the potential vegetation typological units on a mixed abiotic base.

Typological regionalization. The typological regionalization is based on the classification of geobiocomplexes by various features: BTS physiognomy, vertical and horizontal structure and edaphic conditions.

Classification of geobiocomplexes *by BTS physiognomy* consists of 3 stages (Table 4). The leading factor of the first level (geobiocomplex type) shows the most general human impact on the vegetation cover of our country and is described by two parameters – percentage of forest cover (%) in the geobiocomplex and the number of forest patches up to 2000 ha in a geobiocomplex.

A class of geobiocomplexes (II level) was defined according to the average distance between forest patches. This feature reflects the living organism dispersion characteristics in the regional level.

A subclass of geobiocomplexes (III level) was defined according to the aspects of the forest patch shape, reflecting the local impact on the living organisms. This is the degree of forest patch shape complexity.

There are 53 subclasses determined in the III level. Their descriptions reflect all the parameters of BTS physiognomy (for example, 4–4–3 means that the forest cover in the geobiocomplex is fragmented, weekly connected, dominated by low complexity forest patch shapes). Separate schemes of geobiocomplex territorial distribution according to the BTS physiognomy parameters are composed in this work.

Table 4. Classification features of geobiocomplexes according to BTS physiognomy.

Fragmentation types				
1. Not fragmented [1]≥60% [2]0–99%	**2.** Slightly fragmented 20–60% or≥60% 0–90% or 100%	**3.** Fragmented 0–20% or 20–60% 0–99% or 100%	**4.** Strongly fragmented 0–20% 100%	Woodless
Connection types				
1. Strong [3]≥0–60 m	**2.** Average ≥60–100 m	**3.** Weak ≥100–300 m	**4.** Very weak ≥300 m	
Complexity types				
1. High [4]≥0–0,2	**2.** Average ≥0,2–0,3	**3.** Low ≥0,3–0,5	**4.** Incomplex ≥0,5	
[1] Percentage of forest cover [2] The share of forest patches up to 2000 ha [3] Average distance to the nearest neighbour, m [4] Shape index				

According to the physiognomy of biota territorial structure (forest patch size, shape and nearest neighbour distance indices, showing the peculiarities of forest cover fragmentation, shape complexity and interconnections) the geobiocomplexes of anthropogenic and anthropogenizated types (fragmented forests with week interconnections and low shape complexity) dominate in Lithuania. Not fragmented forests, dominated by strong interconnections and highest shape complexity – slightly anthropogenizated and subnatural types are typical for all woody territories in Lithuania.

Geobiocomplexes were classified according to ***vertical territorial structure of biota***. The main features used were the height type dominant by the area in the geobiocomplex; the edge contrast index prevalent by the area in the geobiocomplex; the edge contrast index dominant by the number in the geobiocomplex (Table 5).

Table 5. Classification features of geobiocomplexes according vertical territorial structure of biota.

Vertical structure types according the BTSE height			
1. High	**2.** Average height	**3.** Short a) Continuous vegetation cover b) Discontinuous vegetation cover	**4.** Underwater layers
Vertical structure types according to the BTSE edge contrast index			
1. Homogeneous [5]0–30%		**2.** Average homogenuous 31–70%	**3.** Heterogeneous 71–100%
[5] Edge contrast index			

Three levels of geobiocomplex classification by vertical BTS were defined. Each of them has a leading feature: a type (a height type), a class (the value of the edge contrast

index dominated by the area in the geobiocomplex) and a subclass (the value of the edge contrast index dominated by the number in the geobiocomplex). 30 subclasses, describing each geobiocomplex by the set of all vertical structure features, were formed. Typological regionalization schemes of Lithuania, according all features mentioned above were composed.

According vertical structure (BTSE height and BTSE edge contrast index) geobiocomplexes with average BTSE height and average BTSE homogeneity are dominant in Lithuania. They are characteristic of the Central Lithuanian Lowland and scattered in the Aukštaičiai, Dzūkai and Žemaičiai uplands. Homogeneous BTSE of average height occupies smaller territories in Lithuania and dominate in the East Žemaičiai Plateau, Kuršas Upland, southern part of Pajūris Lowland and Užnemunė Lowland. Big height and heterogeneous BTSE are dominant in the most forested geobiocomplexes. Nemunas delta and its deltaic valley stand out from all Lithuanian vertical structure, by dominance of low height and homogeneous BTSE.

The following parameters characterize the geobiocomplexes according to *horizontal territorial structure of biota*: 1) the type of all BTSE parts (%) ratio in geobiocomplex (Table 6) ; 2) the type of BTSE size and number of adjacent BTSE ratio, dominated by the area in the geobiocomplex (Table 3) ; 3) the type of BTSE size and number of adjacent BTSE ratio, dominated by the number in the geobiocomplex.

The classification of geobiocomplexes according to horizontal structure is presented. The type level (I level) has the leading feature based on the all BTSE parts (%) ratio in geobiocomplex. A class (II level) has a leading feature based on the type of BTSE size and number of adjacent BTSE ratio, dominated by the area in the geobiocomplex. Differently from the classification of geobiocomplexes by the BTS physiognomy and vertical structure, this classification has only two typological levels – types and classes. Subclasses level was not discerned. The reason is that the last parameter – the type of BTSE size and number of adjacent BTSE ratio, dominated by the number in the geobiocomplex does not give the territorial differences. There are 24 classes, characterizing each geobiocomplex according the horizontal BTS features defined. Typological regionalization schemes of Lithuania, according to all features mentioned above were composed.

Table 6. Classification features of geobiocomplexes according to horizontal territorial structure of biota.

Horizontal structure types according to all BTSE parts (%) ratio in geobiocomplex				
1. [6]Matrix	**2.** [7]Poriferous background	**3.** [8] Large mosaic	**4.** [9]Fine mosaic	**5.** [10]Corridor
[6] BTSE occupies 100% of the geobiocomplex area; [7] Patches occupies 0 - 40% of the (>60%) matrix in the geobiocomplex; [8] No matrix element; the remaining BTSE occupies 50 - 60% of all geobiocomplex area; [9] No matrix element; the remaining BTSE occupies 0 - 50% of all geobiocomplex area; [10] The water flows discerned on the M 1:200 000.				

According to horizontal structure (ratio of all BTSE area (%) in a territory; ratio of BTSE area and number of neighbours indices) the geobiocomplexes characterized by fine mosaic; small areas (<500 ha) with small number of neighbours (< 23 neighbours), dominated in highlands, prevail in Lithuania. The second type is patch matrix; large areas (>2000 ha) with big number of neighbours (>123 neighbours) in geobiocomplexes are dominant in West Žemaičiai Plateau, Central Lithuanian Plain and Southeastern Sandy Plain. The transitional type of horizontal structure going from uplands towards lowlands is large mosaic; average size BTSE with average neighbour number.

The significant edaphic characteristics of landscape biota territorial structure were chosen for the geobiocomplex description: 1) types of potential vegetation that is an expression of edaphic conditions, if there is no human impact on the Earth surface (Lithuanian vegetation map (Brundza, Pakalnis, Budriūnas, 1981) is used as a basis. It was improved according to

results of factor analysis); 2) relief–lithology types (Lithuanian landscape morphologic map M 1: 400 000 (© Ministry of Environment; © JSC Urbanistika, 2001 is used as a basis).

These two features are used for the geobiocomplex classification according to edaphic conditions. The potential vegetation is a visual expression of edaphic conditions in the landscape. Thus it was used as a leading feature for the major classification category – types. Relief–lithology types were used as a leading feature for the formation of the lower taxonomical level – class level. There were 71 classes formed in this geobiocomplex classification. Typological regionalization schemes of Lithuania were formed according to these classification features.

According to edaphic conditions, reflecting the complex feature of potential vegetation and relief–lithology types, the most significant differences are observed between the following territories: Baltic coastal zone (sandy lowland dominated by mossy and shrubby pine forests *(All. Dicrano–Pinion)*); West Žemaičiai Plateau (south taiga shrubby spruce forests *(All. Piceion abietis)* and pine forests dominated by green mosses with elements of broad – leaved forests *(All. Dicrano–Pinion, All. Carpinion betuli, All. Alnion incanae)*; Central Lithuania (broad-leaved–spruce forests *(All. Piceion abietis, All. Carpinion betuli, All. Alnion incanae),* broad–leaved forests *(All. Carpinion betuli, Alnion incanae)*) and East–Southeastern Lithuania (sandy lowlands dominated by pine forests with green mosses *(All. Dicrano–Pinion)*).

Individual geobiomorphologic regionalization. The typological regionalization of the territory forms the basis for the separation of large regions, characterized by the unique geobiocomplex combinations (i.e. for the individual regionalization). Firstly, the individual regionalizations according to the parameters of BTS physiognomy, vertical and horizontal structures as well as edaphic conditions were composed. Afterwards, the integrated geobiomorphological regionalization of Lithuania was designed.

Regionalization according to the biota territorial structure physiognomy. Since the fragmentation feature reflects the most general impact on the natural cover of all our country *(percentage of forest cover in a geobiocomplex and the share of forest patches up to 2000 ha in a geobiocomplex),* it was chosen as a leading feature for the delineation of the largest regionalization units – **regions**.

The average distance to the nearest neighbour, reflecting the living organism dispersion characteristics in the regional level was chosen as the leading feature for the delineation of the boundaries of smaller regionalization units – **districts**. *The evaluation of the shape complexity* of each forest patch reflecting the local impact on the living organisms was chosen as a leading feature for the delineation of the smallest units – **subdistricts**.

There were 3 regions and 20 districts determined and 5 districts subdivided into subdistricts in the Lithuanian territory. Thus, there are 29 smallest territorial units in Lithuania.

Regionalization according to vertical biota territorial structure. The BTSE height reflecs the most general vertical structure differences, important for biota; therefore the leading feature of the largest territorial units – regions – is the height type dominant by the area in the geobiocomplex. According to this parameter, four regions are obviously distinguished in Lithuania. The edge contrast index specifies the impact between the adjacent BTSE. The woody BTSE have the highest contrast level and biggest influence to adjacent BTSE. They reflect the territorial differences of a vertical structure on a regional level. Therefore, the edge contrast index prevalent by the area in the geobiocomplex indicates the most heterogeneous territories and was chosen to delineate *regional* level of territorial units – districts. Subdistricts were defined according to the edge contrast index dominated by the number in the geobiocomplex. This feature delineates the homogenous territories especially in Central Lithuania.

Consequently, 3 regions, 13 districts were delineated and 5 districts were subdivided into subdistricts according to vertical biota territorial structure on the Lithuanian territory. Therefore 29 smallest territorial units were formed.

Regionalization according to the horizontal biota territorial structure. The leading feature of the largest regionalization units – regions delineation is the dominated type of all BTSE parts (%) ratio in geobiocomplex. It accurately reflects the main orographic units of Lithuania – highlands and lowlands. Districts were delineated according to the type of BTSE size and number of adjacent BTSE ratio, dominated by the area in the geobiocomplex. This feature discerns the transitional areas between highlands and lowlands and shows the regional differences of biota territorial structure. The smallest regionalization units – subdistricts were not discerned since the prevailing territorial structure according the type of BTSE size and number of adjacent BTSE ratio, dominated by the number in the geobiocomplex, is quite homogeneous. There were 4 regions and 19 districts determined in the Lithuanian territory.

Regionalization according to the geobiocomplex edaphic conditions. There were two features reflecting edaphic conditions used for the regionalization of Lithuanian territory in this work. Since the potential vegetation is a visual expression of abiotic conditions in the landscape, it was chosen as the leading feature to delineate the largest regionalization units – regions. Relief–lithology types, discerning the differences of edaphic conditions, were chosen as the leading feature for the delineation of the smaller territorial units – districts. 4 regions and 32 districts were delineated.

Integrated geobiomorphological regionalization. The integrated geobiomorphological regionalization was composed, according to the edaphic conditions and structural biota territorial structure features. Each taxonomical level has a leading feature.

If Lithuanian surface was not affected by the human activity, the features of landscape biota territorial structure would depend only on edaphic differences. Therefore edaphic conditions, described by the complex of potential vegetation and relief–lithology became the leading feature of the largest individual regionalization units – regions.

The feature complex describing biota territorial structure physiognomy characterizes the contemporary earth surface transformed by the human activity. The parts of regions that were affected by the different influence of human being and obtained the different landscape visual outlook are considered to be the districts.

However, a district is quite large territorial unit. A different mosaic of patches (various structural combinations of BTSE) is being formed under the influence of human activity inside the one district. These differences of the Earth surface differentiate the biota complexes and create different living conditions. Therefore, the parts of districts that obtained the different features of horizontal structure are considered to be the lower level regionalization units – I level subdistricts.

The horizontal biota territorial structure differences do not describe the interconnections of living organism habitats (i.e. how much the influence of one BTSE penetrates into the adjacent BTSE). This feature determines the interaction of living organisms in the local level as well as the character of habitat transitional zones. These parts of subdistricts, where the different vertical types BTSE are discernable are the lowest regional stage units – II level subdistricts.

Thus, 4 regions, 24 districts, 21 I level subdistricts and 17 II level subdistricts were delineated in the territory of Lithuania (Fig. 2). There are 48 smallest territorial units in total.

In summary, it is possible to outline the general features of Lithuanian biota territorial structure. Anthropogenic and anthropogenized biota territorial structure type prevail in Lithuania. The highest degree of anthropogenization is typical of the districts of Pajūris Lowlands, Kuršas Uplands, northern valleys of Venta River, Žiemgala, Central Lithuania,

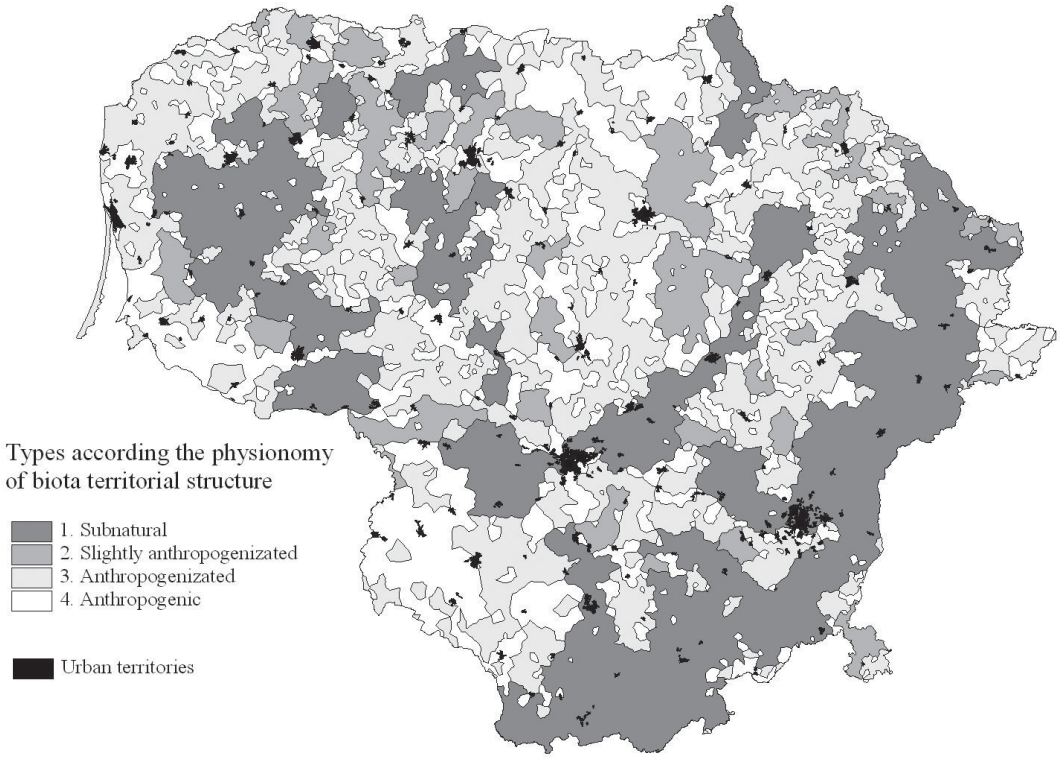


Fig. 2. Complex geobiomorphological regionalization of Lithuania.

Žemaičiai Upland, Eastern Žemaičiai–Karšuva and Sūduva lowlands as well as Sūduva Highlands. The geobiocomplexes are characterized by weak or very weak connections and by low complexity or incomplex forest patch shapes. Nemunas delta and its deltaic valley stand out from all Lithuanian vertical structure, by dominance of low height and homogeneous BTSE. Patchy matrix horizontal structure prevails in all subdistricts of the above-mentioned districts with exception of Pajūris lowland and Žemaičiai Upland subdistricts, where the fine mosaic territories dominate. The first type indicates the territories of intensive agriculture.

The districts situated mostly in Lithuanian highlands are less affected by the human activity, but are still characterized by anthropogenic and weakly anthopogenized biota territorial structure type (Venta – East Žemaičiai Plateau, Nemunas valley – Dzūkai Uplands, Aukštaičiai Upland, Medininkai – Riešė Uplands; Švenčioniai, Ašmena and Dysna districts). Average height and average homogenous biota territorial structure prevail. The dominant horizontal structure is characterized as fine mosaic horizontal structure - small BTSE (up to 500 ha) are dominating in the geobiocomplexes.

Only 6 districts (out of 24) can be characterized by the subnatural landscape. These are Curonian Spit, Baltic coastal area, West Žemaičiai Plateau, Nemunas valley, Eastern part of Central Lithuania, Laky complex–Žeimena Lowland, Vokė–Merkys–Dainava Lowland districts. They are characterized by high BTSE and heterogeneous vertical biota territorial structure.

A woody patchy matrix territorial structure is forming in the subdistricts of these lowlands (Curronian Spit, Baltic coastal area, Nemunas valley, Žeimena Plain, Vokė–Merkys and Dainava lowlands subdistricts). The same horizontal structure is identical to the territories of intensive agriculture. However, the matrix is comprised not by the cultivated field habitats, but by the subnatural large forested areas in the above-mentioned subdistricts.

To conclude, nowadays, the abiotic environment conditions are not the single determinant, influencing the formation of the landscape biota territorial structure. The differences of Lithuanian zonal vegetation cover – forests essentially can be analysed in the

terms of potential vegetation in our contemporary anthropogenizated landscape. A human being creates the vegetation cover combinations, consisting of the different size and configuration patches. They constitute heterogeneous landscape mosaic. The consistent patterns of it physiognomy, vertical and horizontal arrangement influence the habitat conditions of living organisms. Therefore, the human impact is the most important precondition when analysing the consistent patterns of landscape biota territorial distribution and territorial morphology peculiarities.

Consequently, the landscape biomorphostructure exists together with the well - studied lito-, pedo-, hidro-, techno- and other structures of Lithuanian landscape. This structure obtains edaphic features from the abiotic landscape components (surface rocks, soil, relief) and structural features from anthropogenic component. Thus, an individual biota territorial structure is being formed in the landscape. Delineation of its territorial units – geobiocomplexes and the regionalization of Lithuanian territory by its characteristic features contributes to the cognitive system of natural and anthropogenic landscape components and constitutes the integrated geographical territorial structure model of landscape biotic component.

Conclusions

1. The research of the dynamic landscape component – biota (in broad sense) was put apart in the Lithuanian landscape geography science, as a focal research point of it was always considered to be the stable lithological basis. Biota plays a passive (visual–indicational) role in the majority fundamental works of landscape geography and is considered as one of the constituents of landscape morphological units. However, the increasing human activity and the disappearance of landscape diversity form a strong motivation to research the landscape changes from the biota territorial structure point of view.

2. The notion of landscape biota territorial structure formed in this work reflects the morphological peculiarities of biotic landscape component in the ecosystem level. Ecosystems themselves become the cartographical objects – biota territorial structure elements (BTSE), continuously covering the Earth surface. This fact enables the theoretical aspects of BTSE morphology (BTSE physiognomy, vertical and horizontal situation) transform to the fundamental features of landscape biota territorial structure.

3. The methodology, specifying the natural–geographical peculiarities of biotic landscape component – vegetation was created. It could be adapted to determine the correlation features of spatial distribution of the others correlated landscape components.

4. The notion of landscape biota territorial structure units – geobiocomplexes was formed and the methodology of their discernment was proposed. It is based on the typical BTSE combinations, appearing in the territory of homogeneous edaphic conditions. There are 3367 territorial units determined in Lithuania's territory. Such a small division of our country into the territorial units, characterized by the different biotic structure is a sufficient basis for the detailed analysis of landscape biota territorial structure features.

5. There are 8 typological, 4 individual and the one integrated individual geobiomorphological regionalization of Lithuania composed in this work. It reflects the regions of different biota edaphic conditions and structural feature combinations, contributes to the cognitive framework of natural and anthropogenic landscape components and constitutes the integrated geographical territorial structure model of landscape biotic component.

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References

Brundza K., Pakalnis R., Budriūnas V. (1981). Lietuvos augalijos žemėlapis M 1: 1000 000. *Lietuvos TSR atlasas.*

Čekanavičius V., Murauskas G. (2002). Statistika ir jos taikymai, Vilnius: TEV, t. 2.

Dierssen K. (1996). Vegetation Nordeuropas, Stuttgart.

Forman R. T., Godron M. (1986). Landscape Ecology, New York: John Wiley and Sons.

Forman R. T. T. (1995). Lands Mosaic. *The Ecology of Landscapes and Regions*, Cambridge: Cambridge University Press.

Forman R. T. T., **Godron M.** (1981). Patches and Structural Components for a Landscape Ecology, *Bioscience*, Vol. 31, No. 10, p. 733–740.

Godron M., Forman R. T. T. (1983). Landscape Modification and Changing Ecological Characteristics. *Disturbance and Ecosystems: Components of Response.* H. A. Mooney, M. Godron (Eds.), New York: Springer–Verlag. p. 12–28.

Lietuvos Respublikos kraštovaizdžio politikos krypčių aprašas (2004), *Valstybės žinios*, Nr. 174–6443.

Matuszkiewicz W. (2002). Przewodnik do oznaczania zbiorowisk rošlinnych Polski. *Ser.: Vademecum Geobotanicum*, Warsaw: PWN.

Navasaitis M., Ozolinčius R., Smaliukas D., Balevičienė J. (2003). Lietuvos dendroflora, Kaunas: Lututė.

Plečkaitis R. (2004). Logikos pagrindai, Vilnius: Tyto Alba.

Saunders D. A., Hobbs R. J. and Margules C. R. (1991). Biological Consequences of Ecosystem Fragmentation: a Review, *Conservation Biology*, Vol. 5, p. 18–32.

Tansley A. G. (1935). The Use and Abuse of Vegetational Concepts and Terms, *Ecology*, Vol. 16, No. 3, p. 284–307.

Балявичене И. (1991). Синтаксономо-фитогеографическая структура растительности Литвы, Вильнюс: Мокслас.

Харман Г. (1972). Современный факторный анализ, Москва: Статистика.

Девис Дж., Радионов Д. А. (ред.) (1977). Сатистика геологических данных, Моска.

Одум Е. П. (1986). Экология, Москва: Мир.

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Kraštovaizdžio biotos teritorinės struktūros morfologija (Lietuvos teritorijos pavyzdžiu)

Santrauka

Kraštovaizdžio geografijos moksle didžiausią dėmesį skiriant stabilaus litogeninio pamato tyrimams, ilgainiui į šalį buvo atidėtas dinamiškas, nepastovus kraštovaizdžio komponentas – biota (plačiąja prasme), daugelyje fundamentinių darbų suprantama kaip atliekanti pasyvią (vizualinę-indikacinę) funkciją bei esanti morfologinių kraštovaizdžio vienetų dedamoji dalis. Šiuo metu dėl sparčios antropogeninės invazijos, nykstant kraštovaizdžio įvairovei atsiranda būtinybė į kraštovaizdyje vykstančius pokyčius pažvelgti pro biotos teritorinės struktūros prizmę.

Kraštovaizdžio biotos teritorinė struktūra nebepriklauso vien nuo abiotinių aplinkos sąlygų. Dabartniame kraštovaizdyje natūralią zoninę mūsų krašto augalinę dangą – miškus – iš esmės galima analizuoti tik „potencialios augalijos“ sąvokos rėmuose. Žmogus, antropogenizuodamas Žemės paviršių, sukuria savitus augalinės dangos derinius. Šie formuoja įvairialypę vizualinę kraštovaizdžio mozaiką, kurios pobūdžio, vertikaliojo ir horizontaliojo išsidėstymo ypatybės veikia gyvųjų organizmų gyvenamąsias sąlygas. Todėl kraštovaizdžio biotos teritorinio pasiskirstymo dėsningumų neįmanoma nagrinėti be žmogaus poveikio aplinkai, atspindinčio biotos teritorinės morfologijos subtilybes.

Darbe suformuluota kraštovaizdžio biotos teritorinės struktūros samprata nusako biotinio kraštovaizdžio komponento morfologines ypatybes ekosistemų lygmeniu. Pačios ekosistemos virsta realiai kartografuojamais, tolygiai Žemės paviršių dengiančiais biotos teritorinės struktūros elementais (BTSE). Tai įgalina teoriškai klasifikacijoje atsispindinčius BTSE morfologinius aspektus (pobūdį, vertikaliąją bei horizontaliąją padėtį) perkelti į objektyvią realybę ir transformuoti į kertinius kraštovaizdžio biotos teritorinės struktūros požymius.

Todėl, be išsamiai išnagrinėtų Lietuvos kraštovaizdžio, litologinio, pedologinio, hidrologinio, technologinio ir kitokio pobūdžio struktūrų, egzistuoja itin svarbi – tarpinė kraštovaizdžio morfostruktūra, kuri iš abiotinių kraštovaizdžio komponentų (paviršinių uolienų, dirvožemio, reljefo ir pažemio oro) įgauna edafinių bruožų, o iš antropogeninio komponento – struktūrinių ypatybių. Taigi kraštovaizdyje formuojasi savita biotos teritorinė struktūra. Jos teritorinių vienetų – geobiokompleksų nustatymas bei Lietuvos teritorijos rajonavimas pagal jai būdingus požymius įtraukiamas į bendrą kraštovaizdžio gamtinių ir antropogeninių komponentų bei ryšių pažinimo sistemą ir formuoja integruotą geografinį kraštovaizdžio biotinio komponento teritorinės struktūros modelį.

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MELIORATION SYSTEMS OF THE VISTULA DELTA

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1. Hydrographic Characteristics of the Study Area

Presently, the coastal alluvial plains represent the type of areas where the hydrodynamic balance is maintained artificially. This is due to their excessive moistening, which is caused by the lack of natural outflow. This, in turn, is an effect of the minimal land gradient, isolation from receivers by dykes and causeways, flooding of larger unregulated rivers, inflow and sub-flow of foreign surface and ground waters from the surroundings. Hence, in order to maintain the hydrodynamic balance and simultaneously provide conditions for man's activities, it is necessary to employ a water and melioration system.

For the purpose of the research, there was selected the easternmost part of the Vistula delta of 460 km^2 of area (Augustowski, 1976), known as Żuławy Elbląskie (Fig. 1). This area, according to J. Kondracki (1978), is a physical-geographical unit that constitutes part of Gdańsk Coast, a macroregion of South Baltic Coastlands.

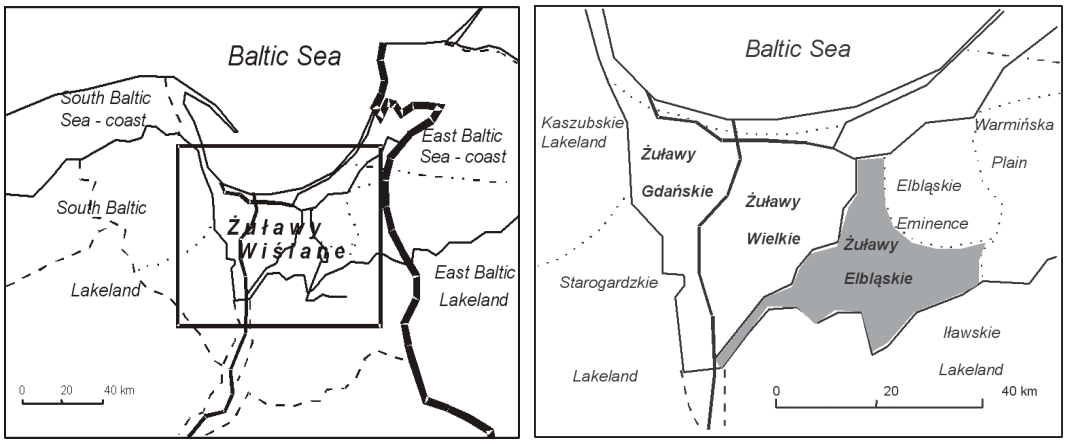

Fig. 1. Area of study.

2. Methods

The hydrographic interpretation is the key issue in the research procedure of this study. This method lies at the basis of the analysis from the perspective of the mutual spatial relationships of individual hydrographic elements.

The cartographic material was assumed to be the basic source of information. This covered hydrographic maps at a scale 1:50 000 (Mapa..., 1986–1987) and water and melioration maps at a scale 1:10 000 (Mapa…, 1987). The data from the District Department of the Water Facilities and Melioration Authority in Elbląg (Rejonowy Oddział Zarządu Urządzeń Wodnych i Melioracji) were also used.

3. Melioration Systems in the Eastern Part of the Vistula Delta

The water and melioration system protects the land from water-logging and flooding, and performs the functions of drainage and irrigation. From the very beginning of the

functioning of the system, the basic goal was the drainage of the primeval swamps and lagoons spreading between the outlet arms of Vistula. These actions were conditioned by the natural hydrographic system of the delta. The remaining actions that enabled the maintenance of drained areas in a condition appropriate for habitation and use were related to land melioration. The manner of melioration depended on the moment when it was performed, as the goals of these actions and melioration techniques changed throughout centuries together with the hydrotechnological advances. Thus, the changes caused by melioration depended more on local conditions than on the mesoscale hydrographic situation.

Both draining and melioration actions led to the formation of one compact water and melioration system in the Vistula Delta, rated among the so-called great water and melioration systems (GWMS) (Cebulak, 1991). The present functioning of the system is the resultant of natural conditions and the actions of many generations in the scope of forming, modernizing and exploiting the hydrotechnical facilities. Polders are the basic hydrological units in this great system. The unit that has a sufficiently individualized system of melioration ditches and canals – sometimes called the small water and melioration system (SWMS) – is also the basic hydrographic unit.

Water circulation is conditioned by the geographical environment of alluvial plains what is proved in the slightly permeable grounds, small land gradients and frequent location in depressions. Such areas require a dense network of ditches. On the other hand, the density of the network of ditches is limited by agrotechnical demands, as too big a number of ditches leads to high losses in arable land area and hinders mechanized farming. From the agrotechnical perspective, the length, distance between and direction of the course of ditches are important too. A decisive role of the existing hydrographic network of the delta may be demonstrated in the layout of the network of detailed land melioration. In this case, the manner in which it is performed is influenced by the distance from the receiver, the degree of anthropogenic transformation of the receiver and the orientation with regard to the receiver of the general direction of flow.

When the types of layouts of the small water and melioration systems (Fac, 1997) were determined it became possible to analyse the hydromorphic similarities and differences in the water network of polders (Table). Twenty three types were recorded in the eastern part of the Vistula Delta (Żulawy Elbląskie) (Fig. 2).

Table. Participation of the basic areas and tied types of melioration systems in Żuławy Elbląskie.

Types of basic systems	**Area (km^2)**	**Participation of area (%)**
perpendicular /P/	151.08	37
parallel /R/	41.08	10
diagonal /D/	81.3	20
unordered /U/	134.02	33
total	407.48	100
Types of tied systems		
perpendicular /p/	140.22	34
parallel /r/	0	0
diagonal /d/	61.47	15
mixed /m/	178.17	44
none	27.62	7
total	407.48	100

Fig. 2 shows that the greatest area among the main types is covered by regular ordered perpendicular (Prp, Prd, Pr) and irregular ordered perpendicular systems (Pip, Pid, Pim, Pi). A comparison of the distribution of these types with the data on the time of settling individual parts of the delta (Drwal, 1991) indicates that this type of SWMS systems could have been used to drain polders from the 16th till the 17th century. It was then that inhabitants of the present Dutch territory intensively settled in this area (Fac (Fac–Beneda J.), 1997).

One more regularity was also observed. The analysed type of systems occurs in the areas of the densest water network, exceeding 20 km/km^2 (Błaszkowski, 1992). The extent of these areas coincides almost completely with the extent of depression. In such areas, the circulation of water is forced mechanically rather than gravitationally. There is no need to construct ditches using natural land gradients. The canals collecting and discharging water to the main canals can join them at right angles.

The irregular unordered systems (Uip, Uid, Ui) that cover the second largest area (about 134 km^2, i.e. 33%) and occur near the main watercourses in the present Nogat delta and on the edge of Elbl¹g Plateau represent another main type of systems. These systems correspond in their layout to the natural hydrographic network. They were meliorated earlier than the areas with the ordered systems, i.e. before the 16th century. They lie beyond the depression and belong to the areas of the sparsest water network in Żuławy Elbląskie, less than 8 km/km^2 (Błaszkowski, 1992). Before the 16th century these areas were often affected by floods. In order to use them, it was necessary to drain them as fast as possible after each flood. Thus, systems discharging waters the shortest way to the receiver, i.e. the natural watercourse, often using the natural land gradient (the area built of alluvia accumulated by these receivers was slightly elevated above them) were constructed.

Two types of systems: regular and irregular ordered diagonal (Drp, Drd, Dr, Dip, Did, Dim, Di) and regular and irregular ordered parallel (Rrp, Rr, Rip, Rid, Rim, Ri) take up a much smaller area. There is also no clear pattern of their distribution. A rational interpretation is that these are systems somehow "joining" the above mentioned perpendicular and mixed systems.

Fig. 2 is also helpful in analysing the distribution of the tied types of melioration systems, determined on the basis of the layout of ditches of the third and lower orders with respect to ditches of the second order. The analysis reveals that mixed systems cover by far the larger area (Pim, Rim, Dim, Uim). These systems occur in the immediate surroundings of natural watercourses emphasizing the course of these flows. The layout of the ditches is, thus, to some extent conditioned by the system of the general hydrographic network. The necessity of fast draining of the frequently flooded areas adjacent to the natural watercourses, made people dig straight sections of ditches and canals according to the local land gradients.

The distribution of the tied types of perpendicular systems (Prp, Rrp, Drp, Pip, Rip, Dip, Uip) and diagonal systems (Prd, Drd, Pid, Rid, Did, Uid) is different. They occur at large distances from the main natural watercourses. One can risk the statement that such a situation was conditioned by the requirements of the melioration technology and agrotechnical needs, rather than by the system of the natural hydrographic network.

The tied systems do not form parallel systems. Drainage ditches, due to the role they play, must join the collecting ditches at right or acute angles. Drainage by parallel ditches would not perform the required task.

A small percentage of Żuławy Elbląskie (~7%) is taken up by systems lacking ditches of the third and lower orders (Pr, Rr, Dr, Pi, Ri, Di). Their greatest cluster occurs in polder Fiszewka S and is probably conditioned by strong secondary anthropogenic transformations in this area. Small patches of such systems are also found in peripheral areas, which is due to greater land gradients.

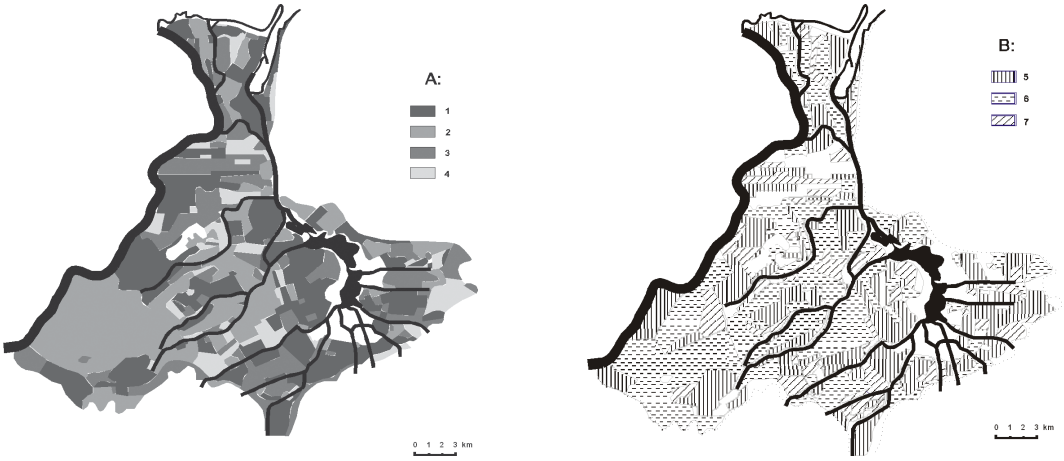

Fig. 2. Melioration systems. A – types of basic systems, B – types of tied systems, 1, 5 – perpendicular, 2, 6 – mixed, 3, 7 – diagonal, 4 – parallel.

Conclusions

The layout of the melioration network is conditioned by the occurrence of places with a considerable excess of moisture, by the manner and intensity of water supply, topographic features, ownership rights and settlement policy. Both at the level of main types as well as the tied ones, the occurrence of melioration systems classified as unordered and mixed was conditioned by the natural hydrographic network of the delta. On the other hand, the occurrence of perpendicular and diagonal types of systems at this level was determined by local conditions and hydrotechnical advances. The types of melioration systems do not reveal a relationship with the settlement network, including the road system. This is justifiable as it were the roads that corresponded to the network of ditches and canals, and thus to the already existing MSWM systems.

Summarising, it is worth mentioning that the distribution of individual types of melioration systems was determined mainly by natural conditions, especially water relationships and requirements of agriculture, and to a smaller degree, though clearly noticeable, the chronology of settlement and economic events.

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References

Augustowski B. (1976). Charakterystyka geomorfologiczna. *Żuławy Wiślane* (pod red. B. Augustowskiego), Gdańsk: GTN.

Błaszkowski J. (1992). Mapa gęstości sieci wodnej Żuław Elbląskich, *Zesz. Nauk. Wydz. BGiO, UG, ser. Geografia*, s. 164–170.

Cebulak K. (1991). Ocena i prognoza rozwoju polderowego systemu melioracji basenu jeziora Druzno. *Basen jeziora Druzno* (pod red. J. Drwala), Gdańsk: Wyd. UG, s. 19–38.

Drwal J. (1991). Przyrodniczo – techniczne uwarunkowania powstania, trwania i dalszej ewolucji basenu jeziora Druzno [w:] Basen jeziora Druzno pod red. J. Drwala, Uniwersytet Gdański, Gdańsk.

Fac J. (1997). Przemiany hydrograficzne na Żuławach Elbląskich w okresie gospodarczej aktywności człowieka: maszynopis rozprawy doktorskiej//Katedra Hydrologii UG.

Kondracki J. (1978). Geografia fizyczna Polski, Warszawa: PWN.

Mapa Hydrograficzna Polski w skali 1:50 000 (1986–1987), Warszawa: Główny Urząd Geodezji i Kartografii.

Mapa Wodno-Melioracyjna Żuław Elbląskich w skali 1:10 000 (1987), Elbląg: Rejonowy Oddział Zarządu Urządzeń Wodnych i Melioracji w Elblągu.

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Vyslos deltos melioracijos sistema

Santrauka

Vyslos delta yra vienas įdomiausių ir svarbiausių Lenkijos regionų. Regionų, kur būtų taip artimai susiję gamtinis ir antropogeninis kraštovaizdžiai, yra nedaug. Tai ypač pasakytina apie hidrografinį tinklą, kuris jau nuo XII a. buvo stipriai pertvarkomas ir pritaikomas žmogaus reikmėms.

Melioracijos sistemos apsaugo teritorijas nuo užmirkimo bei užliejimo, taigi atlieka sausinimo funkciją, taip pat drėkinimo. Pagrindinė Vyslos deltos vandens ir melioracijos sistemos paskirtis nuo pat jos veikimo pradžios buvo tarp deltos protakų esančių pelkių bei lagūnų sausinimas. Vėlesni melioravimo būdai priklausė nuo nusausintų plotų naudojimo tikslų bei melioracijos techninių galimybių, kurie nuolatos keitėsi.

Melioracijos sistemos išplanavimą lemia perteklingai drėkinamų plotų išsidėstymas, vandens prietakos būdai bei intensyvumas, topografinės vietovės ypatybės, žemėvaldos formos bei gyvenviečių išsidėstymas. Planinės struktūros atžvilgiu melioracijos sistemos skirstomos į statmenąsias, lygiagrečiąsias, įstrižąsias, netaisiklingąsias bei mišriąsias. Netaisiklingųjų bei mišrių melioracijos sistemų paplitimą lėmė natūralus deltos hidrografinis tinklas. Taisyklingų formų (statmenųjų, įstrižųjų) melioracijos sistemų kūrimąsis priklausė nuo lokalių ypatumų, taip pat hidrotechnikos pažangos. Melioracijos sistemų tipų analizė neatskleidė glaudaus ryšio tarp šių tipų bei gyvenviečių ir kelių tinklo.

Taigi melioracijos sistemų tipų pasiskirstymą lėmė natūralios sąlygos, ypač vandentėkmės, bei žemės ūkio poreikiai, o nuo gyvenviečių bei ekonomikos plėtros jis priklausė mažiau.

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IMPROVEMENT OF LAKE SAPROPEL QUALITY: A NEW METHOD

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Introduction

Seeking to satisfy its needs, modern society is developing different kinds of industrial production. The intensive economic activity in the past and present is responsible for the ever-increasing environmental pollution. Not only human activities but nature itself affects ecosystems. Lakes may serve as an example of ecosystems affected by natural factors. Mud formation processes are taking place in them. The shores of lakes overgrow with higher plants-macrophytes. As the lakes grow shallow, macrophytes tend to penetrate into their deeper parts occupying new areas. Slowly such lakes convert into fens and, later, into high moors. Lakes are aging and declining. These processes are especially typical in case of small lakes. In Lithuania there is about 1 billion m^3 of pure sapropel which lays mostly in 1 to 2 m thick layers but in some places layers are up to 5 m, and there is about 6 billion m^3 of sapropel in mixture with other sediments (Tarybų…, 1987). About 4.5 bill m^3 of sapropel underlie the peat layer of lacustrine swamps. The now cleaned silted up lakes (a few hundred) have accumulated 1.5 billion m^3 of sapropel.

Formation of organic sediments in lakes depends on many factors, one of them being changes of the climate in the past. Thick layers of sapropel are linked with longer spells of dry climate (Basalykas et al., 1958).

Lakes are a great national treasure. They are important from the natural and economic point of view. First, lakes are a source of fresh water. They are also used for modern fish-culture, development of hunting economy, hydroenergetical, water sports, recreational and tourism purposes. Therefore, recovery of silted lakes is very important. On the other hand, sapropel is a valuable lake product. In agriculture it is suitable for soil fertilization and as addition to food for animals, and is a good raw material for chemical and even building industry or a remedy in health cure (for mud baths).

An ecosystem is regarded as recovered when it has sufficient biotic and abiotic resources for further independent functioning without human interference. The remediated ecosystem – lake – must be identical to a standard undisturbed ecosystem. It must have the same combinations of species and structure of communities. The remediated lake ecosystem must be integrated into a wider ecological environment – landscape – through biotic and abiotic flows and exchange. It must be as resistant to environmental factors as a natural one. The dynamics of its components under changing environmental conditions must be analogous to the dynamics of components in a standard ecosystem.

Based on the mentioned principles of ecological recovery, the article discusses the issues of lake remediation related with elimination of sapropel from silted lakes and improvement of sapropel quality. There is a double advantage of ecological recovery: a renovated lake and a valuable product sapropel which can be used for different purposes.

1. Methods

The content of nitrogen in sapropel was determined by photometric method using sodium salicilate and hypochlorite solution in alkaline medium. The content of phosphorus was determined photometrically using ammonium molybdate solution in acid medium. The method of potassium bichromate in a medium of sulphuric acid was applied for determining the content of organic carbon. Soluble hydrocarbons were determined photometrically using anthron reagent. The summary fraction of lipids was determined by mass analysis. The extraction was performed with the aid of ethyl alcohol and diethyl alcohol mixture followed by petrol ether. Trace elements were determined by the method of emission spectroscopy. Vitamins of B and other groups were evaluated using microbiological methods. Chromatographic methods (Потапова, Куприн, Фролова, 1980; Топачевский, 1975; Жукова, Одинцова, 1967; Звягинцев, 1991; Standard…, 1992; Флора..., 1993–2003) were employed for determining the concentration of free amino acids in sapropel. All data are attributed to the weight of dry sample.

2. Results

Lithuania is a country of the Baltic basin. Its area is 65 200 km^2. It has 4000 lakes and is called "a country of lakes". One of the European lake-abundant zones coinciding with the glacier margin of the last Ice Age runs across Lithuania.

Peat, silt and sapropel are valuable lake products. Sapropel is composed of sediments (Liužinas, Jankevičius, 2005). Sediments are of double origin: autochthonous and allochthonous. The autochthonous sediments are composed of dead phyto- and zooplankton and, at the end of the vegetation period, of macrophytes (Liužinas et al., 2004). This category of sediments also includes the material of coastal erosion. Allochthonous sediments are composed of drift from external drained basins and material transported by streams, rivers and airflows. Pollution of the territories of farmlands, animal-breeding farms, settlements and industrial objects increases the load of allochthonous material on lakes.

Sedimentation rates in lakes with different nutrient income are varying from a few to a few tens of centimetres.

Mineral, organic or intermediate types of sediments prevail in different lakes. Organic sediments tend to accumulate in lakes with high nutrient income. They form an unstructured mud composed of remains of plankton and benthic organisms with some mineral components. The term sapropel is applied to this kind of mud.

2.1. Chemical composition of sapropel

According to its chemical composition, sapropel can be organic, calcareous, siliceous, and mixed (organic–calcareous and organic–siliceous).

The quantitative chemical composition of sapropel varies within a wide range depending on maturity, lying depth and formation conditions. The data on chemical composition of examined sapropel are given in Table 1.

Table 1. Chemical indices of sapropel samples.

Nitrogen (N), %	Phosphorus (P_2O_5), %	Organic carbon, %	Soluble hydrocarbons, %	Summary fraction of lipids, %
0.2–2	0.1–0.2	9–35	0.4–4	0.3–2

The highest concentrations of nitrogen occur in the organic sapropel. High concentrations of phosphorus occur in organic and organic–calcareous sapropel.

Humic acids in sapropel account for about 11–38%, fulvic acids for 2–23% and unhydrolized remains for 5–22% (Бракш, 1971; Лопотко, Евдокимова, 1986). The composition of trace elements in sapropel is demonstrated in Table 2.

Table 2. Concentrations of trace elements in sapropel, mg/kg.

Li	B	Mn	Ti	V	Cr	Co	Ni	Cu	Zn	Pb	Mo	Sr	Cd
6–15	24–53	280–660	1000–2400	11–35	9–25	3–5	9–27	12–63	29–120	7–31	1–3	48–130	2–4

Trace elements are very important for biological effects. They (30 of them) are indispensable for normal vital activity of plant and animal organisms. For example, copper (Cu) is included in the composition of important respiratory enzymes, zinc (Zn) is a constituent of many enzymes (carboanhydrase, carboxypeptidase, different dehydrogenases) and molybdenum (Mo) is included in the active centre of nitratreductase. The concentrations of trace elements determined in sapropel do not exceed the permissible general hygienic values and limit values for phytotoxines. The value of sapropel depends on the content of physiologically active substances – vitamins and amino acids. We examined the content of these substances in different kinds of sapropel (Tables 3 and 4).

Table 3. Concentrations of some vitamins in sapropel, µg/kg.

Inosite	Biotin (H)	Thiamine (B_1)	Pantothene acid (B_3)	Pyridoxine (B_6)	Nicotinic acid (PP)	Para-amine benzoic acid	Vitamin B_{12}
7500–45000	0.6–26	3.3–136	1200–16000	3.1–54	700–11000	1.7–66	3.5–73

Vitamins play an important role in metabolism and other vital functions. The content of vitamins in sapropel considerably exceeds the values found in the soils of medium fertility: inosite, thiamine (B_1) and pantothenic acid (B_3) by 14 times, biotin (H) by 12 times, pyridoxine (B_6) and nicotinic acid (PP) by 4 times, and para-amine benzoic acid and vitamin B_{12} even by 25 times.

Amino acids are characterized by high physiological activity. They participate in protein synthesis and as a starting material in the synthesis of hormones, coenzymes and pigments. Especially important are essential amino acids lysin, hystidin, arginine, threonine, valine, methionine, leucyne, isoleucyne, phenylalanine, and tryptophan. Animal organism is unable to synthesize them. It must receive them with food. It is a virtue of sapropel that it contains high concentrations of essential amino acids (48–60% of the total amount of aminoacids).

Table 4. Free amino acids and their content in sapropel, mg/100g.

Cystine	Lysin	Hystidin	Arginine	Aspartic acid	Serine	Threonine
0.001–0.7	0.1–0.5	0.1–0.4	0.2–0.7	1.1–1.6	1.0–1.1	traces

Glutamic acid	Alanine	Tyrosine +Tryptophan	Methionine	Valine +Phenylalanine	Leucyne +Isoleucyne
0.7–0.8	1.4–1.7	1.3–1.8	0.9–1.1	0.9–1.9	1.6–2.3

2.2. Practical use of sapropel

The results of ecogeochemical evaluation of sapropel and physiological active substances detected in it, revealed a possibility to use it for improvement of agrochemical and physical properties of soils. A positive influence of sapropel on yields of various cultures has been reported in many research papers (Bakšienė, 1996; Christensen, 1985; Korschens et al., 1984).

Latvian, Polish, Belarusian, Russian, and German researchers investigate various possible methods of soil fertilization with sapropel and its optimal amounts for different cultural plants. The effect of sapropel on yields of plants depends on its chemical composition, the methods of its processing for fertilization, type of fertilized soil, soil productivity, and culture.

Taking into consideration that sapropel abounds in physiologically active substances (vitamins, amino acids, etc.), it is investigated for suitability as fodder supplement. Investigations of this kind are carried out in Lithuania (Малашкайте, 1962) and Belarus (Лопотко, Евдокимова, Кузмицкий, 1992). Fodder supplements made of sapropel are produced as granules, briquettes or powder. It is experimentally proved that sapropel granules increase the value of combined fodder enriching it in mineral macro- and microelements.

It is known that sapropel can be used for mud therapy (Виръясов, Иванова et al., 1997). Organic sapropel is rich in bioactive substances and is highly colloidal. These properties account for its hydrophilic capacity, high thermal recipience and ability to retain heat for a long time. The use of sapropel as curative mud mixed with peat or combined with aromatic officinal plant extracts is rather promising.

Detailed examination of sapropel lipids revealed that they resemble wax in their chemical composition. They contain compound ethers, hydrocarbons, cyclic and aliphatic alcohols, acids, į- and ā- unsaturated carbonylic and other compounds. The content of lipids in sapropel is rather high and their extraction could be profitable. The sapropel lipids can be used in cosmetic and pharmaceutical industries.

Technologists of production of new materials are also interested in sapropel. It was tested as an additive facilitating formation of pores in the raw material used for production of poriferous stone wear. Sapropel containing low content of ash (when ash do not exceed 30% of its dry weight) is tested as an adhesive able to replace combinations of glues. Algal-zoogenic sapropels are best fit for this purpose. Peat sapropels do not have adhesive properties.

A possibility to use a combination of sapropel with perlite in the production of insulation materials has been worked out (Виръясов, Иванова et al., 1997).

The spectrum of sapropel utilization is rather wide. Sapropel is a valuable raw material. At present, sapropel is used as a fertilizer for improvement physical and chemical properties of soils and for increase of yields. Therefore, it is expedient to investigate its specific properties.

Sapropel is a colloidal formation. Organic colloids are able to absorb much water; 90% and more. It hardly vaporizes water and becomes very solid after drying. Due to its structure, sapropel is distinguished by low filtration capacity.

Sapropel contains much iron and aluminium oxides. Ash of different types of sapropel contains 2.3–8.3% of iron (Fe_2O_3), 1.1–3.9% aluminium (Al_2O) and 6.8–36 % of silicon (SiO_2) (Katkevičius, Ciūnys, Bakšienė, 1998). Iron and aluminium oxides form gels in sapropel. They are colloids in a more solid form than a solution. Gels are friable and elastic. Friable gels do not swell. They (iron gel, aluminium gel and silica gel) retain their form and volume when drying. These properties are characteristic of some kinds of sapropel containing greater amounts of Fe, Al and Si.

Phosphorus (P) is an important element for plant growing. A plant assimilates phosphorus in the form of phosphates (PO_4^{2-}). Phosphorus participates in many essential reactions of metabolism and energy exchange. Iron ions combine phosphates of sapropel and fertilized soil into poorly soluble or insoluble salts. $FePO_4$ is a product of this reaction.

When using sapropel as a fertilizer we must bear in mind that chemical sorption can occur (combining of cations and anions into poorly soluble salts). These processes inhibit the access of ions to plants and are unwanted.

Seeking to increase the value of sapropel as a fertilizer, we tested the efficiency of sapropel blends with various organic and mineral substances (7 variants). The following

blends were prepared: 1. Sapropel + peat (1:1, 1:2, 1:3); 2. Sapropel + soil (1:5, 1:10, 1:15); 3. Sapropel + rye straw (10:1); 4. Sapropel + NPK mineral fertilizers (40 mg of each element per one kg of sapropel); 5. Sapropel + soil (1:10) + straw (10% of the sapropel mass); 6. Sapropel + soil (1:10) + straw (10% of the sapropel mass) + NPK mineral fertilizers (40 mg of each element per one kg of sapropel) and 7. Sapropel + soil (1:10) + peat (10% of the mass of blend) + straw (10% of the mass of blend) + NPK (40 mg of each element per one kg of sapropel). The efficiency of the blends was determined according to their influence on viability of cucumber ("Alfa" variety) seeds and their germination energy and on growth of test-microorganism *Escherichia coli* (in the latter case, water extracts of substrata were used).

Preliminary results showed that NPK increased the efficiency of sapropel fertilizer by 7%, NPK + straw 16% and NPK + straw + peat 20%. This is related with microorganism activity what is proved by higher reproduction rates of *Escherichia coli*. Components activating microorganism activity in sapropel increase its biological value. The obtained results encouraged us to search for simple methods of enrichment of sapropel with easily degrading organics and activation of microbiological activity facilitating the disintegration of organic material to simple mineral compounds easily accessible to cultural plants.

3. Methods of Lake Recovery (Renovation)

Lake renovation is a complicated task. A scheme of the main stages of regeneration is given in Fig.

Cleaning of silted lakes can be started after topographic, hydrogeological, hydrochemical, and comprehensive hydrobiological survey of a locality. Evaluation of environmental effects is indispensable prior to elaboration of limno-technological plan of sapropel extraction.

Sapropel extraction and lake recovery were assumed in Lithuania in 1960 (Ciūnys, Lazauskienė, Katkevičius, 1994; Linčius, 1997). At approximately the same time (a project for recovery of Trumen Lake in Sweden by elimination of sediments in 1970–1971), lakes were renovated in Sweden, Finland and other countries (Björk, 1972, 1985; Ripl, 1976; Edmondson, Lehman, 1981; Forsberg, 1985).

In Lithuania, 13 lakes were deepened by excavation of sapropel. Twenty-eight Lithuanian lakes have been so far limnologically investigated. Their limnological–technological plans were compiled. The lakes are due to be cleaned.

Lithuania has gained certain experience in sapropel excavation and lake remediation. The hydraulic sapropel excavation method is most widespread. The sapropel pulp is transported through pulp pipes to reservoirs. The reservoirs are built in impermeable rocks. They represent 120–150 m long, 60–120 m wide and up to 2.5 m deep areas encircled by dikes. The reservoirs are filled with sapropel pulp to the depth of 1.2 m.

A new method was suggested for sapropel extraction and improvement of its quality. Sapropel pulp is transported to reservoirs by pulp pipes until it forms a 30–40 cm thick layer. It is given some time for thickening. After sedimentation of pulp particles, the layer is planted with common reed (*Phragmites australis*) rhizomes (4 seedlings/m^2). Rhizomes are accommodated to high organic and mineral loads. They immediately strike roots and sprouts and act as biological absorbers. The clarified water is regularly drained away into the lake, and the reservoir is filled with a new portion of sapropel. When reeds are growing in the reservoir, the pulp layer may be 100–120 cm thick.

Advantages. Reeds speed up the evaporation of water from the reservoir (evaporation is backed up by transpiration) and drying of sapropel. The root system of reeds and rhizomes

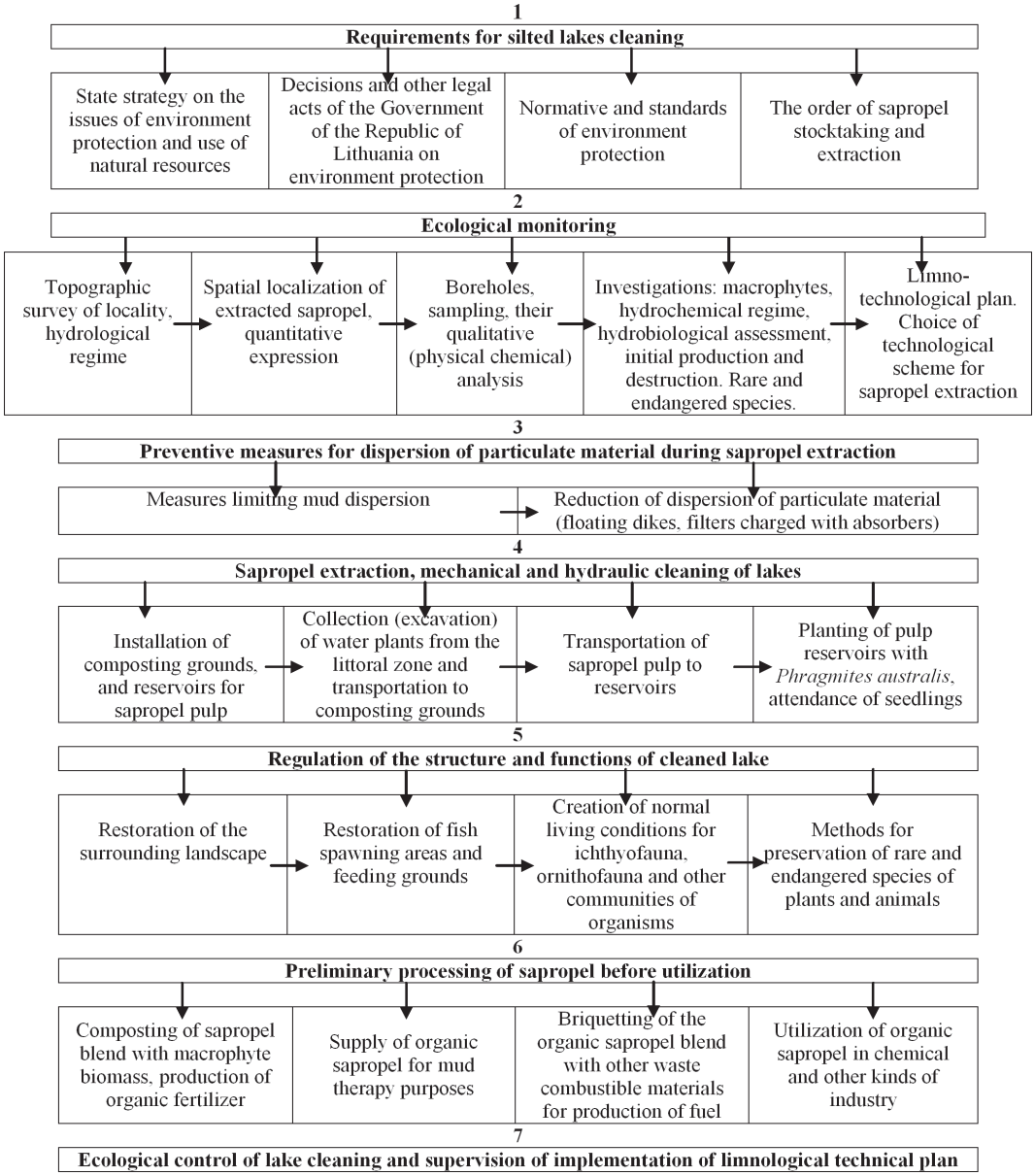

Fig. Scheme of sapropel extraction and utilization.

emit H^+ ions and organic acids. They release the cations strongly consolidated with humus (NH_4^+, Mg^+, K^+, Ca^+, etc.) and anions (NO_3^-, PO_4^{3-}, HPO_4^{2-}, SO_4^{2-}, etc.) making them easily available to plants. After blending with reed roots, rhizomes and plant biomass, sapropel is composted and converted into a high quality marketable (in the country and abroad) organic–mineral fertilizer.

Conclusions

Lakes are a great national treasure (fresh water source can be used for hydroenergy production, recreation, fishery, etc.). Yet lakes tend to age, bog up and disappear. Therefore, they have to be renovated (remediated) by elimination of mud (sapropel). Sapropel is a valuable natural raw material. It abounds in biogenic elements, physiologically active substances (vitamins and amino acids) and lipids. The spectrum of sapropel utilization is wide. It is especially fit

for soil fertilization. In order to optimize utilization of sapropel as a fertilizer, we sought for measures facilitating the concentration of free cations and anions in it. We showed that the water plant *Phragmites australis*, which is planted on the thickened sapropel pulp, emit H^+ ions and organic acids by rhizomes and roots releasing the elements necessary for growth of cultural plants. Moreover, transpiration by leaves and stems of *Phragmites australis* facilitates rapid desiccation of sapropel.

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References

Bakšienė E. (1996). Karbonatinio sapropelio efektyvumas velėniniame jauriniame priesmėlio dirvožemyje, *Žemės ūkio mokslai*, Nr. 4, p. 3–8.
Basalykas A. et al. (1958). Lietuvos TSR fizinė geografija, Vilnius, t. 1.
Björk S. (1972). Swedish Lake Restoration Program Gets Results, *Ambio*, Vol. 1, p. 153–165.
Björk S. (1985). Lake Restoration Techniques. *Proceedings of the International Congress on Lake Pollution and Recovery/*European Water Polution Control Association, Rome, p. 281–291.
Ciūnys A., Lazauskienė L., Katkevičius L. (1994). Sapropelis – mūsų lobis, Vilnius, 65 p.
Christensen M. S. (1985). Influence of Fish Pond Sediments on Yields of Maize and Bean (*Phaseolus* A*ureus*), Trop. Agr., No. 2, p. 115–120.
Edmondson W. T., Lehman J. T. (1981). The Effect of Changes in the Nutrient Income on the Condition of Lake Washington. *Limnol. Oceanogr*., Vol. 26, p. 1–29.
Forsberg C. (1985). Lake Recovery in Sweden. *Proceedings of the International Congress on Lake Pollution and Recovery/*European Water Pollution Control Association, Rome, p. 352–361.
Katkevičius L., Ciūnys A., Bakšienė E. (1998). Ežerų sapropelis žemės ūkiui, 92 p.
Korschens M. et al. (1984). Einsatz von Seeschlamm auf humusverarmten Sandstandorten Agra – Buch, Leipzig, s. 23.
Linčius A. (1997). Sapropelis ir jo perspektyvos, *Geografijos metraštis*, t. 15, p. 103–112.
Liužinas R., Jankevičius K. (2005). Atgaivinkime ežerus, *Mokslas ir gyvenimas*, Nr. 12, p. 28–32.
Liužinas R., Jankevičius K., Šalkauskas M., Šlapkauskaitė G. (2004). Role of Biological Accreations for Water Treatment. *Intern. Scientific Conference 'Protection and Management of Water Bodies'*, *Proceedings*, p. 125–131.
Ripl W. (1976). Biochemical Oxidation of Polluted Lake Sediment with Nitrate – A New Lake Restoration Method, *Ambio*, Vol. 5, p. 132–135.
Standard Methods for Examination of Water and Wastewater (1992), Washington, USA.
Tarybų Lietuvos enciklopedija (1987), Vilnius, t. 3.
Бракш Н. А. (1971). Сапропелевые отложения и пути их использования, Riga: Zinatne, 258 с.
Виръясов Г., Иванова Л. et al. (1997). Основные направления использования сапропеля. *Intern. Scientific Conference 'Improvement of Natural Lakes and Artificial Wwater Reservoir'*, *Proceedings*, Kaunas, p. 66–69.
Жукова С. В., Одинцова Е. Н. (1967). Докл. АН СССР, т. 172, № 3, с. 706–708.
Звягинцев Д. Г. (ред.) (1991) Методы почвенной микробиологии и биохимии, Москва Наука.
Флора Балтийских республик – Flora of the Baltic countries (1993–2003). *Сводка сосудистых растений – Compendium of vascular plants*. Tartu, т. 1–3.
Лопотко М. З., Евдокимова Г. А. (1986). Сапропели и продукты на их основе, Минск, 192 с.
Лопотко М. З., Евдокимова Г. А., Кузмицкий П. Л. (1992). Сапропели в сельском хозяйстве, Минск, 215 с.
Малашкайте Б. С. (1962) Ефективность скармливания сапропеля и микроэлементов при откорме свиней. *Тр. Сведловского сельскохозяйственного ин-та*, Сведловск, т. 10, с. 319–328.
Потапова П. Н., Куприн П. Л., Фролова Л. В. (1980). Определение углерода органического вещества в донных отложениях. *Методы исследования органического вещества в донных осадках*, Москва, 250 с.
Топачевский А. В. (1975). Экстрагирование и количественное определение липидов. *Методы физиолого-биохимического исследования водорослей в гидробиологческой практике*, 145 с.

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Ežerų sapropelio kokybės gerinimas: naujas metodas

Santrauka

Poveikį bei žalą ekosistemoms sukelia ne tik žmogaus veikla, bet ir gamtinės priežastys. Tokios ekosistemos, patiriančios gamtos poveikį, pavyzdžiu yra ežeras. Jame vyksta dumblodaros procesai. Dumblas (sapropelis) yra struktūra, kuri susiformuoja iš autochtoninių ir alochtoninių organinių ir mineralinių medžiagų, vykstant jų biodestrukcijai, humifikacijai ir struktūrizacijai. Renovuojant – atgaivinant ežerus, sapropelis yra išsiurbiamas arba iškasamas. Sapropelis tinka ne tik dirvožemiams tręšti, bet yra vertinga žaliava chemijos pramonei. Tačiau sapropeliui kaip trąšai nepageidautini joje esantys geležies (Fe_2O_3 sapropelyje yra 2,3–8,3%), aliuminio (Al_2O – 1,1–3,9%), silicio (SiO_2 – 6,8–36,2%) oksidai. Jie sudaro gelius – koloidinius tirpalus. Dėl to sapropelius sunku išdžiovinti. Juose esantys katijonai ir anijonai jungiasi į nelabai tirpias druskas, todėl jų nedaug patenka į augalus. Bandymais nustatyta, kad sapropelio kokybė yra pagerinama, kai į sutankėjusią sapropelio pulpą, transportuotą į sėsdintuvus, pasodinama paprastoji nendrė (*Phragmites australis*). Sodinama šakniastiebiais (4 sodm./m^2). Nendrių šakniastiebiai ir šaknys išskiria H^+ jonus bei organines rūgštis, kurios atpalaiduoja tvirtai su humusinėmis medžiagomis susijungusius katijonus ir anijonus, pagerina jų prieinamumą žemės ūkio kultūroms, kurios tręšiamos sapropeliu. Dar geriau, kai tręšimo reikalams gaminamas sapropelio ir nendrės biomasės kompostas. Yra dar kitas nendrių privalumas. Jos, augdamos sapropelio pulpoje, dėl transpiracijos keleriopai paspartina sapropelio džiovinimą.

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IMPROVEMENT OF LAKE SAPROPEL QUALITY: A NEW METHOD

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Introduction

Seeking to satisfy its needs, modern society is developing different kinds of industrial production. The intensive economic activity in the past and present is responsible for the ever-increasing environmental pollution. Not only human activities but nature itself affects ecosystems. Lakes may serve as an example of ecosystems affected by natural factors. Mud formation processes are taking place in them. The shores of lakes overgrow with higher plants-macrophytes. As the lakes grow shallow, macrophytes tend to penetrate into their deeper parts occupying new areas. Slowly such lakes convert into fens and, later, into high moors. Lakes are aging and declining. These processes are especially typical in case of small lakes. In Lithuania there is about 1 billion m^3 of pure sapropel which lays mostly in 1 to 2 m thick layers but in some places layers are up to 5 m, and there is about 6 billion m^3 of sapropel in mixture with other sediments (Tarybų…, 1987). About 4.5 bill m^3 of sapropel underlie the peat layer of lacustrine swamps. The now cleaned silted up lakes (a few hundred) have accumulated 1.5 billion m^3 of sapropel.

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2. Results

Lithuania is a country of the Baltic basin. Its area is 65 200 km^2. It has 4000 lakes and is called "a country of lakes". One of the European lake-abundant zones coinciding with the glacier margin of the last Ice Age runs across Lithuania.

Peat, silt and sapropel are valuable lake products. Sapropel is composed of sediments (Liužinas, Jankevičius, 2005). Sediments are of double origin: autochthonous and allochthonous. The autochthonous sediments are composed of dead phyto- and zooplankton and, at the end of the vegetation period, of macrophytes (Liužinas et al., 2004). This category of sediments also includes the material of coastal erosion. Allochthonous sediments are composed of drift from external drained basins and material transported by streams, rivers and airflows. Pollution of the territories of farmlands, animal-breeding farms, settlements and industrial objects increases the load of allochthonous material on lakes.

Sedimentation rates in lakes with different nutrient income are varying from a few to a few tens of centimetres.

Mineral, organic or intermediate types of sediments prevail in different lakes. Organic sediments tend to accumulate in lakes with high nutrient income. They form an unstructured mud composed of remains of plankton and benthic organisms with some mineral components. The term sapropel is applied to this kind of mud.

2.1. Chemical composition of sapropel

According to its chemical composition, sapropel can be organic, calcareous, siliceous, and mixed (organic–calcareous and organic–siliceous).

The quantitative chemical composition of sapropel varies within a wide range depending on maturity, lying depth and formation conditions. The data on chemical composition of examined sapropel are given in Table 1.

Table 1. Chemical indices of sapropel samples.

Nitrogen (N), %	Phosphorus (P_2O_5), %	Organic carbon, %	Soluble hydrocarbons, %	Summary fraction of lipids, %
0.2–2	0.1–0.2	9–35	0.4–4	0.3–2

The highest concentrations of nitrogen occur in the organic sapropel. High concentrations of phosphorus occur in organic and organic–calcareous sapropel.

Humic acids in sapropel account for about 11–38%, fulvic acids for 2–23% and unhydrolized remains for 5–22% (Бракш, 1971; Лопотко, Евдокимова, 1986). The composition of trace elements in sapropel is demonstrated in Table 2.

Table 2. Concentrations of trace elements in sapropel, mg/kg.

Li	B	Mn	Ti	V	Cr	Co	Ni	Cu	Zn	Pb	Mo	Sr	Cd
6–15	24–53	280–660	1000–2400	11–35	9–25	3–5	9–27	12–63	29–120	7–31	1–3	48–130	2–4

Trace elements are very important for biological effects. They (30 of them) are indispensable for normal vital activity of plant and animal organisms. For example, copper (Cu) is included in the composition of important respiratory enzymes, zinc (Zn) is a constituent of many enzymes (carboanhydrase, carboxypeptidase, different dehydrogenases) and molybdenum (Mo) is included in the active centre of nitratreductase. The concentrations of trace elements determined in sapropel do not exceed the permissible general hygienic values and limit values for phytotoxines. The value of sapropel depends on the content of physiologically active substances – vitamins and amino acids. We examined the content of these substances in different kinds of sapropel (Tables 3 and 4).

Table 3. Concentrations of some vitamins in sapropel, µg/kg.

Inosite	Biotin (H)	Thiamine (B_1)	Pantothene acid (B_3)	Pyridoxine (B_6)	Nicotinic acid (PP)	Para-amine benzoic acid	Vitamin B_{12}
7500–45000	0.6–26	3.3–136	1200–16000	3.1–54	700–11000	1.7–66	3.5–73

Vitamins play an important role in metabolism and other vital functions. The content of vitamins in sapropel considerably exceeds the values found in the soils of medium fertility: inosite, thiamine (B_1) and pantothenic acid (B_3) by 14 times, biotin (H) by 12 times, pyridoxine (B_6) and nicotinic acid (PP) by 4 times, and para-amine benzoic acid and vitamin B_{12} even by 25 times.

Amino acids are characterized by high physiological activity. They participate in protein synthesis and as a starting material in the synthesis of hormones, coenzymes and pigments. Especially important are essential amino acids lysin, hystidin, arginine, threonine, valine, methionine, leucyne, isoleucyne, phenylalanine, and tryptophan. Animal organism is unable to synthesize them. It must receive them with food. It is a virtue of sapropel that it contains high concentrations of essential amino acids (48–60% of the total amount of aminoacids).

Table 4. Free amino acids and their content in sapropel, mg/100g.

Cystine	Lysin	Hystidin	Arginine	Aspartic acid	Serine	Threonine
0.001–0.7	0.1–0.5	0.1–0.4	0.2–0.7	1.1–1.6	1.0–1.1	traces

Glutamic acid	Alanine	Tyrosine +Tryptophan	Methionine	Valine +Phenylalanine	Leucyne +Isoleucyne
0.7–0.8	1.4–1.7	1.3–1.8	0.9–1.1	0.9–1.9	1.6–2.3

2.2. Practical use of sapropel

The results of ecogeochemical evaluation of sapropel and physiological active substances detected in it, revealed a possibility to use it for improvement of agrochemical and physical properties of soils. A positive influence of sapropel on yields of various cultures has been reported in many research papers (Bakšienė, 1996; Christensen, 1985; Korschens et al., 1984).

Latvian, Polish, Belarusian, Russian, and German researchers investigate various possible methods of soil fertilization with sapropel and its optimal amounts for different cultural plants. The effect of sapropel on yields of plants depends on its chemical composition, the methods of its processing for fertilization, type of fertilized soil, soil productivity, and culture.

Taking into consideration that sapropel abounds in physiologically active substances (vitamins, amino acids, etc.), it is investigated for suitability as fodder supplement. Investigations of this kind are carried out in Lithuania (Малашкайте, 1962) and Belarus (Лопотко, Евдокимова, Кузмицкий, 1992). Fodder supplements made of sapropel are produced as granules, briquettes or powder. It is experimentally proved that sapropel granules increase the value of combined fodder enriching it in mineral macro- and microelements.

It is known that sapropel can be used for mud therapy (Виръясов, Иванова et al., 1997). Organic sapropel is rich in bioactive substances and is highly colloidal. These properties account for its hydrophilic capacity, high thermal recipience and ability to retain heat for a long time. The use of sapropel as curative mud mixed with peat or combined with aromatic officinal plant extracts is rather promising.

Detailed examination of sapropel lipids revealed that they resemble wax in their chemical composition. They contain compound ethers, hydrocarbons, cyclic and aliphatic alcohols, acids, į- and ā- unsaturated carbonylic and other compounds. The content of lipids in sapropel is rather high and their extraction could be profitable. The sapropel lipids can be used in cosmetic and pharmaceutical industries.

Technologists of production of new materials are also interested in sapropel. It was tested as an additive facilitating formation of pores in the raw material used for production of poriferous stone wear. Sapropel containing low content of ash (when ash do not exceed 30% of its dry weight) is tested as an adhesive able to replace combinations of glues. Algal-zoogenic sapropels are best fit for this purpose. Peat sapropels do not have adhesive properties.

A possibility to use a combination of sapropel with perlite in the production of insulation materials has been worked out (Виръясов, Иванова et al., 1997).

The spectrum of sapropel utilization is rather wide. Sapropel is a valuable raw material. At present, sapropel is used as a fertilizer for improvement physical and chemical properties of soils and for increase of yields. Therefore, it is expedient to investigate its specific properties.

Sapropel is a colloidal formation. Organic colloids are able to absorb much water; 90% and more. It hardly vaporizes water and becomes very solid after drying. Due to its structure, sapropel is distinguished by low filtration capacity.

Sapropel contains much iron and aluminium oxides. Ash of different types of sapropel contains 2.3–8.3% of iron (Fe_2O_3), 1.1–3.9% aluminium (Al_2O) and 6.8–36 % of silicon (SiO_2) (Katkevičius, Ciūnys, Bakšienė, 1998). Iron and aluminium oxides form gels in sapropel. They are colloids in a more solid form than a solution. Gels are friable and elastic. Friable gels do not swell. They (iron gel, aluminium gel and silica gel) retain their form and volume when drying. These properties are characteristic of some kinds of sapropel containing greater amounts of Fe, Al and Si.

Phosphorus (P) is an important element for plant growing. A plant assimilates phosphorus in the form of phosphates (PO_4^{2-}). Phosphorus participates in many essential reactions of metabolism and energy exchange. Iron ions combine phosphates of sapropel and fertilized soil into poorly soluble or insoluble salts. $FePO_4$ is a product of this reaction.

When using sapropel as a fertilizer we must bear in mind that chemical sorption can occur (combining of cations and anions into poorly soluble salts). These processes inhibit the access of ions to plants and are unwanted.

Seeking to increase the value of sapropel as a fertilizer, we tested the efficiency of sapropel blends with various organic and mineral substances (7 variants). The following

blends were prepared: 1. Sapropel + peat (1:1, 1:2, 1:3); 2. Sapropel + soil (1:5, 1:10, 1:15); 3. Sapropel + rye straw (10:1); 4. Sapropel + NPK mineral fertilizers (40 mg of each element per one kg of sapropel); 5. Sapropel + soil (1:10) + straw (10% of the sapropel mass); 6. Sapropel + soil (1:10) + straw (10% of the sapropel mass) + NPK mineral fertilizers (40 mg of each element per one kg of sapropel) and 7. Sapropel + soil (1:10) + peat (10% of the mass of blend) + straw (10% of the mass of blend) + NPK (40 mg of each element per one kg of sapropel). The efficiency of the blends was determined according to their influence on viability of cucumber ("Alfa" variety) seeds and their germination energy and on growth of test-microorganism *Escherichia coli* (in the latter case, water extracts of substrata were used).

Preliminary results showed that NPK increased the efficiency of sapropel fertilizer by 7%, NPK + straw 16% and NPK + straw + peat 20%. This is related with microorganism activity what is proved by higher reproduction rates of *Escherichia coli*. Components activating microorganism activity in sapropel increase its biological value. The obtained results encouraged us to search for simple methods of enrichment of sapropel with easily degrading organics and activation of microbiological activity facilitating the disintegration of organic material to simple mineral compounds easily accessible to cultural plants.

3. Methods of Lake Recovery (Renovation)

Lake renovation is a complicated task. A scheme of the main stages of regeneration is given in Fig.

Cleaning of silted lakes can be started after topographic, hydrogeological, hydrochemical, and comprehensive hydrobiological survey of a locality. Evaluation of environmental effects is indispensable prior to elaboration of limno-technological plan of sapropel extraction.

Sapropel extraction and lake recovery were assumed in Lithuania in 1960 (Ciūnys, Lazauskienė, Katkevičius, 1994; Linčius, 1997). At approximately the same time (a project for recovery of Trumen Lake in Sweden by elimination of sediments in 1970–1971), lakes were renovated in Sweden, Finland and other countries (Björk, 1972, 1985; Ripl, 1976; Edmondson, Lehman, 1981; Forsberg, 1985).

In Lithuania, 13 lakes were deepened by excavation of sapropel. Twenty-eight Lithuanian lakes have been so far limnologically investigated. Their limnological–technological plans were compiled. The lakes are due to be cleaned.

Lithuania has gained certain experience in sapropel excavation and lake remediation. The hydraulic sapropel excavation method is most widespread. The sapropel pulp is transported through pulp pipes to reservoirs. The reservoirs are built in impermeable rocks. They represent 120–150 m long, 60–120 m wide and up to 2.5 m deep areas encircled by dikes. The reservoirs are filled with sapropel pulp to the depth of 1.2 m.

A new method was suggested for sapropel extraction and improvement of its quality. Sapropel pulp is transported to reservoirs by pulp pipes until it forms a 30–40 cm thick layer. It is given some time for thickening. After sedimentation of pulp particles, the layer is planted with common reed (*Phragmites australis*) rhizomes (4 seedlings/m^2). Rhizomes are accommodated to high organic and mineral loads. They immediately strike roots and sprouts and act as biological absorbers. The clarified water is regularly drained away into the lake, and the reservoir is filled with a new portion of sapropel. When reeds are growing in the reservoir, the pulp layer may be 100–120 cm thick.

Advantages. Reeds speed up the evaporation of water from the reservoir (evaporation is backed up by transpiration) and drying of sapropel. The root system of reeds and rhizomes

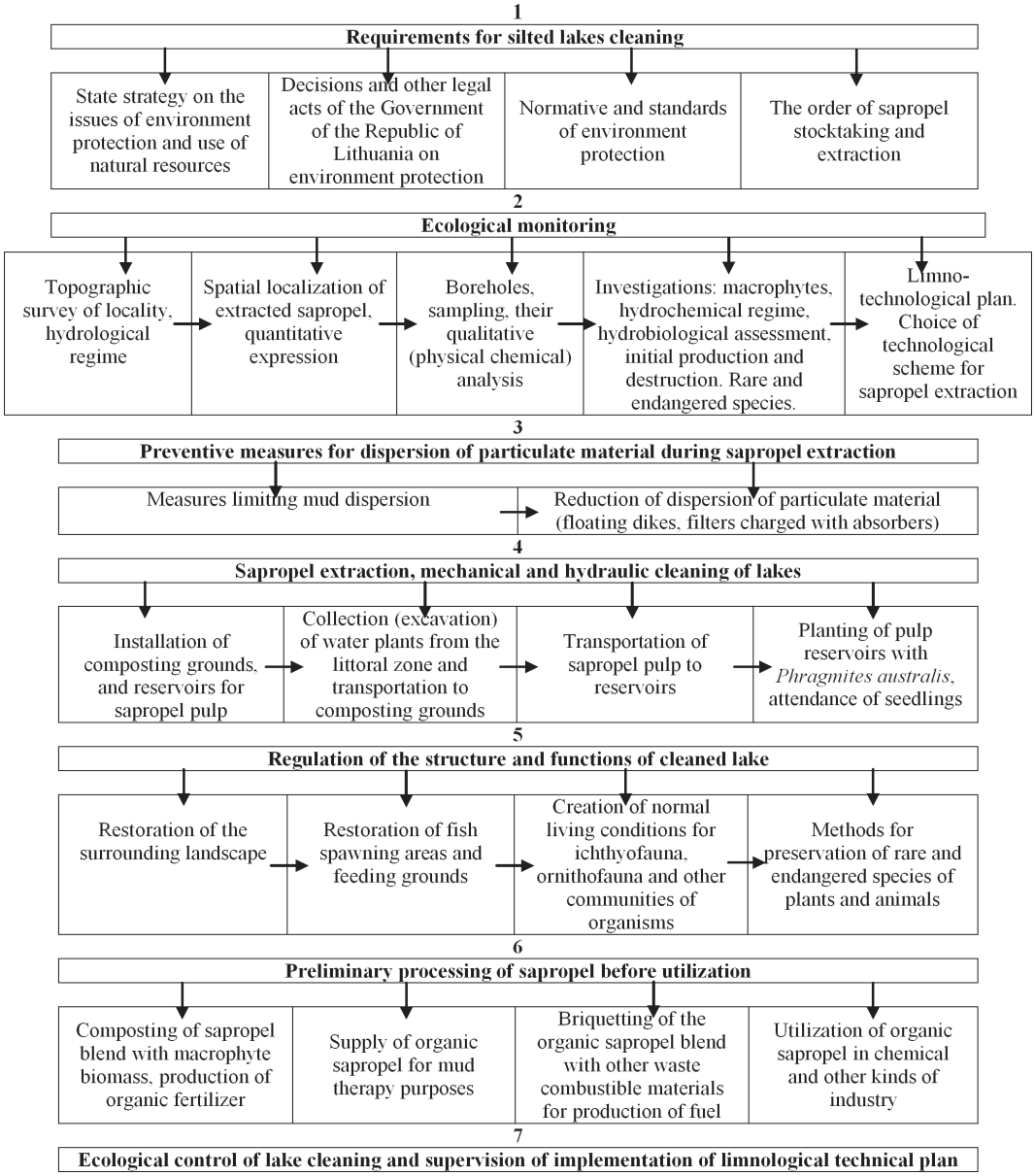

Fig. Scheme of sapropel extraction and utilization.

emit H^+ ions and organic acids. They release the cations strongly consolidated with humus (NH_4^+, Mg^+, K^+, Ca^+, etc.) and anions (NO_3^-, PO_4^{3-}, HPO_4^{2-}, SO_4^{2-}, etc.) making them easily available to plants. After blending with reed roots, rhizomes and plant biomass, sapropel is composted and converted into a high quality marketable (in the country and abroad) organic–mineral fertilizer.

Conclusions

Lakes are a great national treasure (fresh water source can be used for hydroenergy production, recreation, fishery, etc.). Yet lakes tend to age, bog up and disappear. Therefore, they have to be renovated (remediated) by elimination of mud (sapropel). Sapropel is a valuable natural raw material. It abounds in biogenic elements, physiologically active substances (vitamins and amino acids) and lipids. The spectrum of sapropel utilization is wide. It is especially fit

for soil fertilization. In order to optimize utilization of sapropel as a fertilizer, we sought for measures facilitating the concentration of free cations and anions in it. We showed that the water plant *Phragmites australis*, which is planted on the thickened sapropel pulp, emit H^+ ions and organic acids by rhizomes and roots releasing the elements necessary for growth of cultural plants. Moreover, transpiration by leaves and stems of *Phragmites australis* facilitates rapid desiccation of sapropel.

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References

Bakšienė E. (1996). Karbonatinio sapropelio efektyvumas velėniniame jauriniame priesmėlio dirvožemyje, *Žemės ūkio mokslai*, Nr. 4, p. 3–8.
Basalykas A. et al. (1958). Lietuvos TSR fizinė geografija, Vilnius, t. 1.
Björk S. (1972). Swedish Lake Restoration Program Gets Results, *Ambio*, Vol. 1, p. 153–165.
Björk S. (1985). Lake Restoration Techniques. *Proceedings of the International Congress on Lake Pollution and Recovery/*European Water Polution Control Association, Rome, p. 281–291.
Ciūnys A., Lazauskienė L., Katkevičius L. (1994). Sapropelis – mūsų lobis, Vilnius, 65 p.
Christensen M. S. (1985). Influence of Fish Pond Sediments on Yields of Maize and Bean (*Phaseolus* A*ureus*), Trop. Agr., No. 2, p. 115–120.
Edmondson W. T., Lehman J. T. (1981). The Effect of Changes in the Nutrient Income on the Condition of Lake Washington. *Limnol. Oceanogr*., Vol. 26, p. 1–29.
Forsberg C. (1985). Lake Recovery in Sweden. *Proceedings of the International Congress on Lake Pollution and Recovery/*European Water Pollution Control Association, Rome, p. 352–361.
Katkevičius L., Ciūnys A., Bakšienė E. (1998). Ežerų sapropelis žemės ūkiui, 92 p.
Korschens M. et al. (1984). Einsatz von Seeschlamm auf humusverarmten Sandstandorten Agra – Buch, Leipzig, s. 23.
Linčius A. (1997). Sapropelis ir jo perspektyvos, *Geografijos metraštis*, t. 15, p. 103–112.
Liužinas R., Jankevičius K. (2005). Atgaivinkime ežerus, *Mokslas ir gyvenimas*, Nr. 12, p. 28–32.
Liužinas R., Jankevičius K., Šalkauskas M., Šlapkauskaitė G. (2004). Role of Biological Accreations for Water Treatment. *Intern. Scientific Conference 'Protection and Management of Water Bodies'*, *Proceedings*, p. 125–131.
Ripl W. (1976). Biochemical Oxidation of Polluted Lake Sediment with Nitrate – A New Lake Restoration Method, *Ambio*, Vol. 5, p. 132–135.
Standard Methods for Examination of Water and Wastewater (1992), Washington, USA.
Tarybų Lietuvos enciklopedija (1987), Vilnius, t. 3.
Бракш Н. А. (1971). Сапропелевые отложения и пути их использования, Riga: Zinatne, 258 с.
Виръясов Г., Иванова Л. et al. (1997). Основные направления использования сапропеля. *Intern. Scientific Conference 'Improvement of Natural Lakes and Artificial Wwater Reservoir'*, *Proceedings*, Kaunas, p. 66–69.
Жукова С. В., Одинцова Е. Н. (1967). Докл. АН СССР, т. 172, № 3, с. 706–708.
Звягинцев Д. Г. (ред.) (1991) Методы почвенной микробиологии и биохимии, Москва Наука.
Флора Балтийских республик – Flora of the Baltic countries (1993–2003). *Сводка сосудистых растений – Compendium of vascular plants*. Tartu, т. 1–3.
Лопотко М. З., Евдокимова Г. А. (1986). Сапропели и продукты на их основе, Минск, 192 с.
Лопотко М. З., Евдокимова Г. А., Кузмицкий П. Л. (1992). Сапропели в сельском хозяйстве, Минск, 215 с.
Малашкайте Б. С. (1962) Ефективность скармливания сапропеля и микроэлементов при откорме свиней. *Тр. Сведловского сельскохозяйственного ин-та*, Сведловск, т. 10, с. 319–328.
Потапова П. Н., Куприн П. Л., Фролова Л. В. (1980). Определение углерода органического вещества в донных отложениях. *Методы исследования органического вещества в донных осадках*, Москва, 250 с.
Топачевский А. В. (1975). Экстрагирование и количественное определение липидов. *Методы физиолого-биохимического исследования водорослей в гидробиологческой практике*, 145 с.

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Ežerų sapropelio kokybės gerinimas: naujas metodas

Santrauka

Poveikį bei žalą ekosistemoms sukelia ne tik žmogaus veikla, bet ir gamtinės priežastys. Tokios ekosistemos, patiriančios gamtos poveikį, pavyzdžiu yra ežeras. Jame vyksta dumblodaros procesai. Dumblas (sapropelis) yra struktūra, kuri susiformuoja iš autochtoninių ir alochtoninių organinių ir mineralinių medžiagų, vykstant jų biodestrukcijai, humifikacijai ir struktūrizacijai. Renovuojant – atgaivinant ežerus, sapropelis yra išsiurbiamas arba iškasamas. Sapropelis tinka ne tik dirvožemiams tręšti, bet yra vertinga žaliava chemijos pramonei. Tačiau sapropeliui kaip trąšai nepageidautini joje esantys geležies (Fe_2O_3 sapropelyje yra 2,3–8,3%), aliuminio (Al_2O – 1,1–3,9%), silicio (SiO_2 – 6,8–36,2%) oksidai. Jie sudaro gelius – koloidinius tirpalus. Dėl to sapropelius sunku išdžiovinti. Juose esantys katijonai ir anijonai jungiasi į nelabai tirpias druskas, todėl jų nedaug patenka į augalus. Bandymais nustatyta, kad sapropelio kokybė yra pagerinama, kai į sutankėjusią sapropelio pulpą, transportuotą į sėsdintuvus, pasodinama paprastoji nendrė (*Phragmites australis*). Sodinama šakniastiebiais (4 sodm./m^2). Nendrių šakniastiebiai ir šaknys išskiria H^+ jonus bei organines rūgštis, kurios atpalaiduoja tvirtai su humusinėmis medžiagomis susijungusius katijonus ir anijonus, pagerina jų prieinamumą žemės ūkio kultūroms, kurios tręšiamos sapropeliu. Dar geriau, kai tręšimo reikalams gaminamas sapropelio ir nendrės biomasės kompostas. Yra dar kitas nendrių privalumas. Jos, augdamos sapropelio pulpoje, dėl transpiracijos keleriopai paspartina sapropelio džiovinimą.

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DISCUSSION ON RELIABLE PHENOLOGICAL OBSERVATIONS AS A PRECONDITION FOR SEASONAL AND CLIMATOLOGICAL HYDROMETEOROLOGICAL FORECASTS

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Introduction

Rudiments of phenology appeared in high antiquity when people began to memorize the recurring natural phenomena and associate them with other ones, e.g., with the weather and change of climate elements. There are proverbs and sayings in folklore, which are actually, long- or short-term or even seasonal weather forecasts. The science of phenology has derived from the juncture of meteorology, biology and geography. Namely in the junction of various sciences the greatest discoveries were made in the last fifty years.

The father of Lithuanian phenology Stasys Nacevičius started regular observations of natural seasonal phenomena in Dotnuva (Middle Lithuania) in the first half of the 20th century. He also created a network of phenological observations operating within a unified programme, affiliated and exchanged information with the European Centre of Phenological Observations in London.

After World War II, many Lithuanian agrometeorologists, climatologists, foresters and dendrologists developed the general and applied phenology (Taikomoji…, 1983) based on S. Nacevičius' scientific heritage. Yet his attempts to use the data of phenological observations for seasonal weather forecast have remained unappreciated. This is worth mentioning as meteorologists have not yet developed reliable methods for a longer than 5–7 days weather forecast.

After the restoration of Lithuania's independence, phenology is on the decline. The number of observation stations has reduced considerably. The data of the remaining stations is not systematized and inaccessible to specialists of related sciences and students due to interdepartmental barriers. The newly established Society of Phenologists make every effort to develop an amateur network of observations (mostly in schools). Yet it will take some time before the data collected is used for serious scientific purposes.

The present work is based on a limited and far from newest observation data. It is designed for attracting attention of Lithuanian scientific structures to this branch of science. It is necessary to allocate sufficient means for phenological observations and to create a legal basis for use of phenological observation data by scientific research.

1. Data and Methodology

Phenological indicators of different seasons and their stages as well as data of phenological observations in different regions of Lithuania were obtained from the earlier published works on phenology (Nacevičius, 1975; Kulienė, Tomkus, 1990) and from the Lithuanian Hydrometeorological Service. They are far from being sufficient for exhaustive explanation of correlation between phenological and cosmological as well as hydrometeorological parameters but they can show promising results in this field of neighbouring sciences if the necessary steps are taken. The long-term data on solar activity (Wolf indices) are taken from the open files of the Zűrich Observatory in Internet.

From the phenological and phenoclimatic point of view, the seasons are sub-divided into stages mostly based on S. Nacevičius' scheme (it is not perfect in terms of terminology). Table presents the stages of seasons and phenoindicators marking their beginning.

Table. Stages of seasons and phenoindicators marking their beginning (according to S. Nacevičius and others).

Season	Stage I	Stage II	Stage III
Spring	Early spring European filbert, grey alder and coltsfoot come into bloom	Spring proper Goat willow come into bloom	Late spring Bird cherry come into leaf
Summer	Early summer Peony come into bloom	Midsummer	Late summer
Autumn	Golden fall Yellow leaves	Leaf fall Trees shed leaves	Prewinter time Bare trees
Winter	Early winter Ponds freeze over	Winter proper Rivers freeze over	Prespring time Snow melts

2. Main Phenological Parameters Applicable for Hydrometeorological Forecasts

It is already possible to distinguish the trends of the employment of phenological data for seasonal weather forecasts. First, based on the long-term pattern of phenoindicators of early spring (for example, coltsfoot coming into bloom in Dotnuva in 1961–1991) it is possible to predict an approximate date of the beginning of vegetation period for a few coming years (Fig. 1). It is known that the beginning of vegetation period in Lithuania varies considerably – from the end of January until the beginning of April. However, even the knowledge of the beginning of vegetation period (late, proper or late spring) can be of practical use for not only farmers but also for foresters, beekeepers, resort researchers, and managers of tourism industry. European filbert (*Corylus avellana* = *c*), grey alder (*Alnus incana* = *a*) and coltsfoot (*Tussilago farfara* = *t*) are early spring phenoindicators whose blooming approximately coincides with the beginning of vegetation. Thus, observations of their (or at least one of them) blooming time may be of use. The sequence of coming into bloom of these phenoindicators is especially interesting and important. The term **interception** has been applied to derangement of a long-term (dominant) sequence of vegetative events of matching phenoindicators. However, for convenience the term should be applied to vegetative combinations (variation of the date of their vegetative condition) of any phenoindicators the more because any dominant combination tends to change in the course of time. It is useful to know the combinations of not only phenoindicators but zooindicators as well, for example the dates of return of cuckoos and swallows.

European filberts, grey alders and coltsfoot come into bloom almost at the same time in Lithuania but following a certain sequence. In springs when southern air mass transport is dominant, these phenoindicators come into bloom in the same sequence as in the Ukraine. European filberts are first to come into bloom. Grey alder and coltsfoot follow them. The first letters of the Latin names of these plants can write the following interception: *c-a-t*. When eastern continental air masses are more frequent in spring, the sequence of coming into bloom of these plants is different: *t-a-c* (it is typical of the middle part of European Russia). When at the end of winter the humid air mass from the North Atlantic visits Lithuania more frequently, the blooming sequence of the mentioned spring indicators is *a-c-t*. *A-t-c* interception characteristic of the Bay of Finland occurs under dominant northern winds. Other kinds of interceptions may occur in Lithuania (*c-t-a* and *t-c-a*) under the conditions of mixed flows of unstable atmospheric circulation. Analysis of the links between these interceptions and hydrometeorological conditions can be promising for weather forecasts

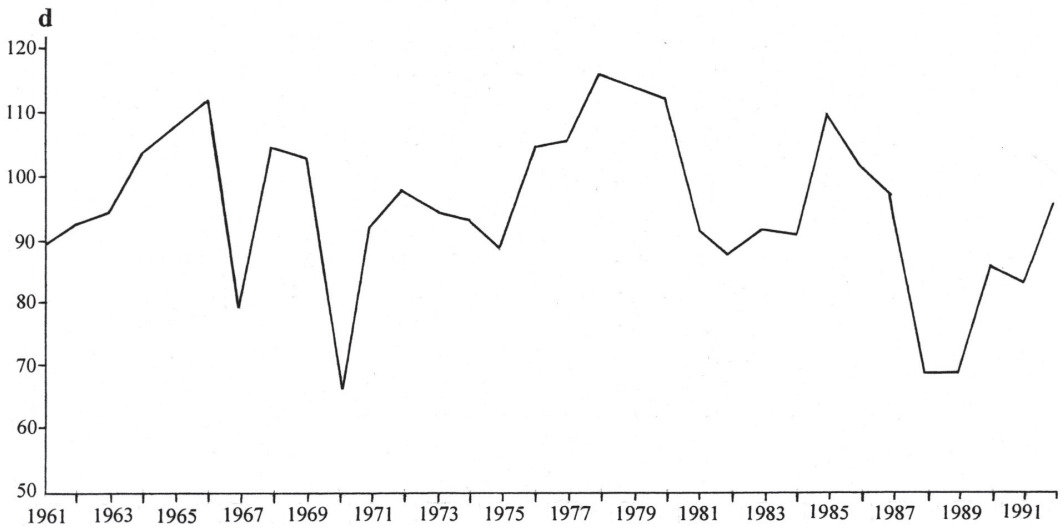

Fig. 1. Coltsfoot (*Tussilago farfara*) coming into bloom in Dotnuva 1961–1991.

for the rest of the season, summer and autumn. S. Nacevičius envisaged other important interceptions for weather forecast: combinations of coming into bloom of lilacs (*Syringa vulgaris*) and rowans (*Sorbus aucuparia*), as well as bird cherries (*Prunus padus*) and sour cherries (*Prunus cerasus*).

Based on interceptions and relations of different phases of phenoindicators with some cosmogenic (solar activity) and hydrometeorological phenomena as well as with the time-scale of agrotechnical works, S. Nacevičius made an attempt to predict frosts, probability and time of pests and optimal time-scales for various farming works. Unfortunately, no detailed description of his research, deeper analysis of the interaction between different factors or methods has been preserved. We have only conclusions and bare statements. His research was based on the data for 1922–1947. We know that the cycles of natural phenomena and their relations with cosmogenic driving forces may vary depending on the long-term variation stage of cosmogenic factors, for example on the cycles of solar activity (Дорман и др., 1987). Cycles of solar activity lasting for 200, 100, 22, and 11 years have been determined. In their different phases (e.g., increase or decline of amount of sunspots within the cycle, running number of 11 years cycle), the links between manifestations of nature cycles may markedly vary (this was not known in the times of S. Nacevičius).

3. Correlation between Phenological Parameters, Solar Activity and Seasonal Weather Conditions

S. Nacevičius determined the weather conditions during the vegetation period depending on the type of interception marking the beginning of spring. According to his data, *c-a-t* interception is dominant in Lithuania, i.e. spring is brought by southern flows. The year of this type of interception is expressive (S. Nacevičius' term), i.e. early. This means that not only spring is early but other phenological seasons as well. The probability of frosts in the third stage of early spring is low. Moreover, summer is warm and autumn is favourable for farm works.

The interception *a-c-t* shows the influence of the Atlantic Ocean. From the point of view of weather forecast, the spring of this type is unreliable as the year may either be depressive (late) or expressive and even mixed because some seasons may be early and others late. In such years, the north wrestles with the south. Spring drags on, summer is not

very warm, sometimes even cool and rainy, and autumn varies. Detailed investigations of a longer sequence of years, perhaps, could help to determine some additional indices for forecasting.

When in spring Lithuania is under the influence of Eurasia, the phenoindicators come into bloom in the following order: *t-a-c*. All spring stages are late, the third one passing without frosts and as if in a rush. Summer comes on time. It is marked by continental hot weather conditions. Autumn is favourable for farm work.

The *a-t-c* interception is not very promising to farmers. It occurs in the Bay of Finland-type of year under the influence of northern flows. Spring is late, summer unstable (combat between the south and the north), and autumn is unfavourable for farmers.

The spring of the *c-t-a* type heralds a depressive year. Yet there are no frosts in spring proper and autumn is favourable for farm work.

Nacevičius noticed that the stability of the prognostic features of interceptions depends on the peculiarities of the cycles of solar activity. In years of maximum number of sunspots and high solar activity, the atmosphere is more susceptible to changes. The typical of interceptions weather conditions usually occur two years before the maximal solar activity and two years after the minimal solar activity, i.e. in the phases of increasing and decreasing solar activity. The probability of cold winters increases, when the number of sunspots is reducing. Winters are warm a few years after the minimal number of sunspots. Comprehensive investigations are necessary for specification of prognostic features of interceptions.

There is a distinct link between the long-term pattern of coming into bloom of the mentioned phenoindicators and cycles of solar activity (Fig. 2).

Astronomers can predict the cycles of solar activity rather precisely. Based on the link between phenoindicators and solar activity, it is possible to forecast the trend of the beginning of spring (early, late and normal) within one cycle. The links get disturbed when the cycle is changing.

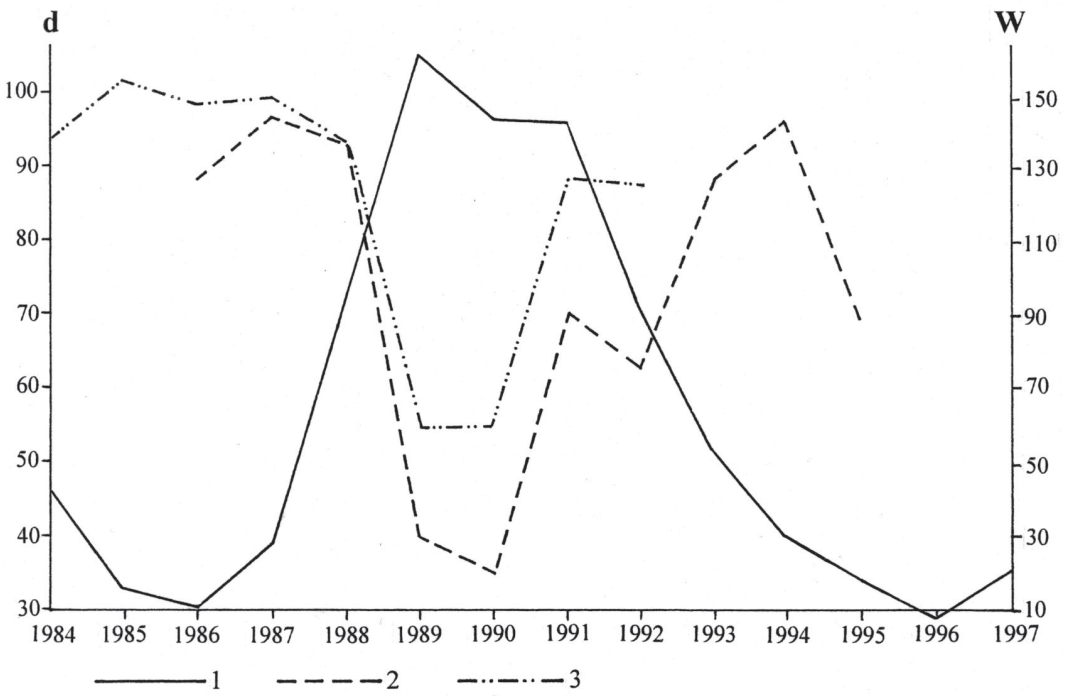

Fig. 2. Long-term pattern of phenoindicators and solar activity in Dotnuva: 1 – solar activity, 2 – grey alder, 3 – coltsfoot.

Attempts already have been made to relate the cycles of phenoindicators and solar activity with air temperature, precipitation, depth of freeze and other hydrometeorological dimensions (Schwartz, 1990). Methods of accurate hydrometeorological forecasts require comprehensive research based on reliable long-term hydrometeorological and phenological observations.

4. Reliable Phenological Data is a Prerequisite of Hydrometeorological Forecast

The Hydrometeorological Service has a fair network of observation stations supplied with modern equipment, qualified observers and own metrological survey. There is no reason to doubt the reliability of hydrometeorological data. The data is accessible to scientists and students. Unfortunately, this is not true about phenological observations. The data is scattered at different departments. Means and specialists are lacking for their generalization and systematization. The data is almost inaccessible to scientists and students who are unable to buy them. This order is a great disadvantage to the science of phenology, its practical application in particular. It is not expedient to use the amateur data because they are unreliable and may discredit good ideas (e.g. the method of interception). The incorrect data (a mistake of a few days suffices) of coming into bloom of phenoindicators change the interception. The seasonal forecast based on these data loses the scientific basis.

Conclusions

The phenological knowledge has been applied in agriculture, forestry and environmental science since long ago. For almost a hundred years, the long-term successions of phenological data sets have been an object of investigation of joint sciences. The present rather superficial analysis is designed to encourage seasonal hydrometeorological and long-term climatological forecasts based on phenoindicators, solar activity and hydrometeorological indices. This requires restoration of the network of phenological observations and accessibility of the data to scientists interested in the development of theoretical and applied phenology.

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References

Kulienė L., Tomkus J. (1990). Bendroji fenologija, Vilnius.
Nacevičius S. (1975). Taikomoji fenologija, Vilnius.
Schwartz M. D. (1990). Detecting the Onset of Spring: a Possible Application of Phenological Models, *Climate Research*, Vol. 1, p. 23–29.
Taikomoji fenologija Lietuvoje: Straipsnių rinkinys (1983), Vilnius.
Дорман Л. И. и др. (1987). Связь космических и геофизических параметров в 19-20-м циклах солнечной активности, *Геомагнетизм и аэрономия*, т. 27, 2, Москва.

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Patikimi fenologiniai stebėjimai – prielaida sezoninei ir daugiametei hidrometeorologinei prognozei

Santrauka

Vien paprastas pavasario fenoindikatorių daugiametės eigos palyginimas su Saulės aktyvumo cikliškumu rodo, kad tarp jų egzistuoja neabejotinas ryšys. Praėjusio amžiaus viduryje į tai dėmesį atkreipė Lietuvos fenologijos tėvu vadinamas Stasys Nacevičius. Daugiausia dėmesio jis kreipė ankstyvojo pavasario fenoindikatorių intercepcijos – jų vyksmo tarpusavio eiliškumo – apraiškoms, jų ryšiui su tų metų vegetacijos laikotarpio ypatumais. Fenoindikatorių daugiametės kaitos ir Saulės aktyvumo cikliškumo koreliacijos pagrindu galima (kol kas kokybiškai) prognozuoti artimiausio dešimtmečio oro temperatūros, kritulių kiekio, sniegingumo, gal ir kitų klimato elementų vidutinius metinius ir sezonų rodiklius. Praėjus daugiau kaip pusei amžiaus atsirado naujų galimybių išplėtoti fenologijos taikymą hidrometeorologijoje, žemės ir miškų ūkyje, kurortologijoje ir kitur, juolab kad plečiasi ir astronomų žinios apie Saulės aktyvumą bei kitus heliogeofizinius veiksnius. Tačiau galimybės fenologijos mokslo plėtrai Lietuvoje prastėja: labai sumažėjo stebėjimo punktų tinklas, stebėjimų duomenis kaupiančios žinybos nepajėgia jų apibendrinti, o suinteresuotiems kitų įstaigų mokslininkams ši nepaprastai įdomi ir svarbi informacija neprieinama, jos negali gauti net studentai savo kursiniams, bakalauriniams darbams.

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RECENT REGIONAL CHANGES OF DEVELOPMENT OF LITHUANIAN ECONOMY

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Introduction

Economic development of Lithuania experienced a lot of different disturbances during the last two decades. Market economy reforms, economic blockade of the Soviet Union, tremendous inflation, crisis in banking sector and most recent economic crisis in Russia have made deep impacts on whole economy of the country. However these impacts are rather obvious and do not raise a lot of questions. Much more difficult is to detect and explain inner regional effects of these disturbances. Previous researches have revealed that greatest regional differences of economical development appear during critical periods of development, when the negative impacts are very uneven. Actually more or less steady but constant growth of economy in post reform period until 2000 was evident just in capital city Vilnius and in lesser extent in Klaipėda (Burneika, 2004). All other municipalities experienced very great, mostly negative fluctuations. However the last crisis has occurred more than 5 years ago and the whole economy of Lithuania is on a steady rise. Though the development pace was one of the fastest in Europe, its inner spatial effects are still unclear.

The main aim of this article is to find out main recent trends of development of economy in Lithuania on a municipal level and to try to establish main regularities of spatial development of economy during the periods of stable growth.

1. Methodology

The article analyses just general trends of economical development not trying to observe structural changes of economy. For these purposes the GDP per capita usually is supposed to be the best indicator, however the Statistical services do not calculate this indicator at municipal level. Trying to solve the problems, the authors have elaborated its own methodology for calculating the indicator. The calculations are based on existing data concerning GDP levels on a County level adjusting them according levels of employment and average earnings in different municipalities. The same methodology was employed during earlier researches and is described in earlier published articles (Burneika, 2004, 2003). However the received data has certain bias, so can be used just for comparative purposes. For example high level of GDP of a county can make certain raising impact on calculated level of GDP in less developed municipalities. Though previous research permits to state that these effects cannot make decisive impact on the results, some disturbances must be considered. For this reason, measuring and comparing general economic development of municipalities, the authors employed data from the State Tax Inspection. The employed methodology is based on differences of income of employees, but on the other hand profit composes the second important part of GDP so data of state tax inspection concerning gathered profit taxation were analysed in the article.

2. Main Trends of Spatial Development of Economy in Lithuania in 1996–2001

Previous researches of spatial development of economy in Lithuania revealed huge and growing disparities of GDP per capita among different municipalities. Analysis of main tendencies, which took place in 1996 – 2001, have shown that the territory of the Lithuania has gone to the great economical depression and the growth of the economy was concentrated in very few points, which include the capital of the country, port Klaipėda and at a smaller scale some and cities, with competitive giant enterprises from the Soviet period. There was no spatial influence from growing centres to the surrounded territories at the first stage, the differences of the GDP per capita were highest only inside Vilnius county.

In 2001 spatial differences of GDP per capita in municipalities reached 5 times. The major part of the country went in even deeper depression comparing with the strongest, from the economical point of view, cities, which have formed rather mute regions of relatively medium economy around themselves.

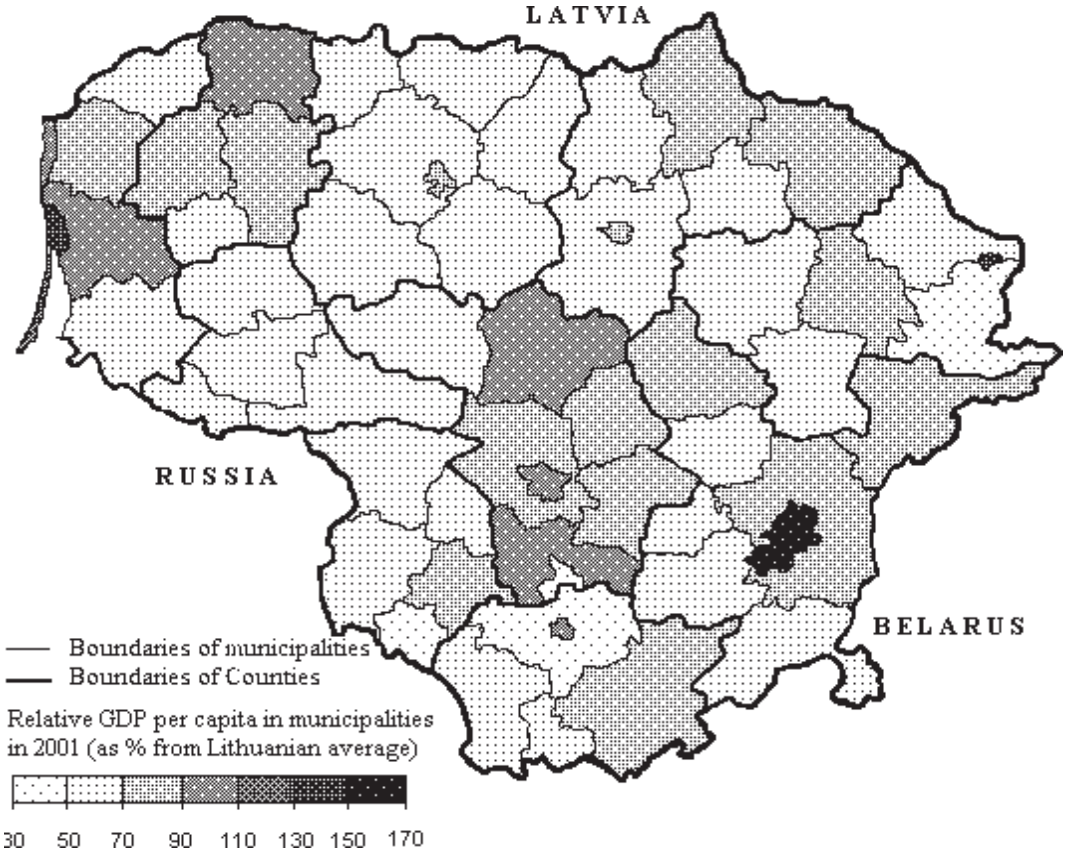

Fig. 1. Differences of GDP per capita in the municipalities of Lithuania in 2001 (% from Lithuanian average).

Consequently three core growing regions could have been found in Lithuania. These included more or less compact territories consisting of 3–4 municipalities around Vilnius and Kaunas as well as around Klaipėda, though the last one was not so uniform (Burneika, 2004). In general, cities presented the most developed territories and they were the fastest developing ones as well. While municipalities surrounding them developed a little bit slower.

The growing regions were mostly related with the new or renovated branches of economy and do not correspond completely with the strongest municipalities from the point of view of present amounts of GDP per capita.

Implemented researches permitted to make an assumption, that the highest spatial economic disparities appear during periods of great economic recessions, while during periods of relatively stable development spatial differences evolve much slower.

The research prepared in 2005 revealed some changes of spatial economic development in Lithuania, though the main economical centres are the same.

3. Peculiarities of Differences of GDP per Capita in Municipalities of Lithuania in 2003

Though general situation of spatial pattern of Lithuanian economy in 2003 did not change very drastically comparing with 2001, some clear changes in some particular cases can be easily spotted. First of all it should be mentioned, that some new centres, with GDP per capita, equal to the one of Lithuanian average appeared. Most of theses positive changes happened in the municipalities, which have giant enterprises built during soviet times and which used to play dominating role in their economy. Among these Jonava, Mažeikiai, Kėdainiai, Elektrėnai should be mentioned. Not necessarily all this growth is related to successful operation of old but renovated industries, in some cases, like in Marijampolė and Klaipėda district municipalities, which also exceeded Lithuanian average GDP per capita, growth is mostly related with new activities, based on export (Fig. 2).

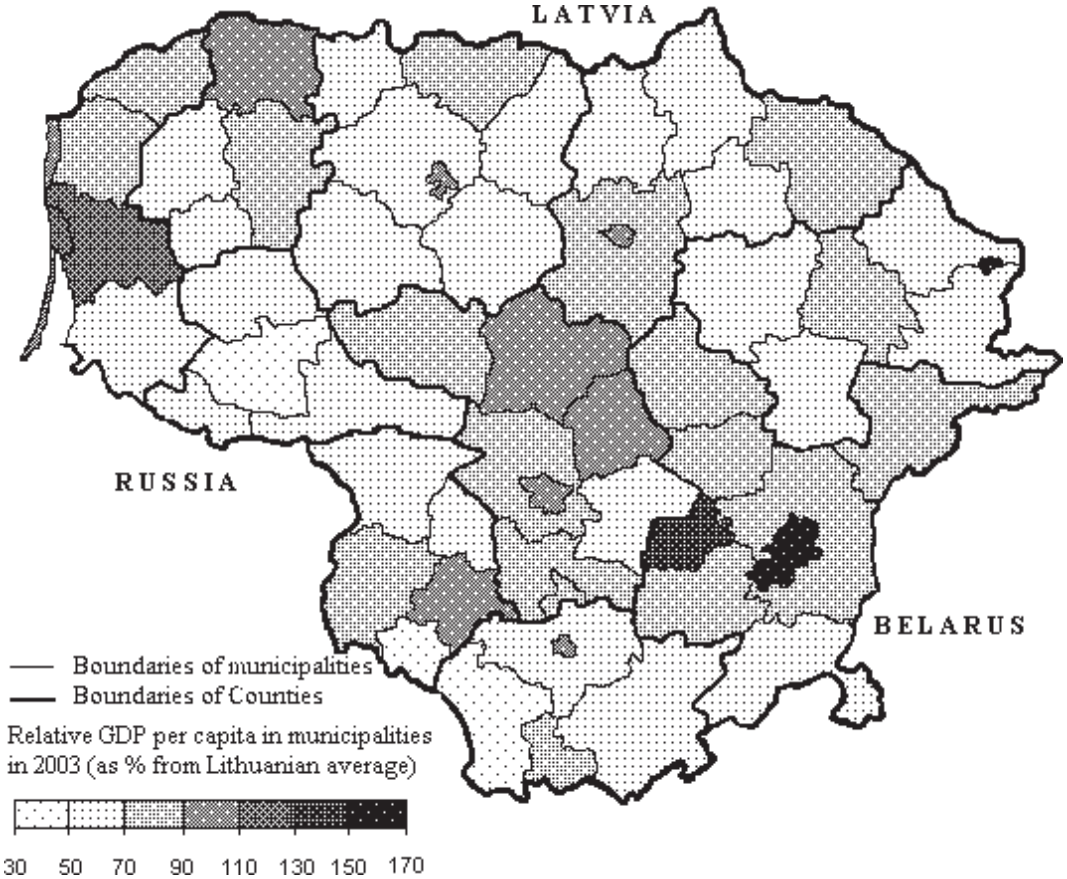

Fig. 2. Differences of GDP per capita in the municipalities of Lithuania in 2003 (% from Lithuanian average). (According to the data of Statistical department of Lithuania: Counties..., 2004.)

Anyway the great misbalance between Vilnius and remaining territory of Lithuania still exists. Capital city composes such a big part of Lithuanian economy, that most other municipalities hardly can reach an average GDP per capita of Lithuania. This forms the situation, when there are just few relatively well developed territories and vast areas remain in economic depression.

Changes of spatial pattern of GDP per capita map in Lithuanian is a consequence of changes of trends of development of economy in Lithuania. Previous researches illustrated great differences of pace of growth of economy, which reached 60% in the period since 1996 untill 2001. The differences of GDP per capita, which existed in 1996, increased during that period considerably (Burneika, 2004). Cities and city regions like Vilnius or Klaipeda developed much faster than country regions. Analyzing situation in longer period we would find out that situation is slightly different. Economic development was concentrated in the same three development cores, though we may observe some spread of the development and it seems that Vilnius and Kaunas are starting to form one bigger development area, which partly corresponds with urban frame of the Country. However the fastest growth was common for city regions (municipalities surrounding main cities) not for cities themselves during the period since 1996 until 2003 (Fig. 3). That is the main difference comparing to the shorter period, when the development of economy was very instable.

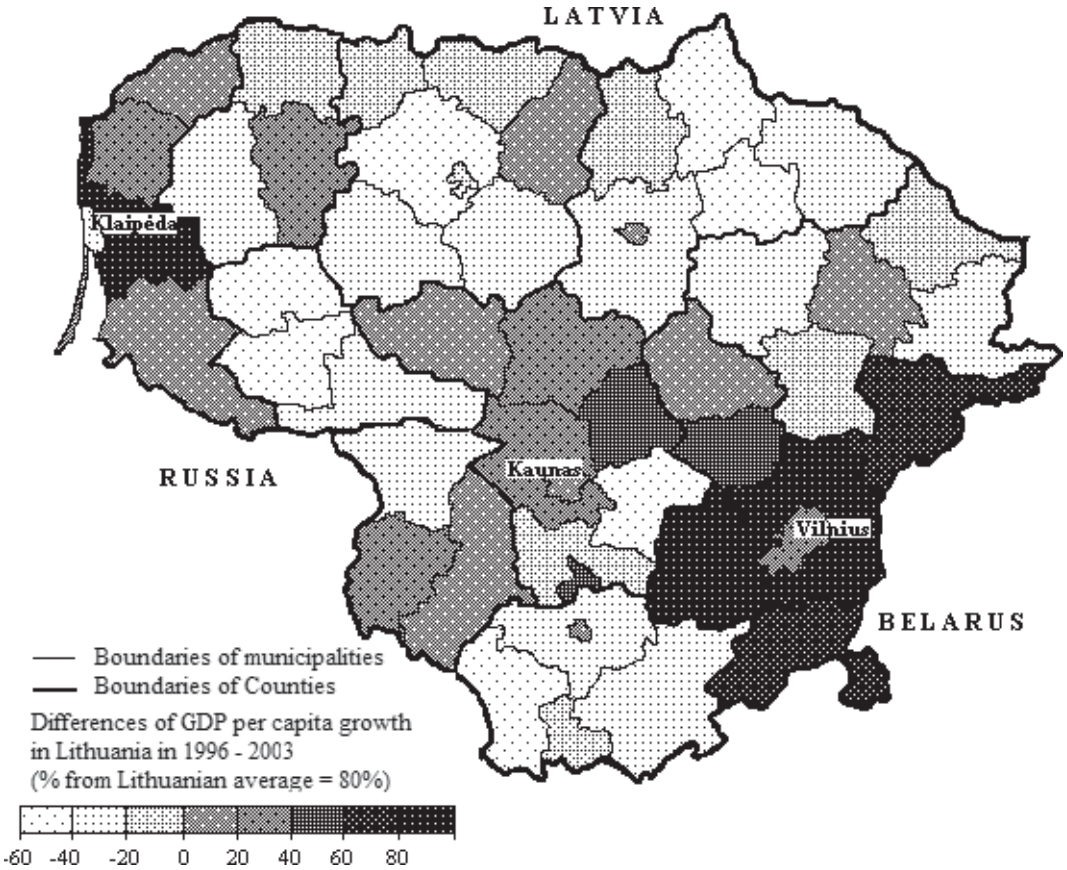

Fig. 3. Differences of growth rates of GDP in municipalities of Lithuania in 1996–2003 (as % from Lithuanian average) (According to the data of Statistical department of Lithuania: www. std.lt).

Such difference comparing to the period before 2001 can be explained by the spatial processes, which took place in recent years. Fig. 4 illustrates the pace of development of

economy in municipalities during recent years of stabile growth of Lithuanian economy. Also there were no changes in territorial administrative system during recent years, so comparison can be more precise. In general it may be stated, that there were no clear bigger regions of growth or decline in Lithuania during these three years. Main trend – faster development of relatively poorer municipalities, but there as well can be found some exceptions. Anyway, we may summarize that in recent years misbalance of economical development has decreased considerably. Visaginas was the only municipality with the highest GDP per capita levels, which still developed much faster than the whole country. It can be easily explained by the stabile and permanent operation of Nuclear Power Plant. So the conclusion that the growth of economy spreads to wider regions during periods of stable growth of economy of the whole Country can be made.

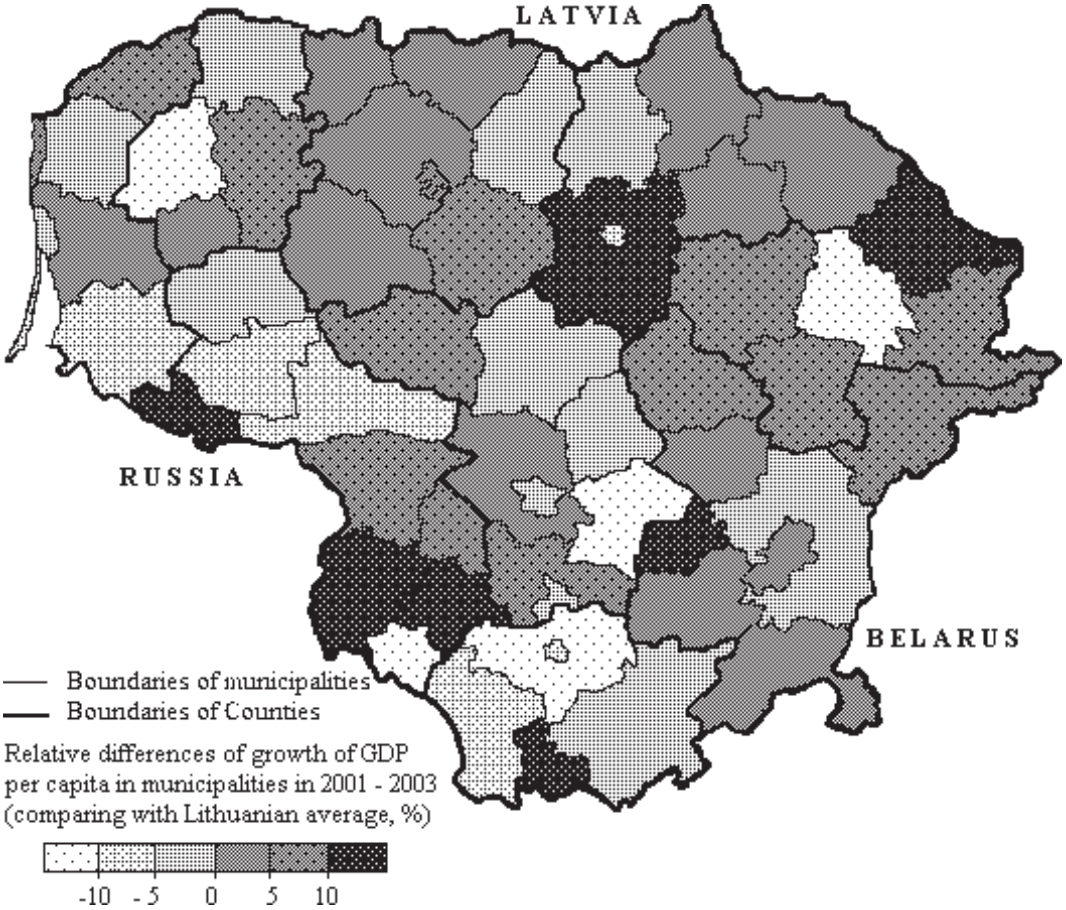

Fig. 4. Differences of growth rates of GDP in municipalities of Lithuania in 2001–2003 (as % from Lithuanian average) (According to the data of Statistical department of Lithuania: www. std.lt).

4. Spatial Differences of Profitability in Lithuania

Calculations of GDP per capita at municipal level were based on differences of employment and salaries, which make main impact on GDP. However second important component of GDP – profit, was not evaluated. Trying to fully evaluate real spatial differences of development of Lithuanian economy, the authors have analysed differences of gathering of profit tax in municipalities. Profit is a part of income, which changes very quickly depending

of trends of development of economy. General trend for Lithuania is rather rapid increase of amounts of gathered profit tax, what is absolutely normal in the after recession period. Gathered amount of profit tax was negative in almost half of municipalities back in 2001. The clear trend of increase of gathered amount of taxes during the last four years illustrates fast development of economy but on the other hand stable amount of gathered income taxes permits to state that benefits of this growth mostly goes to business makers but not for employees.

Spatial pattern of gathering of profit tax was rather similar to the one of GDP with the exception that differences were much higher. This is obvious situation, because headquarters of most companies are located and registered in central cities and pay taxes there. On the other hand profit itself is much more flexible dimension. That's why Utena district pays so much profit taxes, though calculated GDP is not so exceptional.

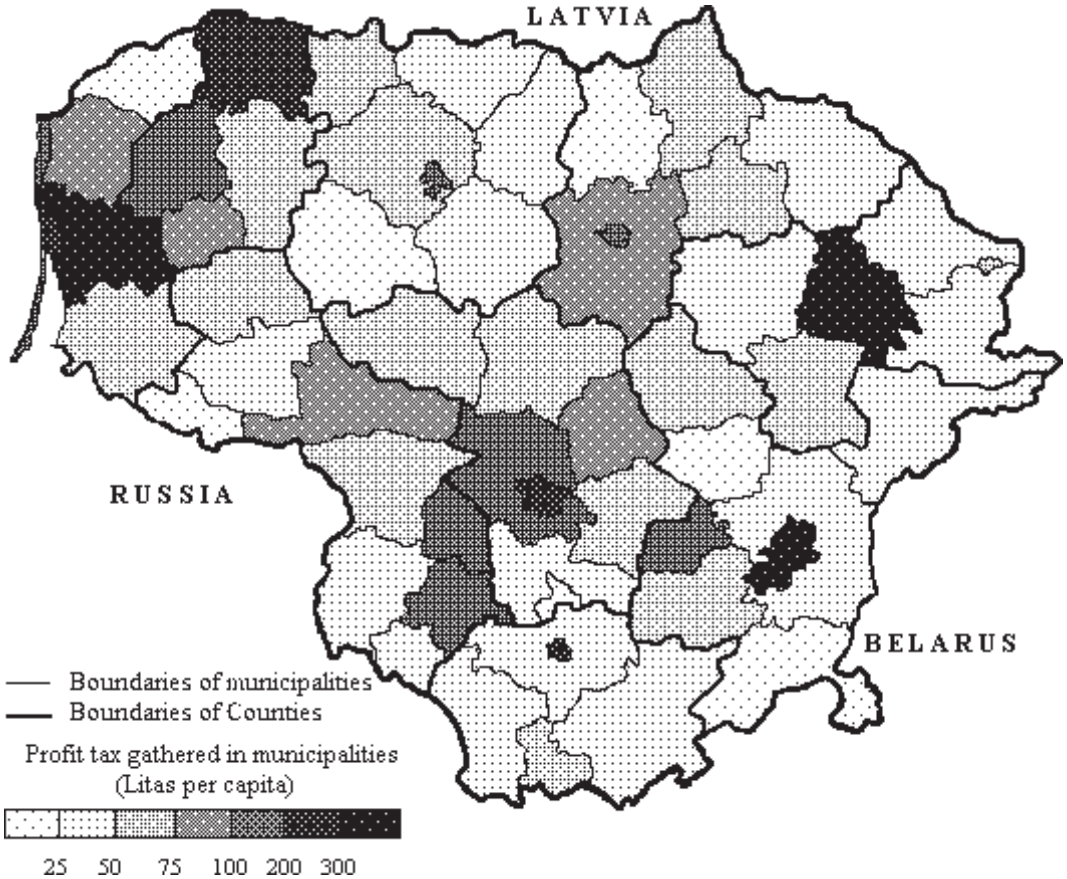

Fig. 5. Differences of gathered profit taxes in Lithuanian municipalities in 2003, Litas per capita. (Data of Lithuanian State Tax Inspection.).

Such a pattern of spatial differences of profitability permits to state that in general previously presented GDP per capita scheme is accurate enough. On the other hand it may be stated, that established differences of GDP per capita should in fact be even higher. Differences between biggest cities and surrounding regions should be higher as well. However these differences are related to some stochastic factor, which can vary a lot in time and so cannot be used very directly defining economical development of the territory.

Conclusions

1. Main regional misbalances of development of Lithuanian economy appeared during period of great economic fluctuations after collapse of Soviet Union and they tended to increase up to the new millennium. Rapid changes of condition of economic development concentrate economic growth into few areas, which have highest relative advantages in the new circumstances.

2. Main regions of growth of economy in Lithuania remain the same but their spatial structure is on the change. Stable growth of economy of the country makes premises for spreading of growth processes into wider regions, which started to grow faster than central city municipalities.

3.Spatial distribution of growing municipalities in recent years shows that this growth is more related to factors of macro-economy or to the growth of whole country but not for the spread of growing potential from core development regions.

4. Analysis of spatial structure of gathered profit tax general confirms established regularities of inner spatial differences of GDP per capita in Lithuania, with the exception that differences between central cities and surrounding regions should be even higher.

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References

Burneika D. (2004). Regioniniai bendrosios ūkio būklės skirtumai ir jų kaita Lietuvoje, *Geografija*, t. 40(1), p. 43–47.

Counties of Lithuania: Economic and Social Development 2001 (2002), Vilnius: Lietuvos statistikos departamentas.

Counties of Lithuania: Economic and Social Development 2003 (2004), Vilnius: Lietuvos statistikos departamentas.

http://www.std.lt

http://www.vmi.lt

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Naujausios Lietuvos ūkio regioninės plėtros tendencijos

Santrauka

Straipsnyje autoriai nagrinėja vidinius Lietuvos ekonomikos vystymosi skirtingumus 1996–2003 metais. Šiam tikslui apskaičiuoti bendro vidaus produkto, tenkančio vienam gyventojui, dydžiai Lietuvos savivaldybių mastu ir palyginta jų kaita minėtu laikotarpiu. Žlugus Sovietų Sąjungai šalies ūkio vystymosi sąlygos ėmė keistis labai greitai tiek laiko, tiek erdvės atžvilgiu – depresijas keitė spartaus augimo laikotarpiai ir atvirkščiai. Autoriai ištyrė, kad iki pat naujojo tūkstantmečio ekonominio išsivystymo lygio skirtingumai šalyje tik didėjo – sparčiai augo keletas miestų savivaldybių, tuo tarpu didžioji šalies teritorijos dalis vystėsi labai lėtai. Tokia situacija rodo, kad esminiai reformuojamos ekonomikos šalių ūkio vystymosi vidiniai skirtingumai formuojasi staigių ūkio vystymosi pokyčių laikotarpiu, kai prie greitai besikeičiančių sąlygų gali prisitaikyti tik keletas santykinį pranašumą turinčių ūkio centrų.

Pastaraisiais metais, kai šalies ūkio plėtra įgavo stabilios plėtros tendenciją, situacija pasikeitė. Apskaičiuota, kad sparčiau ūkis pradėjo augti tose savivaldybėse, kuriose BVP vienam gyventojui yra mažiausi. Kita pastarojo tarpsnio tendencija – spartesnė platesnių didžiųjų miesto regionų plėtra, o ne pačių miestų augimas. Nors apskritai ūkio išsivystymo atžvilgiu ir toliau išsiskiria trys šalies regionai, jų erdvinė raiška kiek keičiasi – darosi akivaizdu, kad Vilniaus ir Kauno regionai jungiasi į vieną – didesnį erdvinį augimo darinį, iš dalies sutampantį su šalies urbanistiniu karkasu.

Trečiame darbo skyriuje analizuojami 2003 m. pelno mokesčio surinkimo erdviniai skirtingumai. Kadangi skaičiuojant BVP erdvinius skirtingumus šalyje remtasi tik kompensacijos dirbantiems gyventojams skirtumais, autoriai pabandė panagrinėti antros pagal svarbą BVP dedamosios dalies skirtingumus. Iš esmės pelno vienam gyventojui erdvinio pasiskirstymo charakteristikos atitinka nustatytus BVP dydžio vienam gyventojui pasiskirstymo dėsningumus, tik šiuo atveju skirtumai padidėja iki keliasdešimt kartų. Daugiausiai pelno mokesčio surenkama centro funkcijas vykdančiuose miestuose, kur registruota daugiausia pelningai dirbančių firmų. Atsižvelgus į tai galima teigti, kad realusis BVP vienam gyventojui dydžių šablonas, įvertinus gaunamo pelno netolygumus, iš esmės atitiktų pateiktąjį straipsnyje, tačiau patys ekonominio išsivystymo skirtingumai tarp labiausiai išsivysčiusių ir labiausiai atsilikusių savivaldybių dar padidėtų.

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THE PROBLEM OF RESEARCH OF RELIGIOUS TENSIONS IN THE SOCIAL FIELD

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Introduction

Religiousness, composition of religions as well as history of religious communities have been explored for many years in Lithuania. Nevertheless, the objects and methodology of these studies were diverse in different historical periods. Greater scientific interest in religiousness – except the ideology of atheism – was devoted after the restoration of independence of the Republic of Lithuania in 1990 (Matakaitė, 2003; Juknevičius, 1998; Žiliukaitė, 2000). Many research papers dealt with the problems of religious composition as well as history and migration of confessions to Lithuania (Akmenytė, 2003; Alperavičius, 2000; Bairašauskaitė, 1992; Čiubrinskas, 1998; Firkavičiūtė, 2000; Hermann, 2003; Kregždė, 1980; Kviklys, 1980–1987; Laukaitytė, 2003; Potašenko, 1993). Furthermore, the findings of the second population census in 2001 (the first one took place in 1923) were relevant for to the analysis of Lithuanian composition of religions, as respondents were questioned about their religious attitudes. A special map of religions in Lithuania has been drawn based on published results of this population census (Adlys, Ambrozaitienė, 2002; Stanaitis, Stanaitis, 2002). However, the reported attitudes on religious behaviour are sometimes very superficial and can be falsely interpreted. They do not render information about actual behaviour of inhabitants. In some cases self–attribution to one religious group meant a deep faith, however, sometimes – only a nominal self–identification with this confession. This ambivalence of attitudes lacks detailed researches about possible territorial differences as well as their changes over time.

Religion as well as society's religiousness is a very complex phenomenon, which might be explored based on different methodological approaches. One possible alternative is the method of social balance field. The basics of this method were founded in Confucius', Aristotle's as and Plato's philosophies. The sociologists (Sorokin, 1966; Bourdieu, Wacquant, 2003) – also some Lithuanian sociologists (Grigas, 1998a,b) – were the first to explore the significance of social field and practically utilize this methodology. After some time geographers investigated social field, as an independent research object. The Department of General Geography of Vilnius University has been engaged in preparation of scientific research "The territorial structures of social field as well as evaluation of transformation in the context of regional policy". Within the framework of this research some works dealing with the theoretical problems of social tension fields (Kavaliauskas, 2001; Kavaliauskas, Bražukienė, 2002; Kavaliauskas, Daugirdas, 2002; Kavaliauskas, Petrulis, 2004; Krupickaitė, 2002) were elaborated. Some of these research papers aim to develop further application of this method in the Lithuanian context (Kavaliauskas, Bražukienė, Krupickaitė, 2004; Krupickaitė, 2005).

The purpose of this article is to explore the apprehension of religious tensions. Thus, the concept of religious tensions, their dichotomy as well as some other relevant theoretical problems are discussed in this article.

1. Position of Religious Tension in the Social Fields

In addition to moral, economic, ethnic–cultural, political, organizational, supranational, demographic fields, a separate field of religious relations, as a part of the social field, was denoted by Dr. Habil. R. Grigas. He was one of the first researchers in Lithuania to apply scientifically the methodology of the social field (Grigas, 1998a). Religious issues were directly attributed to the social organization in his works. Moreover, religion was considered as both historical phenomenon and cultural legacy that in the process of evolution of the society had formed particular traditions and behavioural norms in collective knowledge and social life. Five autonomous couples to define the religious tensions in the social field were specified in his works: religiousness – atheism, ecclesiastical religiousness – individual religiousness, religious cosmopolitism – religious nationalism, traditional religions – untraditional religions, ecclesiastical social organization – secular social organization (Grigas, 1998b).

Explorers of religiousness as a social phenomenon in Lithuania and worldwide emphasize that the cultural component slightly overcomes the religious component defining religion. Religion becomes a way to express the links with particular cultural community. First, religion is an element of culture, especially in terms of cultural values. On the contrary, pure religious regulations as well as orthodox religious values are hardly obeyed in the common life. (Kunovich, Hodson, 1999; Žiliukaitė, 2000). Thus, P. Kavaliauskas and V. Daugirdas suggested a generalized concept of cultural field without distinguishing a field of religious tension (Kavaliauskas, Daugirdas, 2002). However, a part of antinomies of cultural field was expressed through religiousness of the society in their work (atheism – religiousness, traditional religions – untraditional religions, modest religiousness – fundamental religiousness). Cultural field as well as the whole field of social balance is not homogeneous. One could distinguish different tensions of cultural fields in the society – ethnic, religious, moral, socio–cultural, etc. (Fig.). The explored religious tensions are interrelated not only with the cultural field, but also with all processes that take place in the social field (Paltanavičiūtė, 2005).

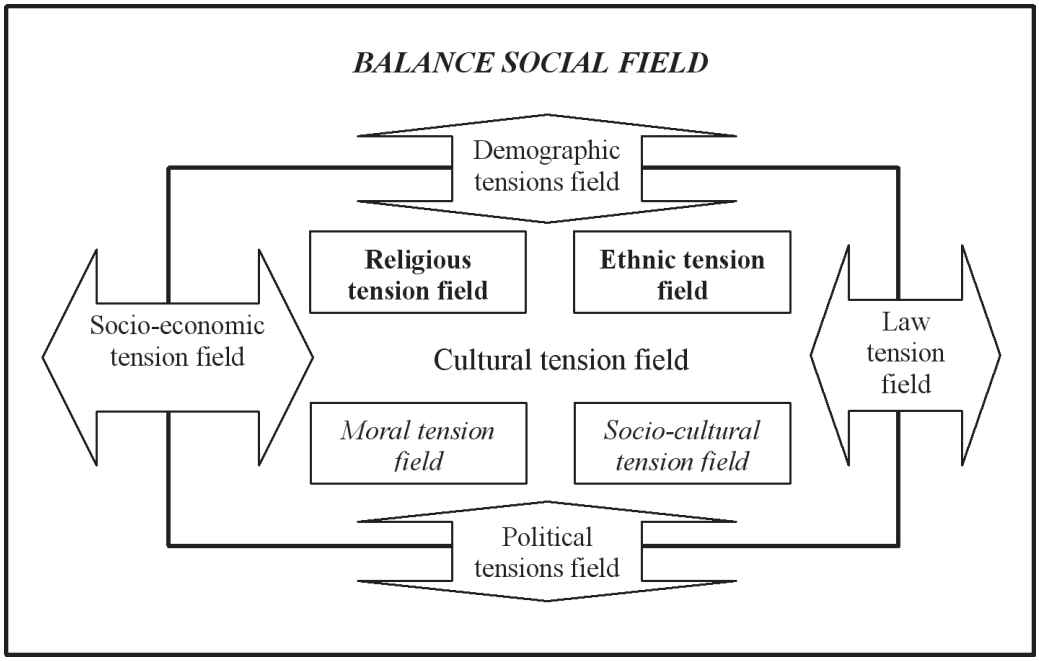

Fig. Dimensions of religious tensions in the Social Field.

The processes in the religious field are influenced even more by the processes in the whole social field rather than in the cultural field. Indeed, religious tensions are more apparent in those regions where some other demographic, economic and political problems coexist. The results of mass report of Lithuanian inhabitants were also utilized by outlining the religious tensions. However, some subjective data, *e.g.* subjective opinions and attitudes, are also to be considered conducting this research.

1. Dichotomy of Religious Tension Field

While exploring the correlation of religious identities and ethnic intolerance in Croatia, R. Kunovich and R. Hodson have outlined five possible reasons of possible conflicts: freedom of speech (especially due to its hampering), perspectives of children's education, independent mass media, political representation as well as freedom to establish independent governments (Kunovich, Hodson, 1999). Summarizing and supplementing antinomies of religious relations worked out by sociologist R. Grigas as well as geographers P. Kavaliauskas and V. Daugirdas, the following eight dichotomies were drafted. They elucidate society's attitude towards religion, state's attitude towards religious communities, society's relation with religious communities and evolution of religion:

1. Religiousness–atheism;
2. Ecclesiastical religiousness–individual religiousness;
3. Religious cosmopolitism religious nationalism;
4. Legislation that is favourable to religious communities–legislation that is unfavourable to religious communities;
5. Correctness of mass media–incorrectness of mass media;
6. Religious activity–religious passiveness;
7. Religious majority–religious minority;
8. Evolution of Church territorial organization–digression of Church territorial organization;
9. Traditional religions–untraditional religions.

It is, however, not always possible to evaluate territorial differences of religious dichotomies in terms of quantities. Not all tensions can be marked quantifiable: they can be unmeasured, problematic and quantifiably measured. The 1–3 items refer to problematic dichotomies. On the other hand, fragmentary and undifferentiated data as well as some specifics of the analysed object stipulate some difficulties to conduct territorial evaluation. The 4–5 dichotomies are impossible to be measured because of the lack of the data referring to the differences in different territories. Furthermore, these dichotomies should not differ in the whole territory of the Republic of Lithuania. Only those dichotomies as specified in the items 6–9 might be explored in terms of quantities in the different regions on the basis of statistical information.

Taking into consideration scientific assumptions on social tensions (Дмитриев, 2003) as well as some other research papers (Kavaliauskas, Bražukienė, Krupickaitė, 2004; Krupickaitė, 2005), the following four categories of tensions were applied: partial neutrality (absence of tension), slight tension, medium tension as well as big tension.

Religiousness–atheism. The wide spreading secularization is one of the features of modern society. It is usually considered not as a decline of religion, but the decrease of religious authority. This process has different effects on individual, organizational and social level. While the secularization processes take place, religion and religious norms loose their importance and influence in the everyday life. As it was noted above, religion is considered just as a part of culture (Chaves, 1994). Despite of the overwhelming processes of

secularization in the Western societies, Lithuania has retained some its own peculiarities in the field of religiousness. According to the different researches conducted in the last years, the role of religion compared with the other vital values is decreasing (Mitrikas, 2005). Albeit the detailed research data of mass report of Lithuanian inhabitants shows that most of the inhabitants (84%) identify themselves as belonging to one of the religious groups, only about 20% of them go to church at least once a week and only about 12% find religion important in their lives (Europa…, 2001).

Ecclesiastical religiousness–individual religiousness. Another consequence of secularization suggests that ecclesiastical religiousness losses its previous social position and importance. People consider religiousness as their personal matter (Chaves, 1994). The traditional ecclesiastical religiousness that denoted a strong emotional attachment to parents' religion competes with the individual religiousness. It means that a person creates it own religion based on his own experience. People tend to trust what they want to trust rather than follow the traditional ecclesiastical doctrine. Thus, persons, who perceive they to be Christians, believe in reincarnation more than in coexistence of heaven and hell. The weakening of orthodoxy in the Lithuanian society shows that only 59% of respondents are convinced that it is important to uphold one religion rather than contemplate different religious doctrines.

Religious rituals related with the birth of a child, wedding or death are regarded as important not only by religious people in Lithuania, but also by those who do not attribute themselves to the any of the churches and those who don't go to church (birth – 93%, wedding ceremony – 89%, death – 95% respectively). Therefore, it is to conclude that religious rituals have lost their original religious meaning. Most of people practice them only as a cultural tradition (Žiliukaitė, 2000).

Religious cosmopolitism–religious nationalism. Religion was the most important feature of self–identification until the end of the 19th Century. The concept "Lithuanian" denoted not only ethnic identity, but religious subordination as well, i.e. respective subordination to the Roman Catholic Church. However, a change of self–perception took place at the beginning of national revival, while nationality was set in the first place (Savukynas, 1997). On the other hand, the stereotypes formed during the centuries have contributed that religious subordination became also a distinguishing feature of nationality. According to the Mass report of 1923 a big part of Latvian Catholics of Northern Lithuania were classified as Lithuanians (traditionally Catholicism predominated in Lithuania) (Akmenytė, 2003). After the end of World War II, the Soviet Union and Germany signed a treaty on repatriation of Baltic Germans. According to the treaty, the Soviet Government had agreed to recognize Lutheranism as an evidence of German origin. After inspection of repatriates, it was ascertained that 1/3 of applicants did not understand German (Hermann, 2003).

The changes in society also stimulate the changes in religious communities. In order to attract churchgoers to St. Soul's Parish *(liet. Šv. Dvasios parapija*) in Vilnius, divine worship is held in Lithuanian, though traditionally the orthodox worship takes place in Russian. On the other hand, common religion – Catholicism – does not prevent all the conflicts between Lithuanians and Poles regarding the applicable language of worship rituals. Thus, sometimes the national identity overcomes the religious sense and can confront the members of the same confession (Gaučas, 1999). Furthermore, a research was carried out during the process of integration to the European Union to ascertain of how people understand European national identity. Accordingly, common European Christian legacy was identified as the main link of national identity between Lithuanians and other Europeans (Šutinienė, 2004).

Legislation that is favourable to religious communities–legislation that is unfavourable to religious communities Legislation can stimulate or, on the contrary, restrain the establishment of religious communities that aim to disseminate their own religion. Nowadays the Constitution of the Republic of Lithuania as well Law on Religious Communities entrench a freedom to promote own religion. There is no state religion in Lithuania. The religious communities nevertheless are classified pursuant to the above-mentioned Law: (i) traditional, (ii) other (untraditional) religion communities as well as (iii) those that are seeking for state's recognition. The concept of "traditional religion (Church)" denotes a historical, spiritual and cultural legacy (Plumpa, 2001). Thus, before obtaining a status of "traditional religious community" the applicant has to present evidence of its cultural and historical value to Lithuanian society. By virtue of the legal classification, religious community acquires different status in the state.

Correctness of mass media–incorrectness of mass media. Currently mass media enjoys a big credibility in Lithuania (for instance, about 60–70% of Lithuanian inhabitants rely on the veracity of mass media (Lietuva…, 2004). Therefore, mass media became one of the main factors to form a public opinion. Researchers, who analyse activities of religious communities as well as attitudes of mass media with respect to various religious matters, highlight that both traditional and untraditional religiousness is depicted as deviation from the generally accepted norms in the mass media nowadays. Newly founded religious organizations are generally attributed to the "sects" (creating prejudices in advance). Furthermore, researchers, who professionally handle these topics, fail to present authoritative comments. There are hardly prepared detailed analyses on the role of religious organisations, *etc*. In general, social and cultural aspects of the activity of religious communities are not discussed sufficiently in public. (Barker, 2001; Kuznecovienė, 2000; Navickas, 2001; Peškaitis, Glodenis, 2000; Žiliukaitė, 2001).

Religious activity–religious passiveness. As it was noted above, a formal denominative attribution to some religious communities does not reflect the actual degree of religiousness in the society. This would be better depicted by the actual attendance of church, a number of schoolchildren attending religious lessons, religious mass media, Sunday schools, non– governmental organisations that deal with religious issues, *etc*.

During the national revival, churches often become a consolidating factor Therefore, sometimes church becomes a very important part of public life (Kunovich, Hodson, 1999). During the first decade after restoration of independent in 1990, the number of persons, who denote themselves as believers, increased significantly. Nevertheless, there was a remarkable increase only of those persons, who attend major religious celebrations, while the respective share of those, who are actively engaged in the activity of religious organisations, remained almost unchanged. Both in 1990 and in 1999, this ratio was about 4% respectively. These findings imply the superficiality of religious revival (Europa…, 2001; Žiliukaitė, 2000).

Religious majority–religious minority. If a majority of particular population attributes themselves to one community, it is relatively more difficult to establish new religious communities. Local media or sometimes even local governments can be instigated to resist against establishment of new religious communities. These obstacles are especially relevant to the new religious communities, while the elder ones have already passed this "recognition test". A majority of Lithuanian population attribute themselves to Roman Catholics. The composition of confessions is a bit more diverse only in bigger towns of the Republic of Lithuania. Tolerance as well as slight tension evolves out of long and complicated coexistence of different religions (cultures). Therefore, some more tolerance is founded in heterogeneous societies, whereas frequent personal contracts contribute to development of tolerance.

(Kavaliauskas, Daugirdas, 2002; Vosyliūtė, 2000). Nevertheless, according the T. Vanhanen's concept, the diverse society stipulates potential tensions as well, as there are many direct contacts between divergent ideologies (Vanhanen, 1999). Therefore, in order to evaluate the "level of tolerance", the changes of the ratio of majorities and minorities should be observed as well.

Evolution of Church territorial organization–digression of Church territorial organization. Tension can be explored considering two aspects of this dichotomy. First, the structure of Church territorial organisation should be considered. Either the network of Church can be equal in the whole territory or there can be significant territorial repartitions or desperately allocated communities (Jordan-Bychkov, Domosh, 1999). The historical development of territorial organisation shows whether the structures have been developing evolutionally or they were influenced by some external factors. For instance, the territorial structure of the current Roman Catholic Church expresses political, historical, cultural events that took place in different historical periods in Lithuania (Paltanavičiūtė, 2002). The maturity of structure expresses the complexity of territorial organisation likewise – whether there is one-tier structure, or there some hierarchical levels, or there are no relevant structure in the territorial community (Мосунов, 1988; Valentine, 2001). Second, the other axis to create a tension is correlation of allocation of Churches with the allocation of believers in the territory. The tension becomes more evident when particular believers do not establish a community – an organisational unit of Church territorial organisation. Some other combinations are possible as well. Due to natural processes (migration, ageing of society, etc.) as well as external intervening (e.g. compulsory expelling), erosion of historically formed territorial Church organisation occurs: there are some blessing facilities; however, there are no old members of the confession left.

Traditional religions–untraditional religions. The newly established religious organisations are a result of society's secularisation (Chaves, 1994), as people consider religion as their personal matter. Eventually many people seek to combine different religious doctrines to find relevant answers. In general, society reacts very divergently to the new religious organisations. Some people accept the differences very respectfully, the others, however, can be hysterically frightened. Religious freedom as well as opportunities to choose own religion have come to Lithuania after the national revival. However, the changed economic and social situation has contributed to the widespread sense of insecurity. Due to the prejudices elucidated in mass media, fresh religious movements were also tackled. A public reaction to the new forms of religion is highly dependant, whether and to which extend they are culturally similar or alien to the values of traditional society. Indeed, ideological or secular point of view was not so important accepting religions (Peškaitis, Glodenis, 2000). Lithuania is more and more integrating to the multicultural and multi–confessional community. Thus, the interrelation between something "traditional" and "untraditional" will be even more frequent in the future. A high degree of tolerance in respect to the other religions prevails in old member states of the European Union. However, even there a big part of population requires rendering a priority to traditional values and norms, especially in family law matters (Attitudes…, 2003).

Conclusions

1. A complex of dichotomies in the social field reflects the tensions between different religious groups, traditional and untraditional religious communities as well as religious communities and the state. These links can be by the following couples of dichotomies: religiousness–atheism, ecclesiastical religiousness–individual religiousness, religious cosmopolitism–religious nationalism, legislation that is favourable to religious communities–

legislation that is unfavourable to religious communities, correctness of mass media–incorrectness of mass media, religious activity–religious passiveness, religious majority–religious minority, evolution of Church territorial organization–digression of Church's territorial organization, traditional religions–untraditional religions.

2. Considering the criterion of territorial difference, religious tensions can be classified to these categories: (i) tensions that can be hardly evaluated in quantities terms, problematic (ii) and quantifiable measured (iii) (these tensions can be evaluated on the basis of mass reports of Lithuanian inhabitants as well as some other statistical material).

3. The new quantities criteria that explain the territorial differences of religious relations should be elaborated. These new criteria should encompass not only the general tensions in the cultural field (ethnic, moral, socio–cultural, etc.), but also socio–economic, demographic, political tensions in the particular location.

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References

Adlys P. G., Ambrozaitienė D. (2002). Romos katalikų daugiausia, *Mokslas ir gyvenimas*, Nr. 12, p. 22–23.
Akmenytė V. (2003). Lietuvos latvių liuteronų bendruomenė 1918–1940 m. *Žiemgala*, Nr. 1, p. 12–15.
Alperavičius S. (2000). Žydų mažumos ir daugumos santykis Lietuvoje. *Tautinės mažumos demokratinėje valstybėje*, Vilnius
Attitudes Towards Minority Groups in the European Union (2003), Vienna: European Monitoring Center on Racism and Xenophobia.
Bairašauskaitė T. (1992). Musulmonų konfesinė bendruomenė Nepriklausomoje Lietuvoje. *Lietuvos istorijos metraštis*, Vilnius.
Barker E. (2001). Žiniasklaida ir naujasis religingumas: komentarai. *Religija ir teisė pilietinėje visuomenėje*, Vilnius.
Bourdieu P., Wacquant J. D. (2003*).* Įvadas į reflektyviąją sociologiją, Vilnius: Baltos lankos.
Chaves M. (1994). Secularization as Declining Religious Authority, *Social Forces*, Vol. 72(3), p. 749–774.
Čiubrinskas V. (1998). Lietuvos sentikių–rusų etnografija: tyrimo patirtis, problemos ir perspektyvos. *Lietuvos sentikiai*, Vilnius.
Europa ir mes (2001), Vilnius: Kultūros ir meno in-tas.
Firkavičiūtė K. (2000). Lietuvos karaimai – etnokonfesinė mažuma pilietinėje visuomenėje. *Tautinės mažumos demokratinėje valstybėje*, Vilnius.
Gaučas P. (1999). Lietuvių kalba Rytų Lietuvos bažnyčiose XIX a. pabaigoje.–XX a. pirmojoje pusėje (iki 1939 m.), *Geografijos metraštis*, t. 32, p. 290–303.
Grigas R. (1998a). Religinių santykių erdvė Lietuvoje: įtampų laukai ir jų pasireiškimo bruožai, *Filosofija. Sociologija*, 4, p. 37–46.
Grigas R. (1998b). Socialinių įtampų Lietuvoje laukai, Vilnius.
Hermann A. (2003). Lietuvos evangelikų bažnyčios, Vilnius.
Jordan–Bychkov T. G., Domosh M. (1999). The Human Mosaic: A Thematic Introduction to Ccultural Geography, New York.
Juknevičius S. (1998). Religingumo raida postsovietinėje Lietuvoje. *Kultūros istorijos tyrinėjimai*, t. 4, p. 289–299.
Kavaliauskas P. (2001). Socialinio lauko pažinimo problema, *Geografija*, t. 37(1), p. 44–48.
Kavaliauskas P., Bražukienė I. (2002). Socialinių įtampų tyrimo problema ekonominiame bei teisiniame lauke, *Geografija*, t. 38(1), p. 46–49.
Kavaliauskas P., Daugirdas V. (2002). Socialinių įtampų tyrimo problema kultūriniame ir politiniame lauke, *Geografija*, t. 38(1), p. 41–45.

Kavaliauskas P., Petrulis V. (2004). Elektorinio metodo taikymas tiriant politines įtampas balansiniame socialiniame lauke, *Geografija*, t. 40(1), p. 34–42.
Kavaliauskas P., Bražukienė I., Krupickaitė D. (2004). Demografinių, ekonominių ir politinių Lietuvos socialinio lauko įtampų teritorinė raiška. *Mokslas Gamtos mokslų fakultete*, Vilnius, p. 200–215.
Kregždė J. (1980). Reformacija Lietuvoje, Čikaga.
Krupickaitė D. (2002). Demografinių įtampų tyrimo problema socialiniame lauke, *Geografija*, t. 38(2), p. 42–47.
Krupickaitė D. (2005). Demografinių socialinio lauko įtampų kaitos tendencijos Lietuvoje, *Geografija*, t. 41(1), p. 11–16.
Kuznecovienė J. (2000). Prievarta religinėse sektose: vizijos ir realybė, *Sociologija. Mintis ir veiksmas*, Nr. 3–4, p. 5–11.
Kunovich R. M., Hodson R. (1999). Conflict, Religious Identity and Ethnic Intolerance in Croatia. *Social Forces*, Vol. 78(2), p. 643–674.
Kviklys B. (1980–1987). Lietuvos bažnyčios, Čikaga.
Laukaitytė R. (2003). Stačiatikių bažnyčia Lietuvoje XX amžiuje, Vilnius.
Lietuva stojant į Europos Sąjungą: ekonominė, sociologinė ir demografinė padėties analizė (2004). Vilnius: Socialinių tyrimų in-tas.
Matakaitė S. (2003). Individualus religingumas ir kasdienis gyvenimas, *Filosofija. Sociologija*, t. 1, p. 37–42.
Mitrikas A. A. (2005). Svarbiausios gyvenimo vertybės šių dienų pasaulyje. *Filosofija. Sociologija*, t. 2, p. 40–45.
Navickas A. (2001). Religijos laisvė, krikščioniškoji tapatybė, žiniasklaida ir laisvės iššūkis. *Religija ir teisė pilietinė visuomenė*, Vilnius.
Paltanavičiūtė G. (2002). Romos katalikų Bažnyčios teritorinės organizacijos formavimas Kaišiadorių vyskupijos pavyzdžiu: Magistro darbas, Vilnius .
Paltanavičiūtė G. (2005). Etninės įtampos socialiniame lauke, *Geografija*, t. 41(1), p. 17–22.
Peškaitis A., Glodenis D. (2000). Šiuolaikinis religingumas: Naujieji judėjimai ir išraiškos formos amžių sandūroje, Vilnius.
Plumpa P. (2001). Valstybės ir religijos santykis Lietuvoje: Lietuvos Respublikos Konstitucijos 43 straipsnio analizė. *Religija ir teisė pilietinėje visuomenėje*, Vilnius.
Potašenko G. (1993). Sentikiai ir Lietuva, *Liaudies kultūra*, Nr. 6, p. 21–26.
Savukynas V. (1997). Religinė epistema lietuvių tapatybės istorijoje, *Kultūros barai*, Nr. 7, p. 45–48.
Sorokin P. A. (1966). Sociological Theories of Today, New York.
Stanaitis A., Stanaitis S. (2004). Lietuvos gyventojų religijos ir jų paplitimas, *Geografija*, t. 40, p. 26–33.
Šutinienė I. (2004). Lietuvių ir tautinių mažumų europinio identiteto paieškos. *Etniškumo studijos 2004*, Vilnius.
Valentine G. (2001). Social Geographies: Space and Society, NewYork.
Vanhanen T. (1999). Domestic Ethnic Conflict and Ethnic Nepotism: A Comparative Analysis, *J. of Peace Research*, Vol. 36(1), p. 55–73.
Vosyliūtė A. (2000). Miestas kaip multikultūrinė erdvė. *Tautinės mažumos demokratinėje valstybėje*, Vilnius.
Žiliukaitė R. (2000). Religinių vertybių kaita Lietuvoje 1990–1999, *Kultūrologija,* Nr. 6, Vilnius.
Žiliukaitė R. (2001). Žiniasklaida ir netradicinės religinės bendruomenės ir bendrijos Lietuvoje. *Religija ir teisė pilietinėje visuomenėje*, Vilnius.
Дмитриев А. В. (2003). Конфликтология, Москва.
Мосунов V. P. (1988). Некоторые тенденции пространственой структуры узовых административних районов. *Иерархия региональных систем и територриальная организация управления*, Москва.

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Religinių įtampų socialiniame lauke tyrimo problema

Santrauka

Religingumas, religinė sudėtis bei religinių bendruomenių istorija Lietuvoje tyrinėjama daug metų, tačiau šių tyrimų pobūdis ir turinys tam tikrais visuomenės gyvenimo etapais skyrėsi. Apie Lietuvos religinę sudėtį bei atskirų konfesijų istoriją bei kelią į Lietuvą yra parašyta nemažai darbų. Tiriant Lietuvos religinę sudėtį labai svarbūs ir naudingi buvo 2001 metų Visuotinio gyventojų surašymo duomenys, kurie suteikė galimybę sudaryti tikslų Lietuvos religijų žemėlapį. Tačiau denominacinė priklausomybė yra labai paviršutiniškas ir neretai klaidingai interpretuojamas religijos rodiklis. Jis neteikia informacijos apie realųjį religinį gyventojų elgesį bei nuostatas, nes vienu atveju savęs priskyrimas tam tikrai religinei grupei gali reikšti gilų tikėjimą, kitu – tik nominalinę tapatybę.

Pastaraisiais metais vis labiau ryškėja, kad religingumo stipresnis kultūrinis, o ne religinis aspektas, religija yra vienas būdų išreikšti savo priklausomybę tam tikrai kultūrinei bendrijai. Religija ir visuomenės religingumas yra sudėtingas reiškinys ir jį galima tirti vis populiarėjančiu socialinio balansinio lauko metodu.

Religinių santykių erdvę, kaip vieną socialinio lauko dalių, išskyrė sociologas habil. dr. R. Grigas. Prof. P. Kavaliausko pasiūlytame socialinio balansinio lauko modelyje religinės įtampos priskirtos kultūriniam laukui. Apibendrinus religinių santykių įtampų lauko bei kultūrinių įtampų laukų antinomijas bei jas papildžius, buvo sudarytos 9 dichotominės poros: religingumas–laisvamanybė, bažnytinis religingumas–individualusis religingumas, religinis kosmopolitiškumas–religinis tautiškumas, religinėms bendruomenėms palanki teisinė bazė–religinėms bendruomenėms nepalanki teisinė bazė, žiniasklaidos korektiškumas–žiniasklaidos nekorektiškumas, religinis aktyvumas–religinis pasyvumas, religinė dauguma–religinės mažumos, bažnytinės teritorinės organizacijos evoliucija–bažnytinės teritorinės organizacijos degresija, tradicinės religijos–netradicinės religijos.

Tačiau ne visada įmanoma kiekybiškai įvertinti religinių antinomijų teritorinę diferenciaciją. Pagal tai išskirtas antinomijas galima grupuoti į kiekybiškai neįvertinamas, problemines ir kiekybiškai įvertinamas. Problemiškų antinomijų (1–3) teritorinį vertinimą apsunkina fragmentiški ir teritoriškai nediferencijuoti duomenys bei tyrimo objekto specifiškumas. Kiekybiškai neįvertinamų antinomijų (4–5) beveik neįmanoma išskirti dėl pačios įtampos neteritoriškumo ir teritoriškai diferencijuotų duomenų stokos – ji vienoda visoje Lietuvos teritorijoje. Statistikos duomenimis, kiekybiškai vertinamas dichotomijas (6–9) galima įvertinti pagal įtampos stiprumo regioninius skirtingumus.